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Foreword

Department of the Navy
Naval Sea Systems Command
25 June 2001

This revision of the U.S. Navy Towing Manual provides the latest information concerning the heavy lift transport of U.S. Navy vessels. Much of this information is a direct result of the successful heavy lift of USS COLE (DDG 67) following the damage caused by terrorist attack in Aden harbor, Yemen.

Comments about or recommendations concerning the U.S. Navy Towing Manual may be forwarded to the Supervisor of Salvage, Naval Sea Systems Command, 1333 Isaac Hull Avenue SE Stop 1072, Washington Navy Yard, DC 20376-1072 or call commercial (202)781-0824, DSN 324-0824.

B. MARSH
Director of Ocean Engineering
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Chapter 1

OPERATIONS OVERVIEW

1-1 Introduction to Navy Towing

Modern Navy towing, as we perceive it today, began at the beginning of World War II. Prior to WWII, the Navy owned few salvage ships of its own and depended heavily on contracted assets to perform the duties of towing and salvage. Merritt-Chapman and Scott was one of the premier towing and salvage contractors of the day and maintained an inventory of assets. They held a contract with the Navy to perform ship salvage on an as-needed, no cure-no pay basis. As the US watched the war in Europe develop, the need for specialized vessels and a dedicated service became apparent. The Royal Navy of Great Britain was forced into performing these tasks as German U-boats inflicted damage throughout the military and commercial fleet. Performing towing and salvage services on damaged vessels was most often a faster and cheaper way of putting the necessary tonnage back into service.

In October of 1941, Congress pressed through legislation that gave the Navy the contracting authority to obtain the salvage resources, public or private, necessary to perform operations that were deemed in the best interest of the country. On December 7, 1941, the Japanese bombed Pearl Harbor and four days later the Navy signed a contract with Merritt-Chapman and Scott establishing the Navy Salvage Service. This service was responsible for performing offshore salvage on east and west coasts, the Caribbean, Alaska, and Panama. To do this, it utilized leased commercial assets including tugs. The responsibility for towing distressed or disabled ships into port, however, did not lie with the Navy Salvage Service. This duty was the responsibility of the tugs attached to the naval districts.

This arrangement made it difficult to muster a large quantity of tugs to respond to large groups of casualties that often resulted from German U-boat attacks. These casualties included not only fleet vessels but merchant ships, which were logistically critical to the war effort. The US knew the value of keeping a strong logistical force operating. To help rectify these shortfalls and to better utilize the available assets, the Navy formed the Navy Rescue Towing Service. This service fell under the command of Commander, Eastern Sea Frontier, and operated exclusively on the Atlantic Coast. All available tugs were organized under this service, which was headed by Edmond Moran of Moran Towing. Edmond Moran understood the towing industry and was enrolled in the Naval Reserve to perform this duty. This organization for the most part alleviated the problems of asset allocation and allowed the rescue of many tons of ships and cargo.

The Navy operated tugs in support of their logistic requirements for many years, but as the war in Europe wore on, the need became apparent for more capable, sea-going tugs. The Navy designed a fleet tug (ATF) for the 1939 shipbuilding program. The NAVAJO (ATF 64) was the first of a fleet of 3,000 shaft horsepower, diesel-electric ocean-going tugs equipped with an automatic tensioning towing engine. Almost seventy of these vessels were constructed before the end of the war. These ships would serve the Navy well for nearly fifty years. Their towing winches proved very successful in taking disabled ships under tow. Their long range and seaworthiness also made them very suitable for combat operations.

The Navy also built many Auxiliary tugs (ATA) to be used in support of the fleet tugs. They were also diesel driven (relatively new technology for tugs) but carried about half the horsepower of the fleet tugs. They had considerable endurance and were well suited to perform operations just outside the combat zone. They would often relieve a fleet tug of a disabled vessel and continue the tow into port. This allowed the fleet tugs to return to the combat zone where they also performed some fire-fighting and salvage assistance. Rescue tugs (ATR) were wooden-hulled, used in submarine infested waters, and provided excellent fire-fighting support. Their range was limited, and although they were not considered the best vessels for long distance towing, they were excellent in coastal areas.

The early designs of the salvage ships were not particularly well suited for towing. This changed with the steel-hulled BOLSTER class (ARS 38) which were built as salvage ships but were of similar horsepower to the fleet tugs (ATF). They were originally equipped with a powered reel for towing, but it was soon discovered that they performed towing duties almost interchangeably with the fleet tugs. Automatic towing winches were diverted from the ATA program and installed on these six vessels. These ships were of excellent design and operated until the last one was decommissioned in the mid-1990's.

The primary mission of the Navy's towing and salvage ships today is not very different from the early days of these vessels. They provide support to distressed or disabled ships in the combat zone. However, during peacetime, the daily operation of these ships differs tremendously. The Navy now operates only a few open ocean towing ships. At the time of this writing, the Navy had four ARS 50 class salvage ships and the Military Sealift Command (MSC) had five T-ATF class vessels operating for the Navy. T-ATFs are manned by civilian crews and do not carry the extensive salvage equipment of the ARS class but are extremely capable towing platforms. In recent years, efforts to reduce military expenditures have resulted in not only decreases in the number of tow ships available but also an increase in the number of all ships being decommissioned. This has placed a high demand on the Navy's few towing assets and has increased the amount of work being sent to commercial firms.

U.S. Navy towing and salvage ships also provide battle damage control as an adjunct duty to their primary role as towing and salvage platforms. Fleet battle damage control is rendered in the combat zone to a battle-damaged ship casualty, often under direct enemy fire. The assistance can take the form of off-ship fire-fighting from a salvage tug's fire-fighting monitors or of a damage control team from the salvage ship boarding the casualty.

Towing can vary from routine, well-planned activities to time-critical emergencies such as rescue or salvage towing. Routine Navy towing includes a wide variety of activities such as harbor work and offshore or open ocean towing. Navy emergency towing consists almost entirely of escort, rescue, and salvage missions. The types of vessels that may require towing include Navy ships ranging from small patrol boats to large aircraft carriers; non-combatant vessels, including targets, large fleet oilers, and supply ships; and vessels such as barges and floating dry docks.

The Navy recognizes several distinct types of towing:

- Harbor towing
- Point-to-point towing
- Rescue and emergency towing
- Salvage towing
- Special ocean engineering projects
- Tow-and-be-towed by Naval vessels

1-2 Harbor Towing

Harbor towing is limited to protected waters. Harbor towing and base support includes docking/undocking, standby duty, and safety escort duty. These services are the province of *yard tugs*. These vessels are incapable of sustaining long-distance, open ocean towing due to design limitations. Harbor tugs do not have the range, crew size, berthing and messing capacity, and, in some cases, the structural or hydrodynamic design needed to support open ocean towing. Their moderate horsepower, limited seakeeping characteristics, and minimal towing machinery also makes these vessels unsuitable for the open sea. The U.S. Navy currently operates three classifications of yard tugs: the YTL, the YTM, and the YTB.

1-3 Point-to-Point Towing

Point-to-point towing can be defined as towing a vessel from one harbor to another. Point-to-point towing and "open ocean" towing are largely synonymous. Open ocean towing was a natural outgrowth of harbor towing. If vessels could be moved from one end of a harbor to the other end, the next step was to move them from one harbor to another.

Until the 1960's, Navy ATAs or similar vessels, were generally home-ported in each naval district in the continental United States, Alaska, Hawaii, and at selected overseas bases. The tugs were used for coastwise towing of floating equipment, such as barges, pile drivers, and dredges. Since the 1960's, the Navy's towing fleet has declined in numbers, with whole classes of towing vessels being decommissioned. The ATF 76, ARS 6, ATS 1, and all ATAs have been decommissioned, and, in FY94, the last WWII vintage ARS 38 class salvage ships were also retired. Consequently, Navy point-to-point towing is currently performed by ARS 50 and the MSC-operated T-ATF class vessels, with an increasingly large percentage of tows contracted to commercial firms.

1-3.1 Inland Towing

Inland towing is point-to-point towing performed on inland waterways such as rivers, bays, canals, or intercoastal waterways. Inland towing in the United States largely originated on the Mississippi and Ohio River systems. This type of towing was also done on the Erie Canal and other inland man-made navigational systems managed by the Army Corps of Engineers, such as the St. Lawrence Seaway and East Coast Intercoastal Waterway. The Navy does very little inland towing.

1-3.2 Ocean Towing

Ocean towing is point-to-point towing where there are few, if any, places of refuge enroute. Open ocean towing was a natural evolutionary step from harbor towing. The demand for open ocean tows led to more advanced tug designs that could accommodate more difficult towing missions.

After harbor towing, open ocean towing is the most widely practiced form of Navy towing. Because of the unforgiving conditions faced on the open ocean; it demands the most preparation; the most robustly designed and constructed equipment; and a higher level of operator knowledge.

1-3.3 Defueled Nuclear Powered Ships

The Navy has devoted a considerable effort in developing guidelines for towing Unmanned Defueled Nuclear Powered Ships. The unique considerations of towing a nuclear vessel that is unmanned have led to the development of specific instructions that deal with this specific situation. NAVSEA has published a series of instructions to specifically deal with unmanned towing of nuclear vessels (including submarines, cruisers, and moored training ships). The information contained in those documents will not be repeated in this manual.

1-4 Rescue and Emergency Towing

The mission of rescue towing encompasses saving a stricken ship at sea and towing to a safe refuge. The vessel may be adrift at sea, or near a shore or harbor. In the latter case, a connection must be made quickly to prevent the disabled ship from going aground. On high value tows, the Navy may assign a tug to escort duty, to provide emergency towing services without the delay of mobilization.

1-4.1 Naval Task Force Standby Duty

Navy salvage ships routinely deploy to the Mediterranean and to the Western Pacific to provide salvage and towing support to the 5th, 6th, and 7th Fleets. Aside from participating in salvage exercises with foreign navies, the salvage ships perform any salvage or towing mission tasked by the Fleet Commander for the deployed Carrier Battle Group, Surface Action Group, or any auxiliary ships requiring salvage or towing assistance.

1-5 Salvage Towing

Salvage towing generally follows immediately after a salvage operation. Immediately after salvage services are rendered, preparations are made to tow the stricken vessel. The vessel may be towed to a safe haven for temporary repairs, or to a port or facility where complete industrial-level repairs are possible. The vessel may also be towed to a disposal site for sinking. In either case, tow preparations usually entail more than the normal tow system installation. The added measures include reinforcing weakened sections of the ship, either through shoring or temporary structural reinforcement, or possible special rigging to release the tow for sinking in a safe, controlled manner.

1-5.1 Combat Salvage and Towing

Ships involved in combat salvage and towing missions often escort amphibious landing forces and battle groups in hostile areas. Their job is to provide towing and salvage services to ships or landing craft that are damaged, afire, disabled, or stranded. They are also prepared to tow transport and supply ships laying off the beachhead. During amphibious landings, these rescue tugs and salvage ships can be subject to enemy fire.

1-6 Special Ocean Engineering Projects

Navy tugs often become involved with unusual projects, such as target services, submersible towing, array movements, deep ocean search and recovery, and classified operations.

Many of the attributes that make salvage ships good salvage and towing platforms also make them good platforms for performing these ocean engineering operations. Specifically, tugs that can perform open ocean tows are often equipped with heavy lift cranes, have large expanses of deck area for temporary installation of specialized equipment, and are designed to keep station or moor over a site of interest. Navy tugs can also serve as diving platforms and perform a variety of deepwater tasks, including the support and recovery of remotely operated vehicles.

1-7 Tow-and-Be-Towed By Naval Vessels

Although most towing is performed by ships that have been specifically designed and built for towing, emergency towing is sometimes accomplished by ships other than tugs. This concept is referred to as “tow-and-be-towed” or “emergency ship-to-ship towing.” In an emergency, any ship can tow another in its own or similar class, with each ship providing half the towline. Ships not specifically equipped for towing can fashion a temporary towline from anchor chains, wire straps, mooring lines, or combinations of these items.

NAVSEA General Specifications require that every class of U.S. Navy ship (except aircraft carriers and submarines) be able to tow-and-be-towed in an emergency. Definitive technical instructions for U.S. Navy tow-and-be-towed operations can be found in Naval Ship's Technical Manual (NSTM) S9086-TW-STM-010, Chapter 582, *Mooring and Towing* (Ref. A). This topic is also covered in Section 6-6 of this manual. In the event of a conflict between NSTM Chapter 582 and this manual regarding tow-and-be-towed operations, NSTM Chapter 582 shall take precedence. *In all other towing matters, with the exception of nuclear tows, this manual is the governing document.* Tow-and-be-towed operations for NATO navies are covered in Allied Tactical Publication (ATP)-43(A) (NAVY), *Ship-to-ship Towing* (Ref. B).

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Chapter 2

OVERVIEW OF TOWING SHIPS

NOTE
Although ocean-going tow ships are significantly different from harbor tugs, the term "tug" will be used to describe all tow ships in this manual to avoid confusion between "tow ship" and "towed ship."

2-1 Introduction

This chapter contains a brief description of some typical design features found on ocean-going tugs. It also presents a good overview of the latest generation of the US Navy's ocean towing ships. Modern harbor tugs utilize recent advances in propulsion and synthetic line, but ocean going tugs remain largely unchanged from earlier versions.

2-2 Requirements Placed on Towing Ships

The degree of service that the tug may be required to furnish to its tow depends upon the circumstances and principal missions of the Navy at the particular time and can cover a wide spectrum of needs. The primary requirement placed on a tug is to provide power that the tow does not have due to its construction, its service condition (i.e., decommissioned), a casualty, or a failure of its main power plant. Secondary requirements include:

- Steering for maneuverability
- Navigation
- Communications
- Security
- Damage control
- Fire protection

For long ocean tows, the tug can be called upon to provide complete logistic support for the tow and the riding crew. The tug may also be required to serve as a supply base and shop for repairs, rigging, and damage control during rescue salvage towing operations. Additionally, the tug may have to supply all the rigging for the towing system.

2-3 Design Characteristics

Most U.S. Navy ships can tow in an emergency, but only properly designed and outfitted tugs make good towing ships. The specific items to be considered in the design of an ocean tug are dependent upon the missions and services that it will be called upon to perform. Characteristically, a tug's superstructure is set forward, allowing a clear fantail so the towing point can be close to the ship's pivot point. The towline, secured well forward of the rudder and propellers, is allowed to sweep the rail without limiting the maneuverability of the tug. In addition to a clear fantail area, characteristics of a good tug may include the following:

- High horsepower
- Slow speed maneuverability
- Large diameter propellers
- Large area rudders
- Towing machinery
- Power capstans
- Towing points
- Bow thrusters
- Deck crane

In general, a Navy ocean tug is a very versatile ship, but its design involves many compromises. Appendix K provides data on features of some commercial tugs. The design of a Navy tug will differ from a commercial tug because a commercial tug must make a profit. This influences manpower, automation, secondary missions, and a host of other characteristics.

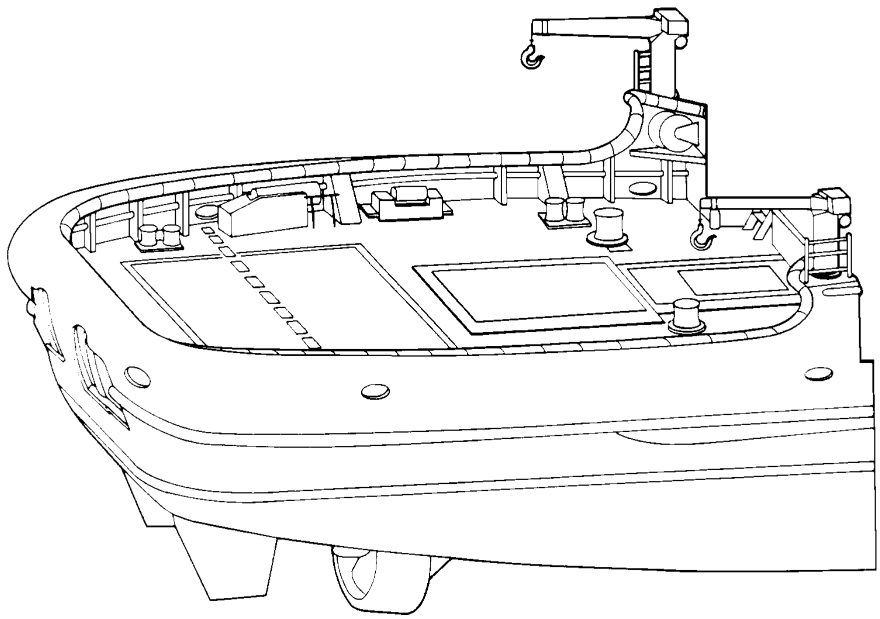


Figure 2-1. ARS 50 Bulwark Forward Limits.

2-3.1 Stern Arrangement

The stern of the tug is designed to minimize chafing and damage to both the tug structure and the hawser. Caprail radius is generous and free from unintended obstructions to the hawser's sweep from side to side as the tug maneuvers in restricted waters. Most tugs have a system to restrain the tow hawser sweep, such as vertical stern rollers or Norman pins, while towing under steady-state conditions at sea. To reduce wear on both the hawser and the tug's structure, chafing gear is often used where the towline crosses the stern.

On most Navy towing and salvage vessels, the bulwark and the caprail are gently curved upward and faired into the deck above the towing deck (see Figure 2-1.). This ship's structure restricts the tow wire from leading forward of the beam at the tug's tow point just aft of the tow winch.

2-3.2 Tug Powering and Bollard Pull

The design of the main propulsion plant is a compromise among wide-ranging requirements. The tug must have high free-running speeds for reaching the scene of a casualty quickly. It also needs good economy with high towline pull for long-distance tows at reasonable towing speeds. High bollard pull is required for holding a distressed ship to prevent it from grounding and for refloating stranded ships. It is also required for alongside operations (docking, maneuvering) and other high power/near zero speed evolutions.

In the absence of a good automatic towing machine or other accurate means of measuring the towline tension, a knowledge of the tug's available towline pull and bollard pull is required for controlling the tension. Appendix K presents the methodology for estimating towline pull and bollard pull.

2-3.3 Fenders

Fenders are energy absorbing materials or devices that protect both the tug and the tow (see Figures 2-2 and 2-3). Modern fendering is an important part of towing operations when alongside evolutions are required. Tugs working alongside submarines should have subsurface fenders. Small tugs working with large ships should have fendering to protect the deckhouse from being damaged during large rolls (see the wing fenders in Figure 2-2).

Three types of standard fenders are currently in use:

- Rubber
- Pneumatic
  - High-pressure (5 to 7 psi)
  - Low-pressure (1 psi)
- Closed-cell foam covered with urethane elastomer

2-3.3.1 Features and Characteristics of Fenders

The most significant features of fenders are:

- Energy absorption
- Durability
- Handling characteristics
- Ease of storage aboard ship
- Ease of maintenance when not in use
- Required support equipment

Other important characteristics include:

- Standoff distance
- End fittings
- Time required for deployment and recovery
- Capability of being used if damaged.

2-3.3.2 Operating Considerations

The following items should be considered when using fenders:

- **Energy Absorption vs. Deployment.** Rubber fenders, as seen in Figure 2-2, are an integral part of a tug's structure. These take no time to deploy but provide little energy absorption beyond simply eliminating steel-to-steel contact. Foam and pneumatic fenders require rigging and handling but are far superior in their absorbing capability.

  Large truck tires are very effective from the standpoint of energy absorption and are inexpensive. They can be rapidly deployed and are particularly useful during salvage where unusual conditions may exist. Some tires should be kept on board for emergency fendering.

- **Size vs. Capacity.** Low-pressure and high-pressure pneumatic fenders have similar characteristics. Because they are filled with air, however, they must be larger than foam-filled fenders to absorb the same amount of energy. On the other hand, equal capacity and quality foam-filled fenders will likely be more expensive and heavier than pneumatic fenders.

- **Pneumatic Fender Maintenance.** In addition to the larger size of pneumatic fenders, other attending disadvantages are the extra equipment needed to pressurize them and to check the internal pressure. Patch kits and special slings to support the fender's midsection when being deployed and retrieved are also necessary for the low pressure types.

- **Pressure Loss.** All pneumatic fenders have safety valves. When these valves relieve under high fender loads, the fenders lose nearly all their energy absorption capability.

- **Fender Displacement.** A major operating problem can arise when either the tug or the tow has a low freeboard relative to the other ship. When the heaving or rolling motions of the two ships

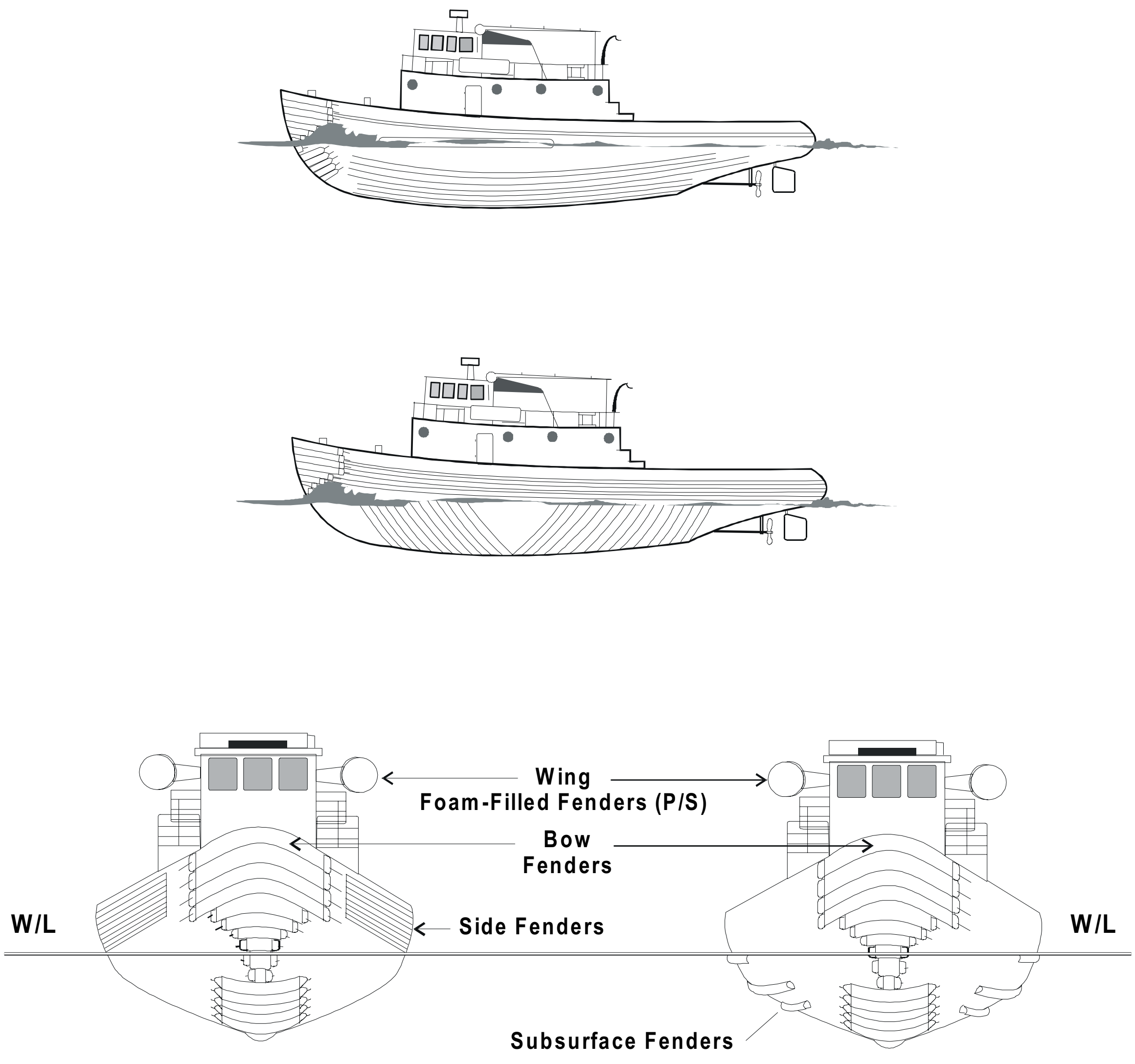
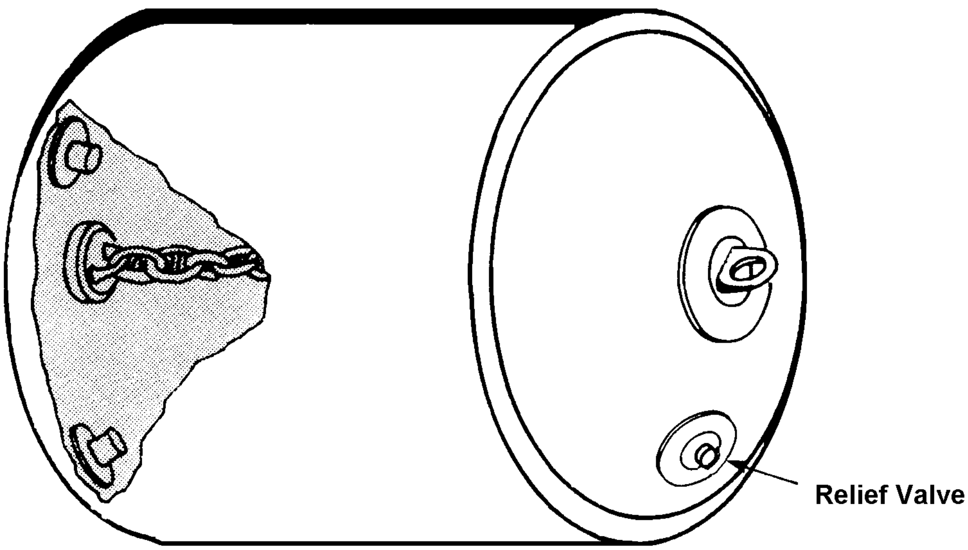
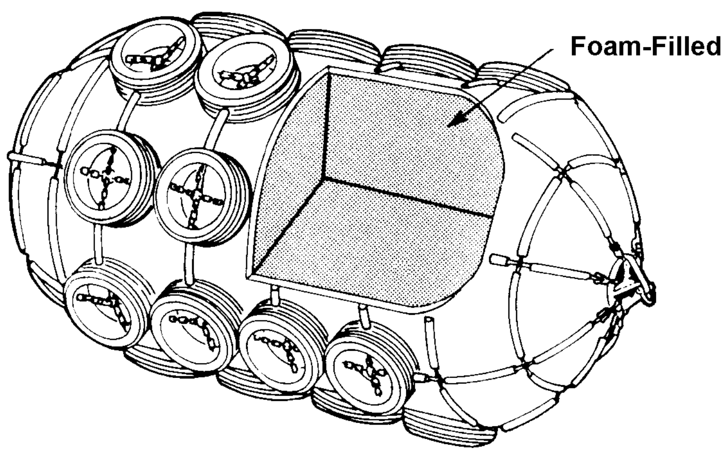


Figure 2-2. Typical Rubber Fenders.



Pneumatic Fender



Foam Fender

Figure 2-3. Pneumatic and Foam Fenders.

get out of step, the fender can be rolled upward between the two ships and pop out onto the deck of the one with the lower freeboard.

- **Friction Damage.** When the tug and the tow have nearly equal freeboard, the out-of-step motions of the two ships can create a great deal of frictional heating on the surfaces of the fenders. Spraying seawater onto the rubbing surfaces helps lubricate them and keep them cool.
- **Ship Shell Plating Damage**. Care must be exercised in the fore and aft placement of the fenders to ensure that they do not bear against relatively large areas of side plating that are not well supported by internal framing and longitudinal structural members. This is especially important in quartering seas when swells will cause the two ships to pivot about the bow or stern and then slam the sides together at the other end.

2-4 Yard or Harbor Tugs

The design of harbor tugs and the equipment they employ varies. The typical Navy harbor tug is a single-screw, deep-draft vessel equipped with a capstan aft, H-bitts forward and aft, towing hawsers, and additional lines for handling ships or barges in restricted waters. Harbor tugs may also be equipped with fenders, limited fire-fighting equipment, and deck equipment to support harbor operations. Twin-screw harbor tugs have greater maneuverability and ship control.

Harbor tugs are classified by shaft horsepower (shp). The U.S. Navy operates three classes of harbor tugs that are used primarily in harbors and sheltered waters. As these vessels age, the Navy relies more and more on contracted vessels to perform harbor operations. This allows the Navy to take advantage of the latest tug designs, but at the same time diminishes its fleet.

2-4.1 YTL Class

Yard tugs having 400 shp and under belong to the YTL class. The primary mission of the YTL class is moving small craft and unloaded barges from one berth to another within a harbor. YTLs can also assist in moving larger vessels because they are small enough to maneuver in tight, confined areas between the large vessel and obstructions. Characteristics of this class are small size, maneuverability, and less robust construction than larger harbor tugs. The term YTL is used to cover an entire spectrum of harbor “pusher boats.” Very few of the vessels are constructed to the same class specifications, and a large number are custom built by the naval base using them. The YTLs are still in service, but literally hundreds have been retired as their useful life has ended (most were built during WWII).

2-4.2 YTB Class

The largest tugs, with 1,000 to 2,000 shp, belong to the YTB class. The larger YTBs currently have as much as 2,000 shaft horsepower and are similar to commercial harbor tugs. YTBs can be used in open-ocean towing, but only for short distances under the most optimal weather conditions. YTBs are mostly confined to harbor operations with occasional point-to-point towing performed on inland waters or on coastwise towing routes. YTBs configured for servicing submarines have a specially designed fender system. YTBs are widely used in all Navy ports, especially overseas bases, but may also face retirement in the near future.

2-5 Ocean Tugs

The Navy’s ocean tugs are far more versatile than harbor tugs in terms of horsepower and range capabilities, as well as in terms of the services they can provide to their tows. Ocean tugs and salvage/rescue type ships are the only U.S. Navy ocean-going ships whose primary mission includes towing. Thus, they are the only types considered to be specifically built for towing and for which towing activities have significantly influenced the design.

Most of the ocean tugs used by the Navy today are carryovers and replacements or successors to similar ships used or developed during WWII. Some of the differences between the WWII vintage and the more modern ships lie in increased horsepower and bollard or towline pull, hawser size, provisions for use of synthetic fiber hawsers, and, of major importance, vastly improved onboard equipment and accommodations.

In addition to their power, range, and endurance capabilities, the ocean tugs can work and survive in heavy weather independently of other auxiliary or support ships. They are also used in stranding and other salvage operations. Ocean tugs should have automatic towing machines and load sensing systems to reduce dynamic loads and, if necessary, rapidly release the towline.

The following section contains a brief description of modern U.S. Navy towing and salvage ships. Due to shrinking budgets, some of these vessels are no longer in service. Their characteristics are presented here for both historic and comparative purposes. For more detailed information, refer to the operations manual of each vessel.

2-5.1 ARS 50 Class

The four ships of the ARS 50 Class (see Figure 2-4) are replacements for the ARS 38 Class. Each ship carries a crew of over 100 and equipment sufficient to handle ocean towing, independent salvage, diving, damage control, and fire-fighting capabilities in times of war.

The automatic towing machine (ATM) on board the ARS 50 Class is a Series 322 winch built by Almon A. Johnson, Inc. (see Figure L-2). This double-drum ATM stores two 3,000-foot, 2¼-inch diameter towing hawsers. The ARS 50 Class also has a Series 400 traction winch for handling synthetic line up to 14 inches in circumference. The traction winch is also useful for mooring and ocean engineering operations. These vessels are extremely versatile. They are capable of supporting a wide range of missions and are excellent towing platforms as well as fully capable salvage ships.

2-5.2 T-ATF 166 Class

The T-ATF Class is a multipurpose, long-range, high-horsepower, seaworthy tug (see Figure 2-5). It can conduct long-distance tows and, when augmented with additional crew and equipment, operate in support of fire-fighting, diving, and salvage missions. These seven vessels were designed for and are operated by the Military Sealift Command (MSC). They carry approximately 20 crew members, and 18 transients.

This ship was conceived and specified to replace the Auxiliary Ocean Tugs (ATA) and Fleet Tugs (ATF) for routine towing. Because it also was designed to serve as a salvage tender, it has a large afterdeck, similar to an offshore supply vessel. Although not normally carried, various suites of special equipment can be installed on board the T-ATF to support air and mixed gas diving, beach-gear operations, off-ship fire-fighting, search and recovery operations, and oil spill recovery. This class is capable in rescue towing applications, but has limited salvage capabilities on its own. With its large fantail area, it can be augmented to perform salvage, but carries little of its own equipment.

This 7,200 horsepower tug class carries a 2,500-foot, 2 1/4-inch wire rope tow hawser. The T-ATF is equipped with a traction winch

These ships replaced the ARS 6 and ARS 38 Class and have modernized salvage and towing capability. They are also equipped with off-ship fire-fighting improvements.

Length (ft):	255	**Shaft Horsepower:**	4200
Beam (ft):	52	**Cruising Range (nm):**	8,000 @ 8 kt
Draft (ft):	17.5	**Fuel Consumption (Gal/day):**	2 engine: 2100 4 engines: 4200
Displacement, Full Load (LT):	3282	**Complement:**	94 crew 16 transients
Propulsion, Main:	4 diesel 2 screws	**Towing Machine:**	*Almon A. Johnson, Inc.* Automatic towing machine, Series 322 (double-drum) 2 1/4-wire, 3000 ft. (will accept 2 1/2-inch wire) and 14-inch traction winch, Series 400
Maximum Sustained Speed (kts):	15	**Bow Thruster:**	1 @ 500 HP

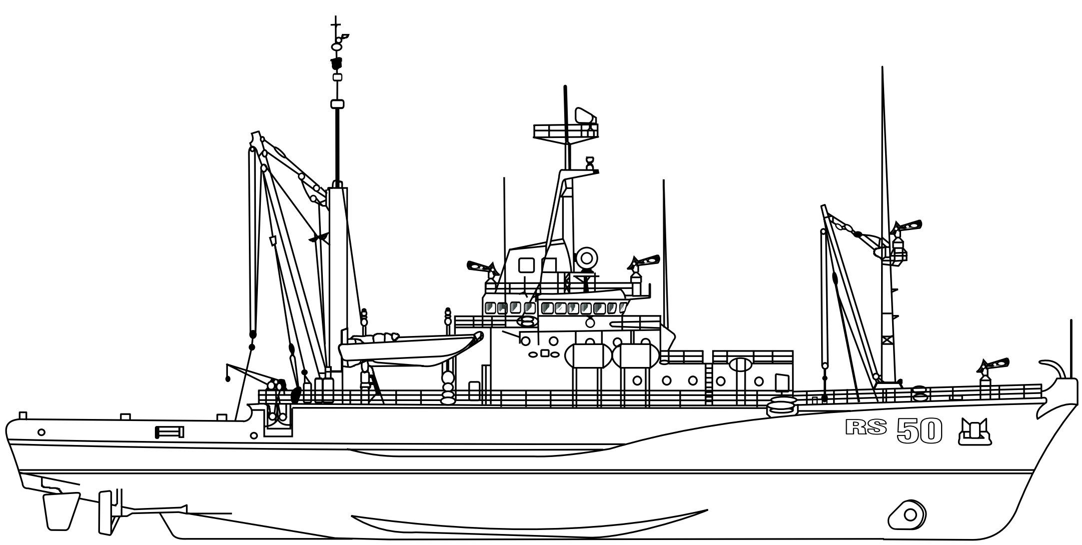


Figure 2-4. ARS 50 Class Salvage Ship.

This class of tug has replaced the ATF 76 Class. These ships have a large working space aft for VERTREP (replenishment by helicopter) and can be readily outfitted for specialized salvage and ocean engineering missions.

Length (ft):	240
Beam (ft):	42
Draft (ft):	15.5
Displacement, Full Load (LT):	2260
Propulsion, Main:	2 diesel, 2 screws Controllable, reversible pitch in Kort nozzles
Maximum Sustained Speed (kts):	15
Shaft Horsepower:	7200
Cruising Range (nm):	10,000 @ 13 kt
Fuel Consumption (Gal/day):	1 engine: 4149 2 engines: 8300
Complement:	16 crew 4 Navy communicators 18 transients
Towing Machine:	SMATCO* 2500 ft. 2 1/4-inch wire winch (15-inch Lake Shore, Inc. traction winch)
Bow Thruster:	1 @ 300 HP

* Some vessels of this class have been refitted with Almon A.Johnson automatic machines.

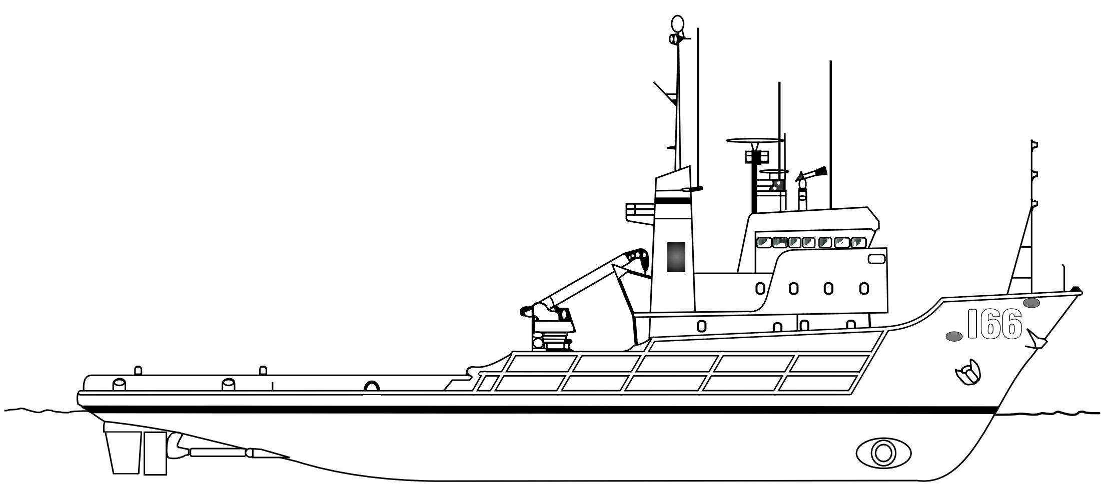


Figure 2-5. T-ATF 166 Class Fleet Tug.

that can handle synthetic hawsers up to 15 inches in circumference. The class was originally equipped with a single-drum, diesel driven, non-automatic SMATCO towing winch relatively common to the offshore oil industry (see Figure L-3). Some members of this class have been refitted with an (Almon A. Johnson) electrohydraulic automatic towing machine (see Figure L-4).

Chapter 3

TOWING SYSTEM DESIGN

3-1 Introduction

This chapter provides guidance on the steps to take when preparing to perform a tow. It contains information for the planner in choosing a tug and for predicting tow speed.

3-2 Designing a Towing System

Tow system design is often an iterative process. Each iteration has three core stages:

1. ***Calculate steady towline tension.*** Starting with the ship to be towed:
    - Select the desired towing speed and calculate the steady state tension that the towline will encounter at that speed (see Section 3-4 and (Ref. G)).
    - Select representative tow speeds above and below the desired speed and calculate the corresponding steady towline tensions. The calculated tensions should be either plotted or arranged in a table to allow interpolation later.
    - Repeat this process for representative wind/sea combinations anticipated during the tow.
2. ***Select the tug and design a rig.***
    - Compare the predicted towline tension to the capabilities of available tugs and select the tug best suited for the task.
    - Once a tug is selected, design an initial towing rig. Select the towing connection elements (such as bridles and chain pendants), determine a recommended hawser length, and check the catenary. Account for the effects of weather, type of towline, and dynamic load mitigation. Use the appropriate safety factors for the materials and equipment involved, anticipated weather, and other conditions of the particular towing mission (see Section 3-4.1 and (Ref. M).
3. ***Make necessary adjustments.***
    - Recheck the refined calculations against the tug's capabilities.
    - If calculated requirements for power or towline strength exceed capacities of available equipment, another iteration is required. Options may include:
        - — Selecting a slower towing speed
        - — Using additional or more powerful tugs
        - — Decreasing resistance by changing the tow's characteristics, routing, and/or schedule.

3-2.1 Tug and Tow Configuration

The design of a towing system is dependent on the type of towing performed, the configuration of the tow, and the number of vessels being towed. For examples of the types of tow configurations used for open ocean towing for single and multiple tows, see (Ref. I).

3-3 System Design Considerations

When planning a tow and designing the tow system, important considerations are:

- Tow size, type, and condition
- Expected or required towing speed
- Capabilities of available tugs (bollard pull, range, equipment, and crew)
- Towing hawser system specifications (type, diameter, expected maximum tension, scope and configuration)
- Towline tension as determined by the total resistance of the tow and re-

spective seakeeping motions of the tug and tow

- Maximum practical towline length, as determined by navigational and hydrographic restrictions on towline catenary depth
- Operational considerations
- Proposed season and route
- Unique characteristics of the anticipated tow
- Stability characteristics of the tug

These factors are interdependent. For example, in theory, the desired towing speed would largely determine the required tow hawser size. But, in practice, there is little choice of tow hawser for a given tug class. Hawser choice is governed by the ship which is available for the towing assignment. For large tows using the full propulsion power of the tug, the tug determines the potential speed of the tow. In other cases, tow speed may be limited by weather or by the condition of the tow. Given the tug and the resulting speed of the tow, the tow hawser size can be checked and an initial towing rig designed.

All of these factors must be considered to determine which ones will dictate the design of the system. The system must then be examined as a whole to ensure that the best configuration has been achieved.

3-4 System Design Methodology

3-4.1 Calculating Total Towline Tension

Total towline tension has two major components: steady tension and dynamic tension. Steady (or static) towline tension can be predicted with a fairly high degree of accuracy. Static towline tension has three components:

- Resistance of the ship to be towed (see 3-4.1.1)
- Resistance of the tow hawser (see 3-4.1.2)
- Vertical component of wire catenary (which contributes to the total tension of the towline itself but not to tug propulsion requirements) (see 3-4.1.3)

Dynamic towline tension, on the other hand, is caused by the random motions of the sea and the ships and is difficult to predict with absolute precision over time. Statistics, however, allow prediction of dynamic tension extremes within probability limits set by the investigating engineer (see (Ref. M)). Dynamic tension has two components:

- Slow dynamic loads caused by the tow's yawing, sheering, and surging (see 3-4.1.4)
- More rapid dynamic loads caused by the effect of waves on the relative seakeeping motions of tug and tow (see 3-4.1.4)

3-4.1.1 Calculating Steady Resistance of the Towed Vessel

Steady resistance (R_T) of the towed vessel may be estimated using the following approximation:

$$R_T = R_H + R_P + R_W + R_S$$

where:

R_H	=	Hydrodynamic hull resistance of the tow
R_P	=	Hydrodynamic resistance of the tow's locked propellers
R_W	=	Wind resistance of the tow
R_S	=	Additional tow resistance due to sea state

(Ref. G) provides methods and a convenient worksheet for predicting each of these components. Effort can be saved by computing the resistance for two or three different speeds for later comparison to tug capabilities. (Refer to the towing speed limitations

Table 3-1. Hydrodynamic Resistance of the Towline.

Wire Size (in)	Wire Scope (ft)	Chain Size (in)	Chain Scope (ft)	Added Resistance (lbs) 10,000 lb. Tension			Added Resistance (lbs) 20,000 lb. Tension		
				4 kts	8 kts	12 kts	4 kts	8 kts	12 kts
1 5/8	3000	--	--	1000	4000	7200	1000	3000	5800
1 5/8	2000	--	--	900	3500	4100	700	2500	3300
2	2000	--	--	2000	2200	6000	1500	2200	4000
2	2000	2 1/4	90	2500	5100	12000	1900	3900	7900
2	2000	2 1/4	270	3100	10000	19300	2000	7200	15000
2	2000	4 3/4	270	3700	12000	24500	2700	8900	17600
2 1/4	2000	2 1/4	90	1500	5200	11500	1300	3800	8000
2 1/4	2000	2 1/4	270	3000	8000	18500	1600	6500	14500
2 1/4	2000	4 3/4	270	5000	14100	25500	4500	12900	23000
2 1/4	3000	2 1/4	90	1900	8300	17500	1600	5700	13100
2 1/4	3000	2 1/4	270	3100	12000	24800	2500	8700	20100
2 1/4	3000	4 3/4	270	5500	14400	27800	5000	13300	26000

Wire Size (in)	Wire Scope (ft)	Chain Size (in)	Chain Scope (ft)	Added Resistance (lbs) 40,000 lb. Tension			Added Resistance (lbs) 60,000 lb. Tension		
				4 kts	8 kts	12 kts	4 kts	8 kts	12 kts
1 5/8	3000	--	--	600	2200	5000	500	1900	4200
1 5/8	2000	--	--	500	2000	3300	250	1000	2500
2	2000	--	--	1000	1700	3500	300	1200	3000
2	2000	2 1/4	90	1200	3200	6500	1000	2500	5100
2	2000	2 1/4	270	1500	5100	10900	1300	4200	8800
2	2000	4 3/4	270	2500	6900	14600	2000	6800	13200
2 1/4	2000	2 1/4	90	1200	3500	6500	1100	3100	5000
2 1/4	2000	2 1/4	270	1400	5100	11500	1200	3700	8500
2 1/4	2000	4 3/4	270	3600	9300	18100	2900	5700	13200
2 1/4	3000	2 1/4	90	1400	4100	9500	1200	2500	5900
2 1/4	3000	2 1/4	270	1900	6500	15500	1300	4200	10900
2 1/4	3000	4 3/4	270	3500	10500	21500	2000	7700	17000

USE OF TABLE: Towline resistance can be selected for the case closest to the actual towline configuration. The figures can be interpolated as required if additional accuracy is desired.

- For towline scopes less than shown, make a proportional reduction from the scopes listed.
- For tension greater than 60,000 pounds, extrapolate assuming a resistance curve between 40,000 and 60,000 pounds in a straight line.

cited in Section 6-4.2) Likewise, wind and sea state resistances should be computed for best and worst expectations as well as for the most probable conditions of each assumed tow speed.

3-4.1.2 Calculating Steady Towline Resistance

In addition to the tensions calculated in Appendix G, the hydrodynamic resistance of the towline must be included, and this can be significant for a typical wire hawser tow rig. The resistance is dependent upon the size, length, and catenary of the towline, which in turn are dependent upon characteristics of the selected tug and towing speed. When using a synthetic hawser, the added resistance of the towline is negligible and can be ignored in these calculations.

If a particular tug has not yet been selected, estimate the hawser resistance (R_{wire}) to be 10 percent of the tow resistance (R_T). Experience has shown that when R_{wire} is significantly more than 10 percent of R_T, the catenary is very deep and tension is, therefore, out of the range of concern for towline strength. If a particular towline configuration is being evaluated, Table 3-1 provides a more refined estimate of the hydrodynamic resistance.

3-4.1.3 Calculating Steady Towline Tension

Normal wire rope towline arrangements will assume a sag or catenary, as depicted in Figure 3-1. The total towline stress at any point is the vector sum of the horizontal and vertical components of the stress at that point. Figure 3-1 includes a vector diagram of the towline forces acting immediately astern of the tug. Maximum stress occurs near the stern because the hydrodynamic resistance of the entire towline is added to the resistance of the tow, whereas no hydrodynamic resistance is added at the bow of the tow. Because stress is highest near the stern of the tug, this is the point of interest to towing planners. Computing the total steady-state towline tension at the tow, even with as much as 270 feet of chain pendant, shows that the total tension is less than at the tug.

The steady-state towline tension at the stern of the tug is expressed by the formula:

$$T = \sqrt{(R_T + R_{wire})^2 + T_v^2}$$

where:

R_T = Tow resistance (Section 3-4.1.1 and (Ref. G))

R_{wire} = Towline resistance (3-4.1.2 and Table 3-1)

T_V = Vertical component of the towline tension

T_V is the weight of the towline forward of the catenary low point, less the slight upward component of hydrodynamic drag on the forward half of the catenary. Location of the catenary low point and the vertical component of the hydrodynamic drag are beyond the scope of this manual. Errors will tend to cancel out, however, if T_V is assumed to be the weight (in water) of one-half the scope of the wire towline. (See Table B-2 in (Ref. B) for dry weights and methods for calculating weights in water.) Do not include the weight of any chain pendant at the tow in this computation.

For example, assume that an ARS 50 is towing a ship that provides a steady tow resistance of 60,000 pounds at 8 knots. The towline consists of 2,000 feet of 2 ¼-inch IWRC tow hawser and 270 feet of 2 ¼-inch chain pendant at the tow. Table 3-2 provides a towline resistance estimate of 3,700 pounds. According to Table B-2, 1,000 feet of wire towline (one-half of the scope) weighs 8,143 pounds in water. Therefore:

T = Total Towline Tension

R_T = 60,000 lbs.

R_{wire} = 3,700 lbs.

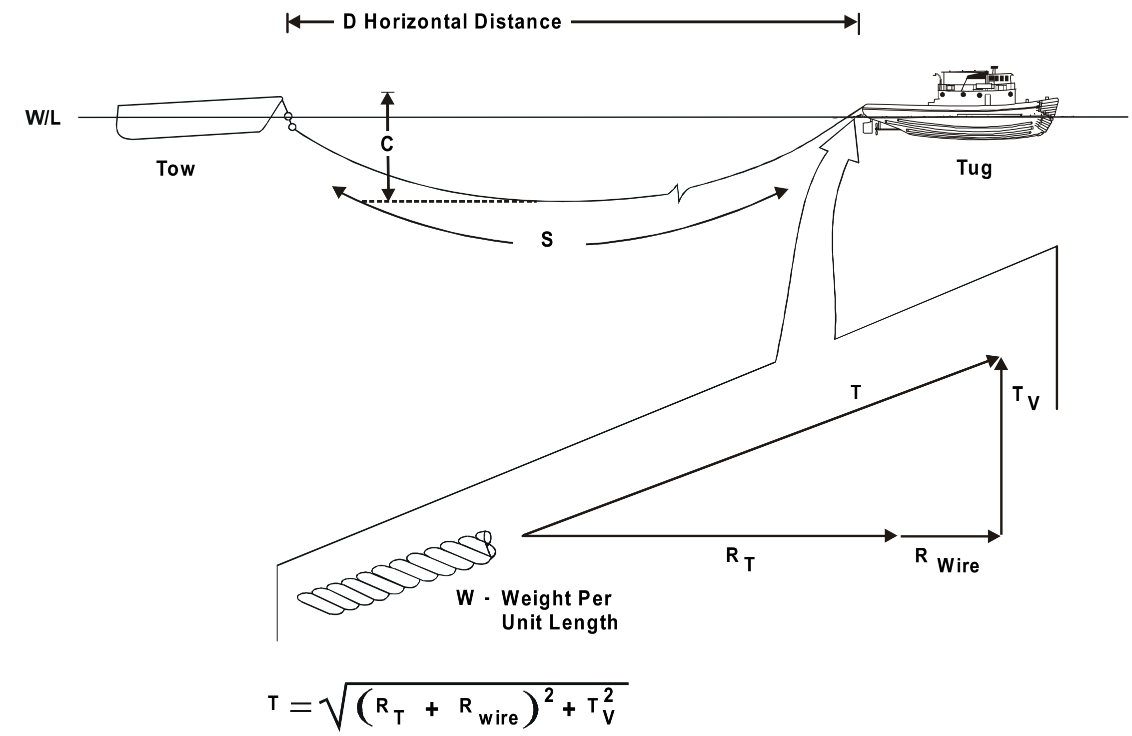


Figure 3-1. Towline Forces at Stern of Tow.

$T_V \;=\; 8{,}143$ lbs.

Solving the vector diagram provides a maximum steady-state tension:

$$T = \sqrt{(60{,}000 + 3{,}700)^2 + 8{,}143^2}$$
$$T = 64{,}218 \text{ lbs}$$

This example supports a rule of thumb that total steady-state tension can be estimated by adding 10 percent to the predicted steady tow resistance (R_T). This method is reasonable and accounts for both the wire resistance and the vertical component of the catenary. In the previous example, adding 10 percent to predicted steady tow resistance of 60,000 pounds would yield a total tension of 66,000 pounds, a conservative estimate when compared to the 64,218 pounds seen above.

In Figure 3-1, the tug must supply excess thrust only equal to the horizontal component of the tension, that is, $R_T + R_{wire}$. While the tug must support the weight of the towline, it does not require forward thrust to do this.

3-4.1.4 Dynamic Loads on the Towline

While towing at constant tug speed in a seaway, the towline tension is not steady, but varies over time (see Figure 3-2). In addition to steady horizontal resistance (T), the towline is also subject to stress from yawing movements (T_{yaw}) and from the wave-induced motions of the tug and tow (T_{wave}), also known as dynamic tensions.

Yawing, also referred to as sheering, is the slow swinging of the towed vessel from one side of the course line to the other. T_{yaw} also includes surge - the slow change of span between the tug and towed vessel. Sheering tension fluctuates in such a way that the average value is zero. Because each swing takes several minutes, sheering tension also takes several minutes to vary from its maximum to its minimum and is sometimes called a "quasi-steady" tension.

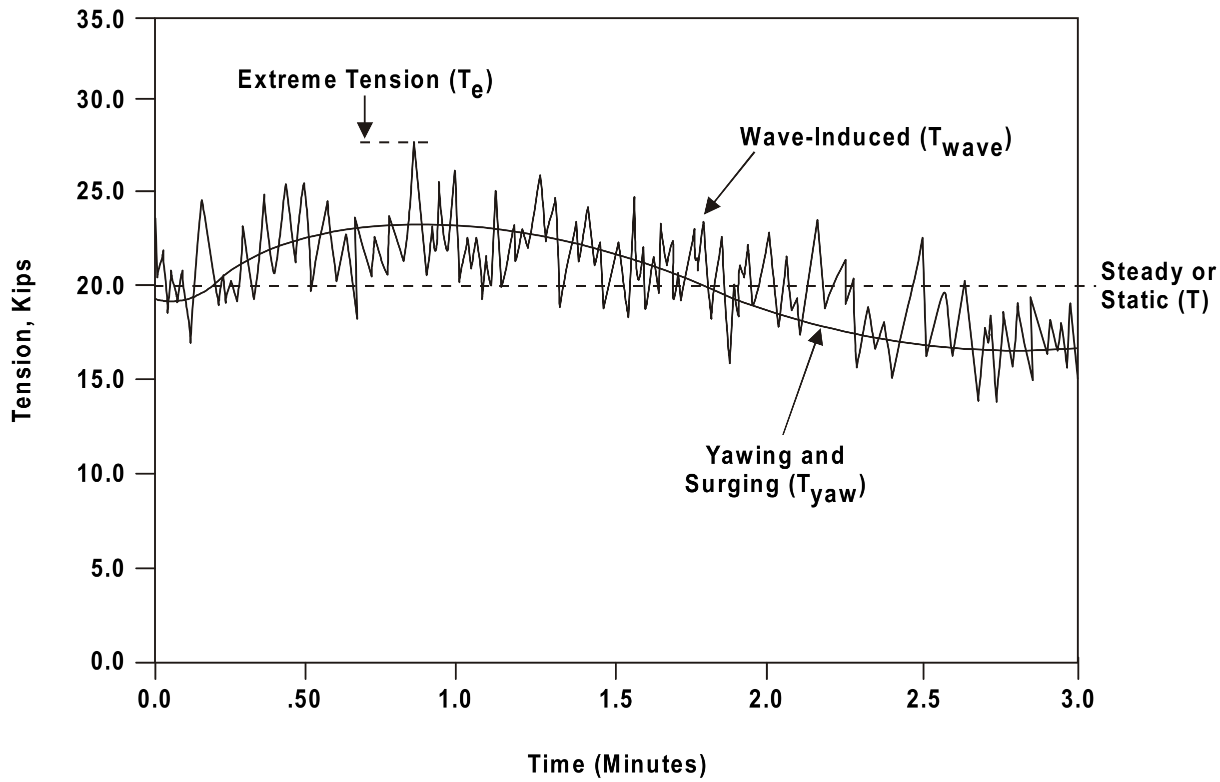


Figure 3-2. Towline Tension vs. Time.

Wave-induced tension is caused by the effect waves have on both tug and tow and is a random process with typical half-periods (the time taken to vary from maximum to minimum) of 1 to 8 seconds. Like sheering tension, wave-induced tension has an average value of zero. Dynamic tension is the accumulation of the complex dynamic responses of tug, tow, and towline to time-varying forces. While both the components of dynamic tension have an average value of zero, at any instant in time, dynamic tension can have a significant, if not catastrophic, effect on the towing system. Specifically, these damaging effects occur when the cumulative tensions from yawing and waves are additive to the steady-state tension in the towing system. The effects manifest themselves in peak loading that can destroy the towing system by pure overload or by metallurgical fatigue induced in the system components after repeated cyclic loading.

Extreme towline tension occurs when yawing tension and wave induced tension are additive. The total towline tension or extreme tension (T_e), can be expressed as:

$$T_e = T + T_{yaw} + T_{wave}$$

where:

T_e = Extreme Tension

T = Steady towline tension ($R_T + R_{wire}$)

T_{yaw} = Time-varying tension due to yawing of the towed vessel

T_{wave} = Time-varying tension due to wave action on the ship and on the tow.

In Figure 3-2, for example, T is 20,000 pounds. T_{yaw} varies between -3,000 and

+3,000 pounds. T_{wave} varies between -5,000 and +5,000 pounds. T_e, in this example, is approximately 28,000 pounds.

The example shown in Figure 3-2 assumes constant speed and could apply to a tow that is small compared to the size and power of the tug. For large tows, where slow swings can take 10 minutes or more, and for the typical situation where the tug's power setting is constant, the tug and tow both slow down to accommodate the increased tow resistance. This is especially true when the tow sheers off to one side. A poorly behaved tow, therefore, cannot be expected to attain the speed predicted by (Ref. G) without a significant increase in tug power and hawser tension, neither of which may be possible or wise.

A badly sheering tow can apply a significant additional tension peak when it "fetches up" at the end of each excursion to the side. This may dictate a further, deliberate slowing to protect the towing gear, especially if the towing machine is not in its automatic mode.

Determination of maximum values for the three components of towline tension is desirable in the planning or design of a tow, as well as in the actual towing operation. During a tow operation, precise determination of towline tension requires precision instrumentation. Normally tugs are not equipped with instrumentation sufficiently accurate to measure T_{wave}. Most tugs, however, are equipped with towing machine tension meters sufficiently accurate for determining steady and quasi-steady tension. T_{wave} must be treated as discussed in the following sections.

3-4.1.5 Factors of Safety

Tow planners and operators have traditionally dealt with unpredictable dynamic tensions by applying large safety factors to steady tensions when sizing components. Recommended factors of safety for various components are presented in Table 3-2. To use this approach, multiply the calculated steady-state tension by the appropriate factor of safety and compare this number to the new breaking strength of the component. Safety factors also account for many other effects such as towline fatigue, corrosion, and wear.

This approach is suitable when the operators have a great deal of experience with the towing system under consideration. Unless it is known that dynamic loads will increase the steady-state tensions by more than 100 percent, apply these safety factors to the calculated steady-state tension to determine the required hawser strength. The safety factor shall be increased appropriately if the tow is unfamiliar or there is significant uncertainty about the degree of dynamic loads or the condition of the hawser. Judgement is required when assessing the situation. If technical assistance is required, contact NAVSEA 00C.

3-4.1.6 Predicting Dynamic Tensions

Until recently, the use of safety factors was the only way to offset unpredictable dynamic loads. Difficulties occur with this approach, however, when using a new towing system or towing a ship or structure with which there is no previous experience. Sometimes this happens when the standard design or material for a towing system has been changed. The more effects that are combined into one factor of safety, the greater the uncertainty.

A new statistical approach is emerging for predicting the impact of ship motion on towline tension in a given sea condition. This approach estimates the extreme dynamic tension level that the towline is likely to encounter under certain conditions. This information can be used by the tow planner if sea conditions are known. More importantly, the data can be used to predict acceptable risks of extreme dynamic towline loadings, rather than relying solely on traditional factors of safety that are based on steady-state tensions. (Ref. M) describes this approach in detail.

When using these new statistical techniques, multiply the "extreme tension" that is calcu-

Table 3-2. Safety Factors for Good Towing Practice.

	Minimum Factors of Safety*						
Towing Mode for Tug	Wire Rope Hawser	** Wire Rope Pendant	Chain Pendant or Bridle	Polyester	Synthetic Line (Other)	Shackles and Detach-able Links	Bitts, Padeyes etc.
Note	1	1	1	2	2, 3	4	5
Long-Scope Wire Rope Hawser							
On automatic tension control	3 (4)***	4	4	-	-	3	3
On the brake	5	6	6	-	-	5	5
On the pawl (dog)	7	8	8	-	-	7	7
On the hook (bitt, pad, etc.)	7	8	8	-	-	7	7
On the hook or brake with chain pendant	4	5	6	-	-	4	4
On the hook or brake with syn-thetic spring	4	5	5	6	-	4	4
Long-Scope Synthetic Hawser with Wire Rope Pendant							
On automatic tension control	-	4	4	4	10	3	3
On the brake	-	6	6	6	12	4	4
On the pawl (dog)	-	8	8	8	12	4	4
On the hook (bitt, pad, etc.)	-	8	8	8	12	4	4

NOTES:

1. Based on Minimum Breaking Strength.
2. Based on Minimum New Dry Breaking Strength. These figures are for 8" circumference and larger. For smaller lines, increase safety factor by 2. (See 4-2.2)
3. For Nylon: Breaking strength is reduced by 15% when wet.
4. Based on minimum breaking strength for links and proof load for shackles.
5. Based on Material Yield Strength.

* "Minimum" applies only to new components, good weather, short duration, or emergency conditions. Old components, possible heavy weather, long-duration use, etc., may impose uncertainties which require use of safety factors greater than the listed minimum safety factors.

** When pendant is used as a deliberate "fuse" (i.e., safety link), use the same factor of safety as for the hawser but applied to the breaking strength of the pendant.

*** See 4-3.1 For Details.

lated by a safety factor of 1.5. This does not supersede the traditional safety factor approach described in the previous section. Both should be checked, since either may control for a specific set of circumstances. The more severe criterion shall be considered the limit until significant quantitative experience is gained with the dynamic theory.

Removal of the uncertainty caused by the dynamic effects may eventually permit reduction in traditional towing system safety factors. As confidence in the dynamic loading approach develops, the use of factors of safety may no longer be required.

3-4.2 Calculating Towline Catenary

When wire rope is used as a towing hawser, the catenary is the primary means of relieving the peak dynamic tensions. The weight of a wire rope towing hawser, either alone or in combination with a short segment of chain at the tow end of the towline, causes a catenary, or sag, in the towline between the tug and the tow. Variations in the towline tension tend to smooth out in the catenary. Temporary decrease of the distance between tug and tow, or a decrease in tension, is absorbed by a deepening catenary depth. An increase in the separation between tug and tow causes the catenary to decrease in depth and the hawser tension to increase. Thus, the wire catenary tends to act as a spring, softening the tug-tow interaction.

Due to the hydrodynamic drag of the wire during the rising of the catenary, the spring effect is not immediate. For load increases of a sharp or sudden nature, the catenary cannot be expected to absorb the accompanying increases in towline tension completely. Using an automatic towing machine or a synthetic spring (see Section 4-6.5) in conjunction with the catenary will help provide an effective relief of changing loads over the full range of conditions.

To avoid dragging or fouling the towline on the bottom, while maintaining a sufficient catenary depth to absorb changes in tug-tow separation, it is necessary to estimate the catenary depth of the towline. A number of methods have been used for estimating towline catenary.

To estimate catenary depth, it is necessary to have the following data available:

- Steady tension in the towline
- Lengths of the towline components
- The weight per unit length in water of each component

The steady tension in the towline may be estimated by using the tension meter on the towing machine, by the estimating procedure in (Ref. G), or by using the chart in Figure 3-3, which presents the calculated tug pull available versus speed through the water. The composition and total length of the towline should be known. Table B-2 and Tables D-1 through D-9 provide the weight per unit length for various towline components. When weight in water of steel components is not given, multiply weight in air by 0.87 to obtain weight in salt water.

An initial estimate of the catenary depth of the towline may be determined using the following formula:

$$C = T/W - T/W\sqrt{1-(WS/2T)^2}$$

where:

C	=	Catenary or sag (ft)
T	=	Steady tension (lbs force)
W	=	Weight in water per unit length (lbs/ft)
S	=	Total scope (ft) (total of all components)

Total weight in water per unit length (W) is computed as the sum of the weights of the individual towline components divided by the total towline scope.

This formula applies to single component wires hanging under their own weight. For calculating, scope (S) and weight (W), when the towline includes a bridle, the total weight of the bridle should be used, but the scope is estimated as a single leg of the pendant. This formula provides an acceptable estimate of towline catenary for towline configurations where the ratio of towline scope (S) to catenary (C) is greater than 8:1. When the ratio is less than 8:1, the catenary depth predicted by this formula does not provide an accurate estimate of the towline catenary.

Based on this formula, Figures 3-4 through 3-12 show the calculated catenary for various common compositions and lengths of towline. These curves may be used for towing speeds up to 12 knots. To decrease catenary, towline scope may be shortened or the towing speed increased.

These graphs assume the chain is attached at the bullnose. If additional chain is used after a wire pendant (i.e., closer to the middle of the tow configuration) a deeper catenary will result. These figures provide estimates and care should be taken when there is a risk of bottom contact.

To quantify effects of changes in tension, a ship can draw its own curve, representing the scope actually used, and proceed along that curve to different tensions to find the new catenary. For example, a ship using a 2-inch hawser and no chain would refer to Figure 3-7. For a scope of 1,500 feet, a new curve could be plotted in between the existing curves for 1,000 and 2,000 feet. This new curve would show that increasing tension from 20,000 pounds to 30,000 pounds would decrease the catenary depth from about 100 feet to about 65 feet. Slowing down to a tension of 10,000 pounds will almost double the catenary to about 190 feet.

Likewise, a ship could plot curves of catenary versus tension for several tension figures to provide a graphical representation of the effect of change in hawser scope. When water depth is limited, the ship can start with the required catenary depth and work backwards to determine the required scope/tension combination. In addition, some towing machine technical manuals include tables or curves to assist in solving scope/catenary/tension questions.

It should be noted that catenary depth will change with varying tensions. If catenary depth is a concern (e.g., bottom contact), expected minimum tensions should be used.

3-4.3 Reducing Anticipated Towline Peak Loads

Several aspects of the towline design can significantly affect the peak towline tensions. Some are adjustable during the tow; some are not, but nonetheless should be considered during the tow planning phase. These measures include:

- Increasing towline scope
- Increasing length of chain pendant or bridle
- Inserting a synthetic spring into the towline system.

The towline scope used during a tow depends primarily on four factors:

- Type of towing rig employed
- Water depth
- Catenary required to absorb changes in towline tension
- Scope required to keep the tug and tow "in step"

To estimate the towline scope required, it is first necessary to estimate the steady towline tension required to maintain the desired towing speed. Calculating total tow resistance is

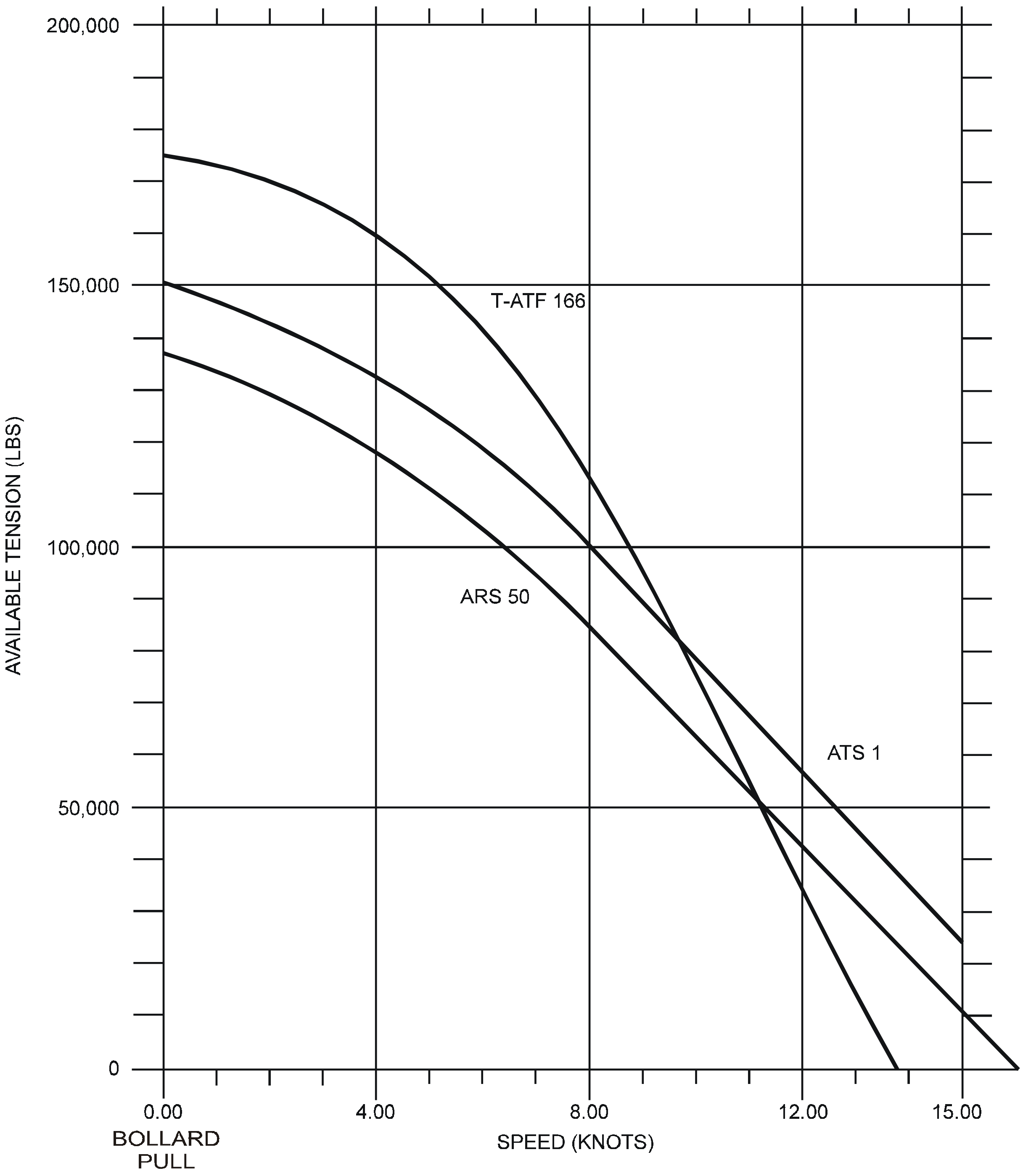


Figure 3-3. Available Tension vs. Ship's Speed for U.S. Navy Towing Ships.

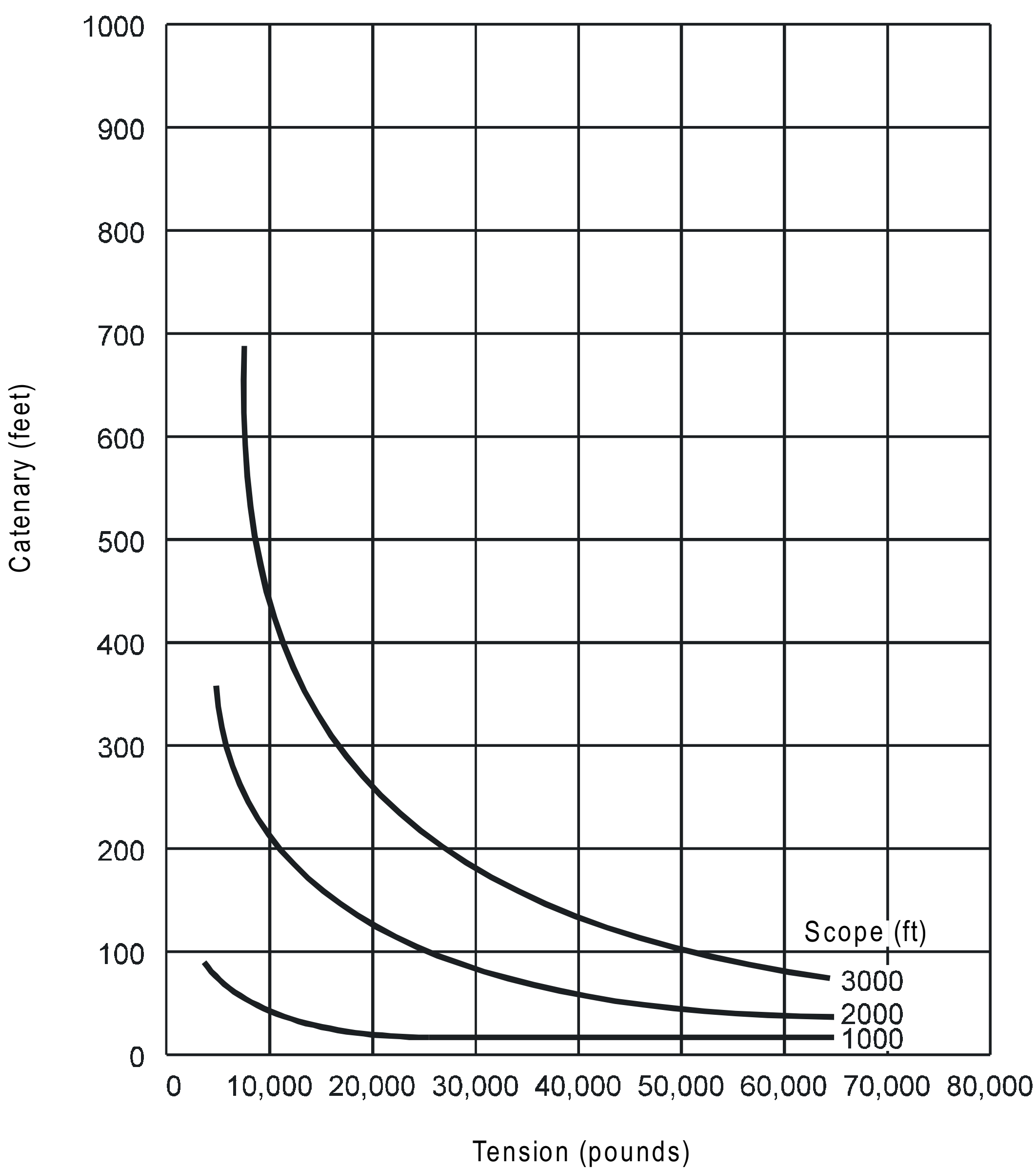


Figure 3-4. Catenary vs. Tension; 1 5/8-Inch Wire, No Chain.

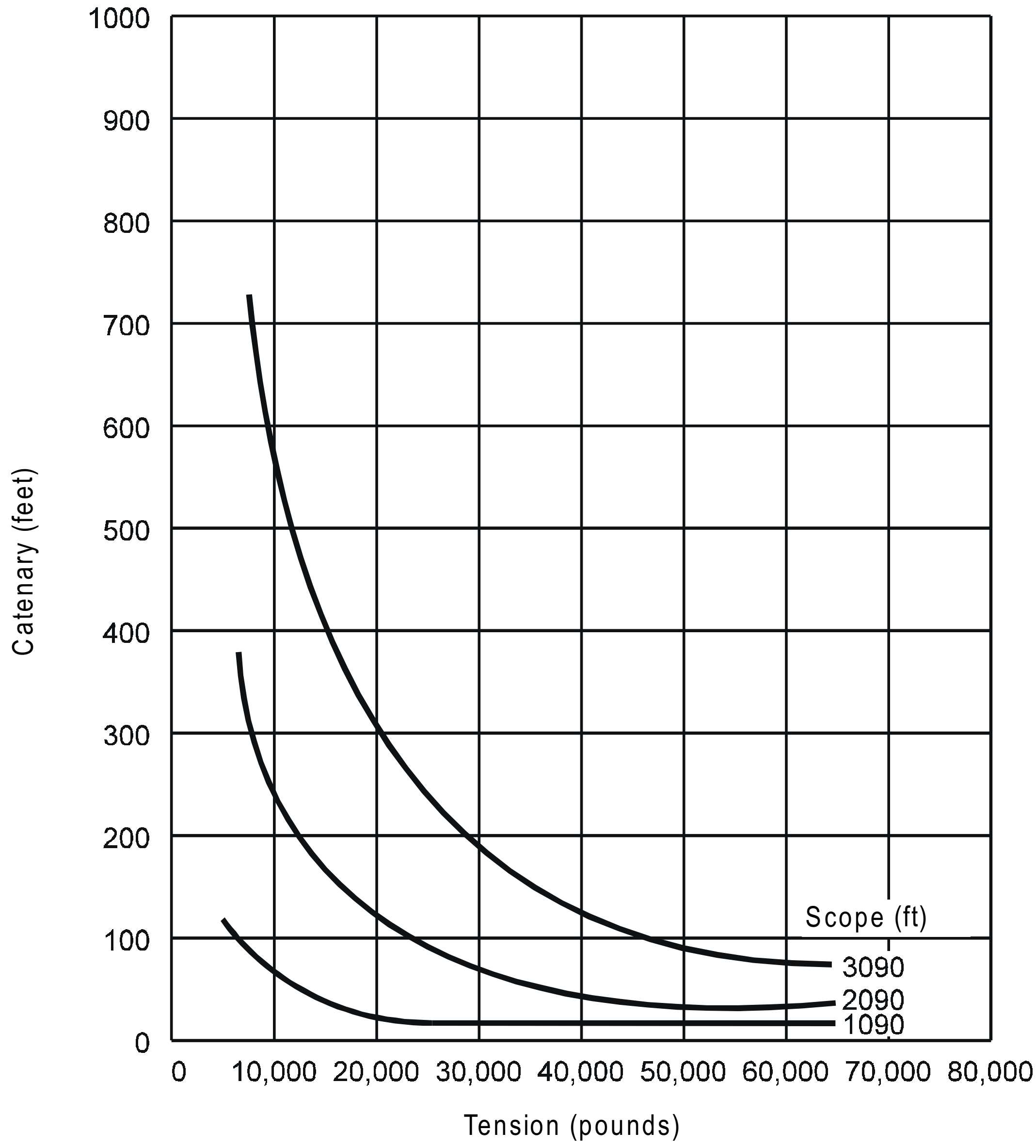


Figure 3-5. Catenary vs. Tension; 1 5/8-Inch Wire, 90 Feet of 2 1/4-Inch Chain.

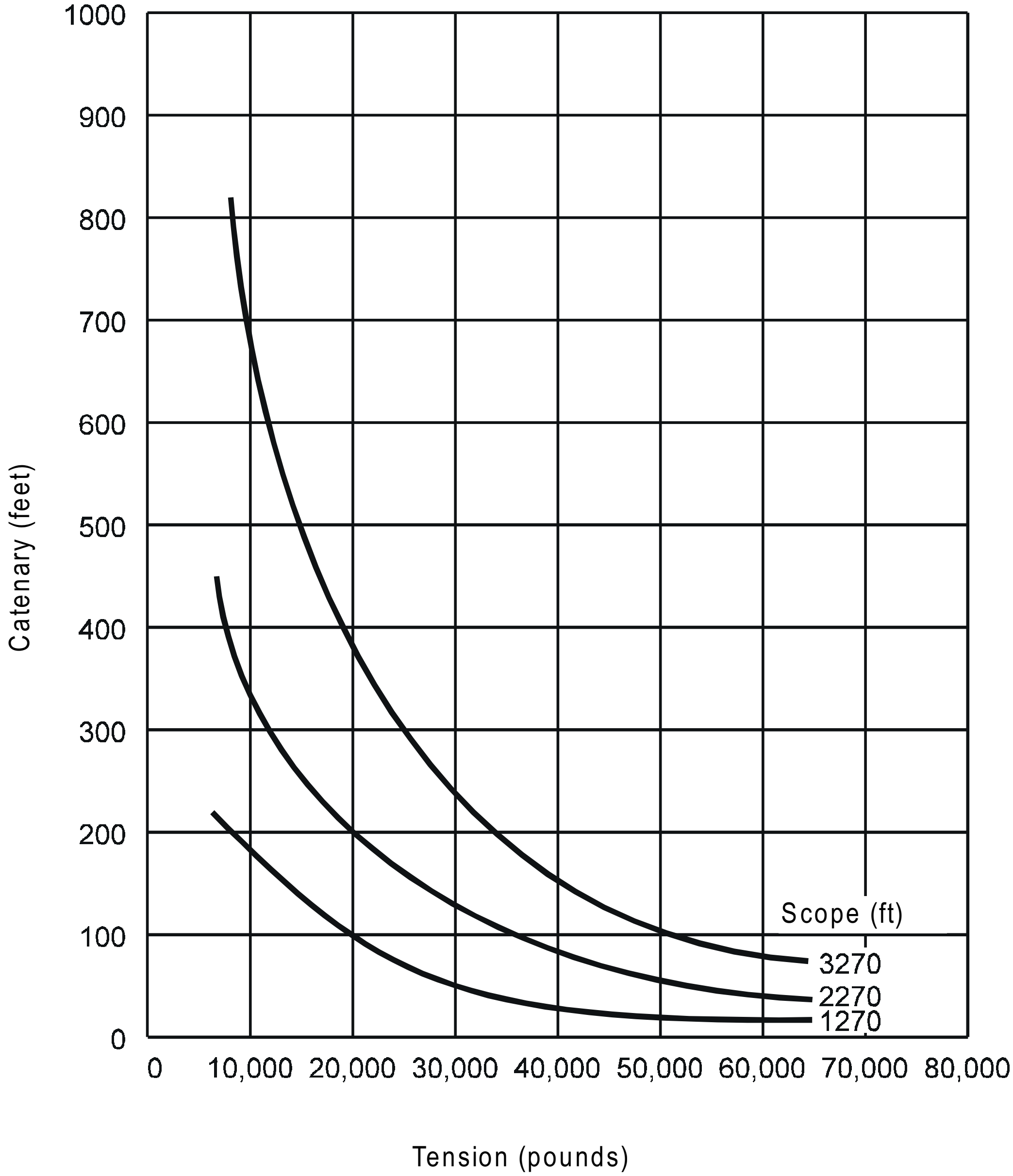


Figure 3-6. Catenary vs. Tension; 1 5/8-Inch Wire, 270 Feet of 2 1/4-Inch Chain.

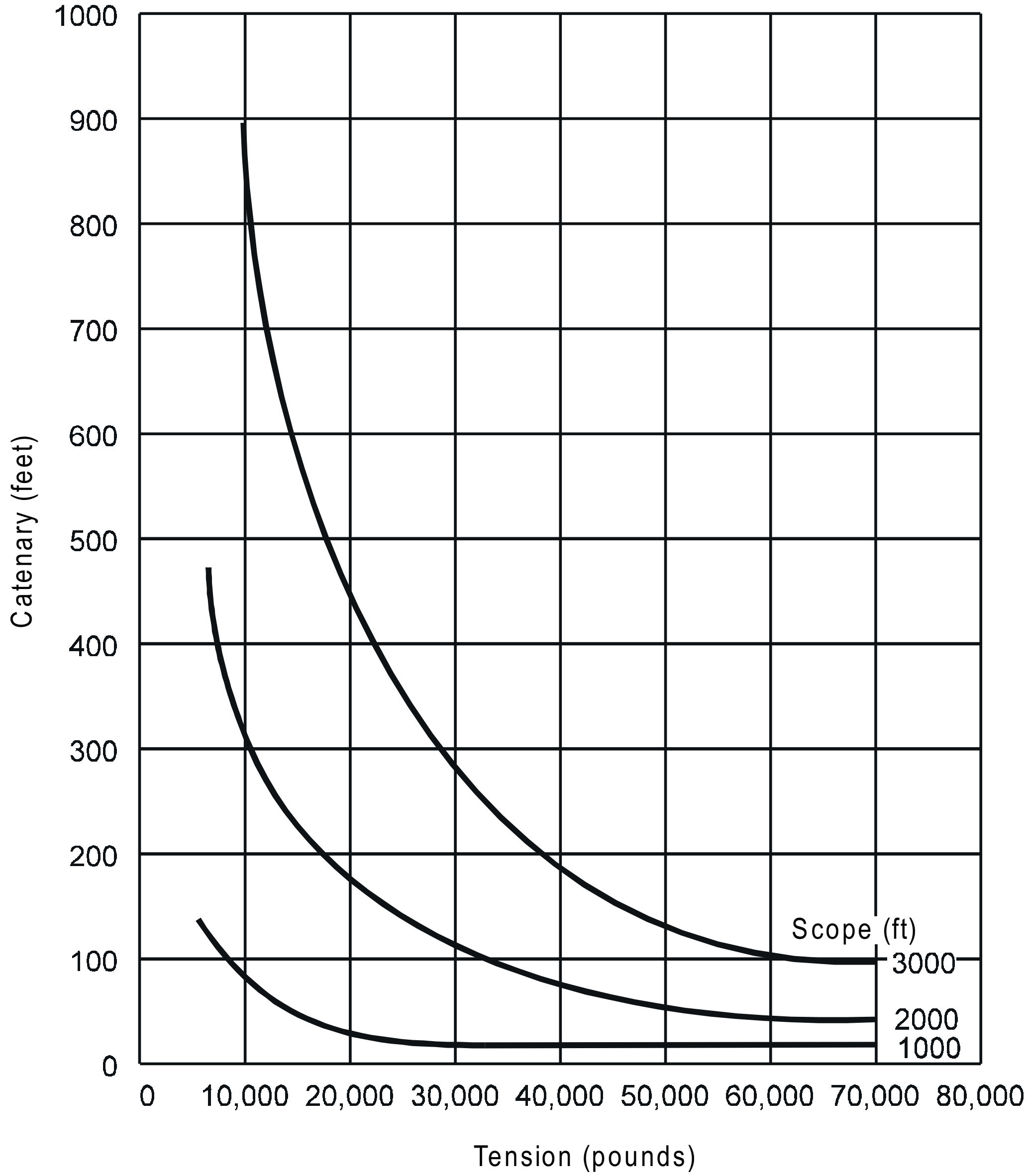


Figure 3-7. Catenary vs. Tension; 2-Inch Wire, No Chain.

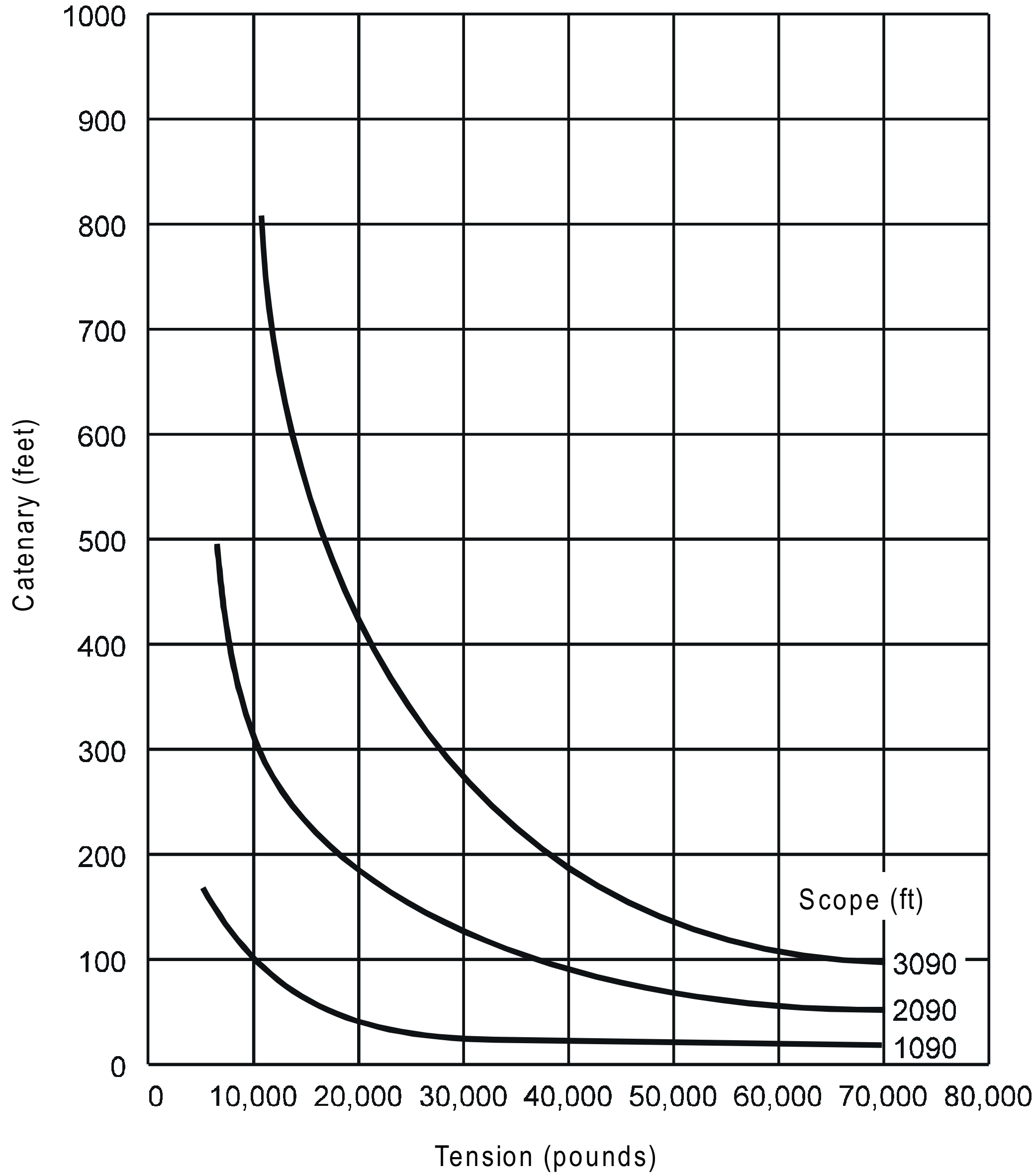


Figure 3-8. Catenary vs. Tension; 2-Inch Wire, 90 Feet of 2 1/4-Inch Chain.

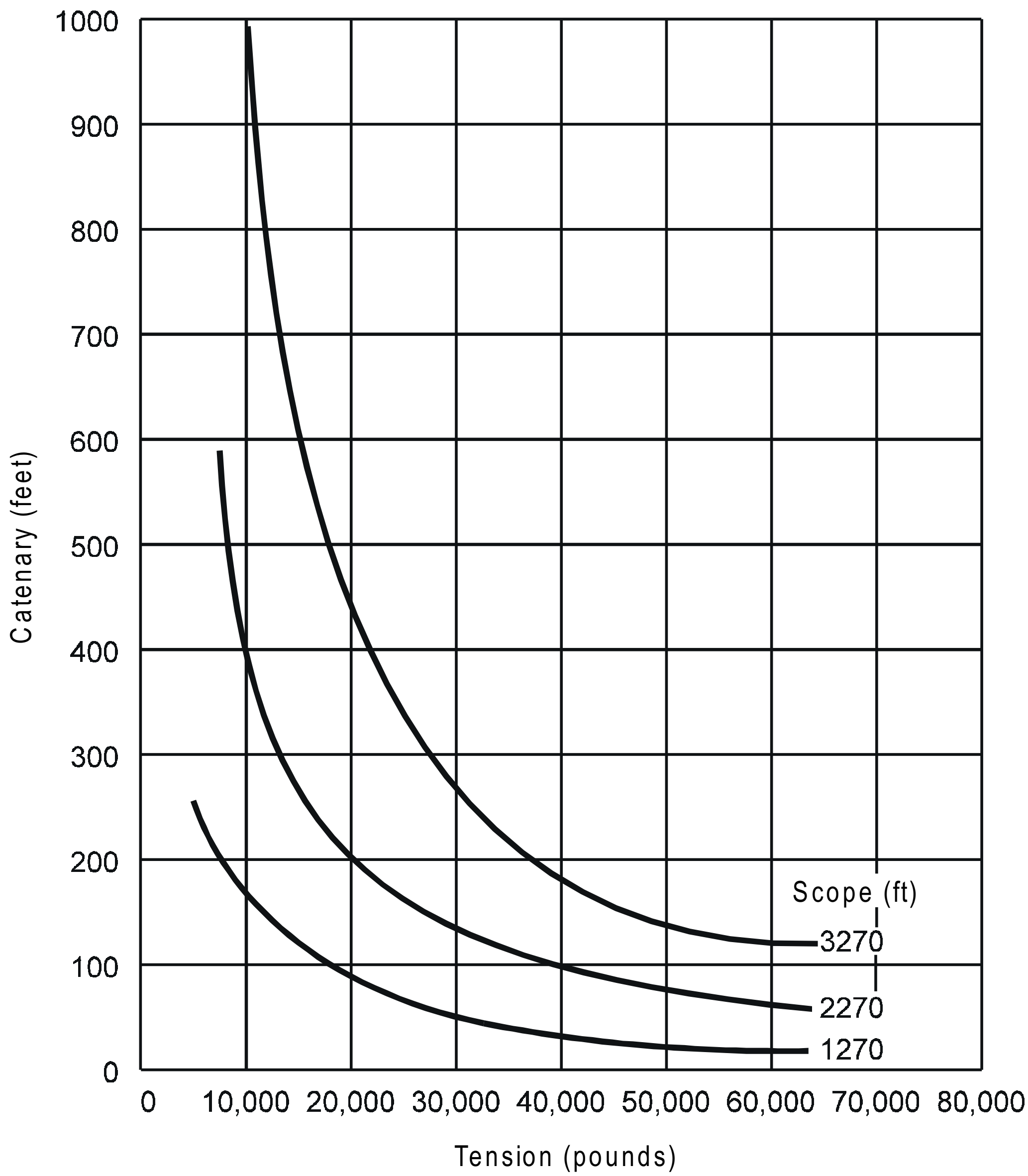


Figure 3-9. Catenary vs. Tension; 2-Inch Wire, 270 Feet of 2 1/4-Inch Chain.

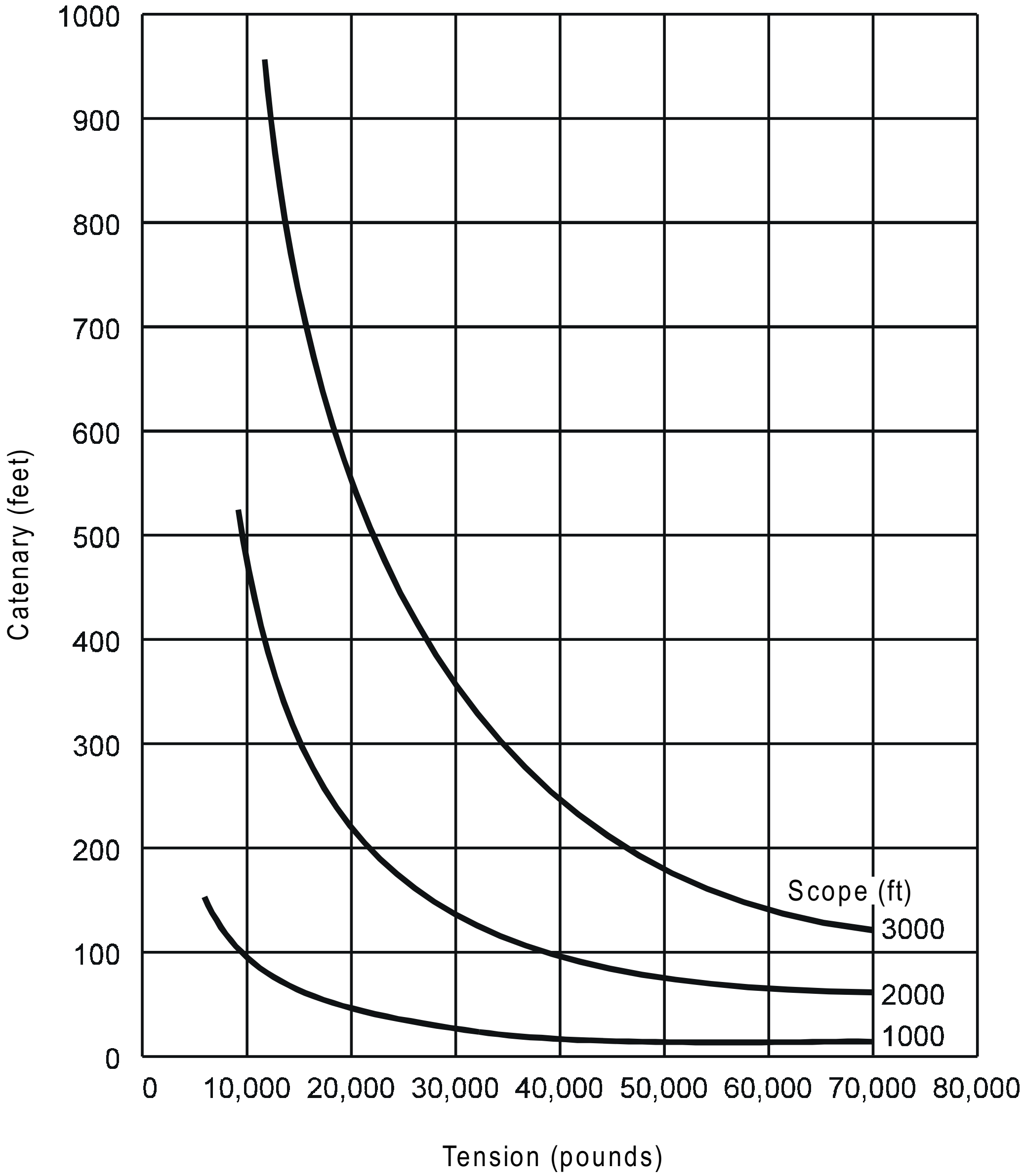


Figure 3-10. Catenary vs. Tension; 2 1/4-Inch Wire, No Chain.

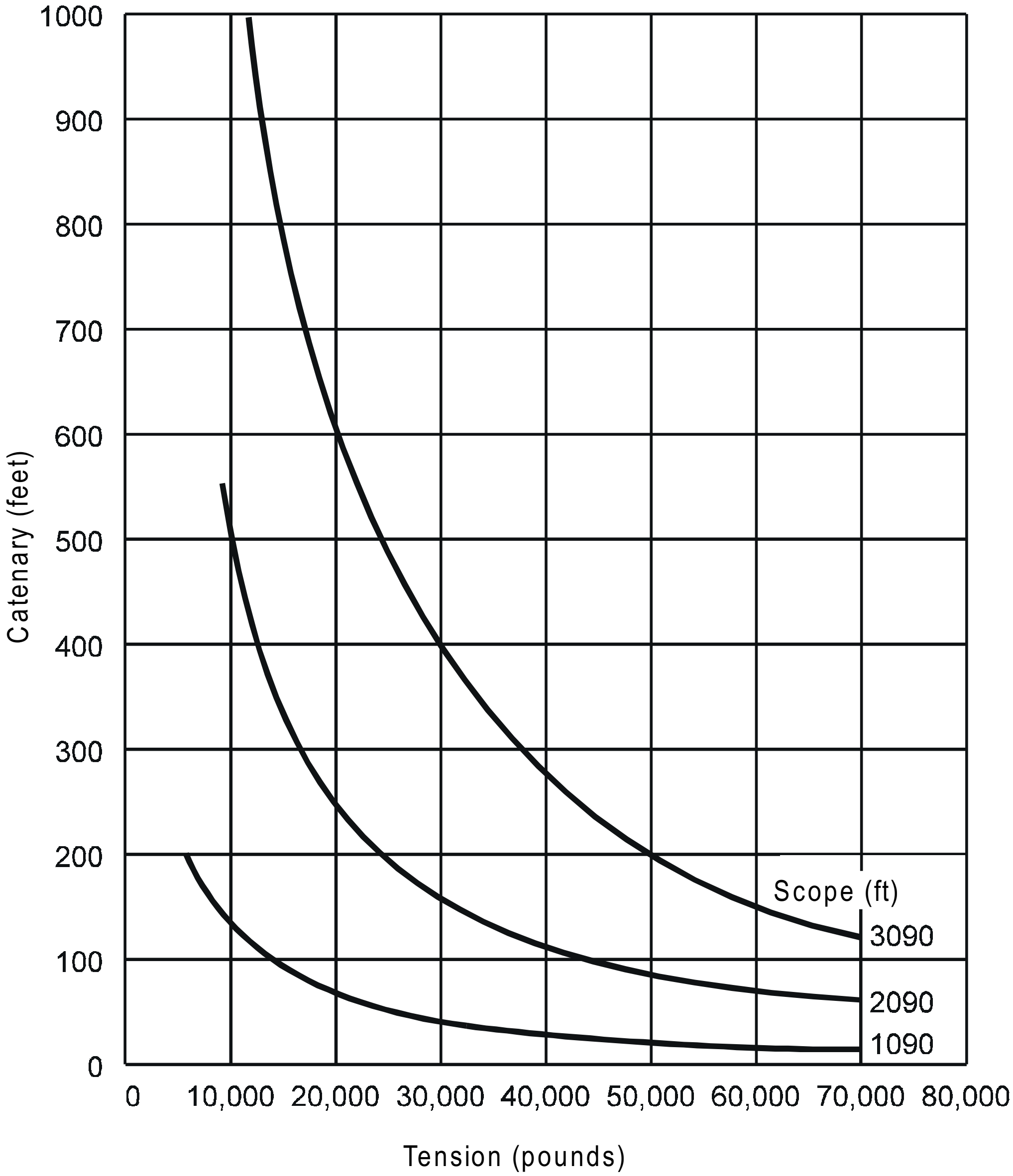


Figure 3-11. Catenary vs. Tension; 2 1/4-Inch Wire, 90 Feet of 2 1/4-Inch Chain.

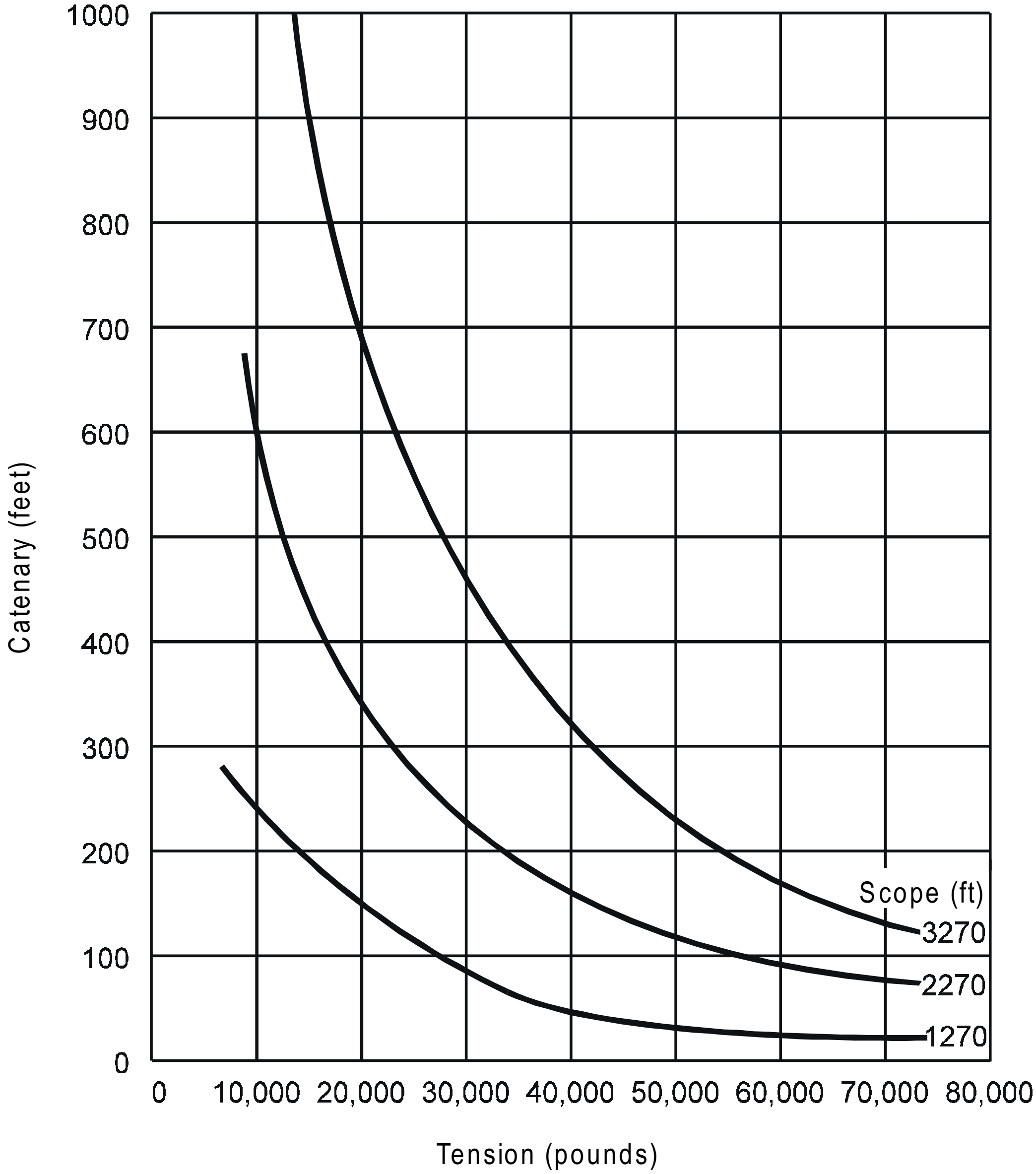


Figure 3-12. Catenary vs. Tension; 2 1/4-Inch Wire, 270 Feet of 2 1/4-Inch Chain.

described in detail in Section 3-4 and (Ref. G).

Having an estimate of the total towline resistance, it is then possible to compute the catenary that will be associated with a chosen towline scope and towline rig. Section 3-4.2 presents a simple formula for estimating the catenary. For hawser scopes greater than or equal to 1000 feet, Figures 3-4 through 3-12 will provide catenary depth directly, given hawser tension.

The following explores the ability of a wire catenary to absorb ship movements by including "stretch" of the wire.

If the effects of hydrodynamic drag are ignored, catenary theory estimates the separation between tug and tow as:

$$D = S(1 - WC/3T)$$

where:

D	=	Horizontal distance between the tug stern and the bow of the tow (ft)
S	=	Total scope of the hawser (ft)
W	=	Weight in water per unit length of the hawser (lbs/ft)
C	=	Catenary or sag (ft)
T	=	Steady tension in the towline (lbs force)

See Figure 3-1 for a graphical representation of these values.

To quantify the effect on the hawser tension for a given change in distance between tug in tow, it is necessary to develop a table or curve of distance (D) vs. tension (T) for various hawser scopes. The computation is fairly direct if tension (T) is assumed for a given scope (S) of hawser; catenary depth (C) is computed, then horizontal distance (D) of the catenary.

Figure 3-13 shows a comparison between an 1800 foot hawser and a 1000 foot hawser. For instance, from an initial tension of 20,000 pounds, the 1,000-foot hawser can absorb about 19 feet of additional separation between the tug and tow before it reaches 200,000 pounds tension; the 1,800-foot hawser will not reach that tension until separation is increased by almost 36 feet. Similarly, a 20 foot stretch of the 1,800-foot hawser increases its tension to only about 75,000 pounds. The longer hawser significantly reduces the peak tensions caused by the same ship movements. A similar trend would be seen with IWRC wire. Ships with different hawsers can prepare a family of curves showing the change in tension as the separation between the ships changes.

The quantitative data shown in Figure 3-13 are based on slow changes in distance or tension. Classic catenary is limited in its ability to absorb tug and tow motions, even where there is a relatively modest average hawser tension. Effectiveness of the classic catenary in reducing dynamic loads has limitations. This is because the hydrodynamic resistance normal to the tow wire significantly impedes it's rise and fall at typical frequencies of dynamic seakeeping loads. Therefore, the wire towline does not always have time to fully resume its former deep catenary when the next surge in tension occurs. So, Figure 3-13 should be used for qualitative comparisons of different towline configurations acting under dynamic loading.

A similar analysis of the advantages of adding chain to the towline can be prepared using the methodology shown in Table 3-4. Plot curves showing the effect of adding one or two shots of chain pendant to a given hawser length. The calculation process is identical, except that the comparison will be between hawsers of the same length but with different total length and unit weights, because the weight of the chain is distributed throughout the hawser length. The analysis will demonstrate that adding only one shot of 2¼-inch chain provides a considerably softer system

Table 3-3. Section Modulus for Wire Rope.

		Wire Diameter		
Wire Type	Load Percentage	1 5/8 inches	2 inches	2 1/4 inches
6 x 37 IWRC	0 - 20%	16.4	24.8	31.4
	21 - 65%	18.2	27.6	34.9
		multiply all values by 10^6		

Table 3-4. Elongation of 1,500 Feet of 6x37, 2 ¼-Inch IWRC EIPS Wire Rope.

Tension	Section Modulus[1]	Se[2]	Scope[3]	Catenary (ft)[4]	Distance (ft)[5]
0	31.4×10^6	0	1500	--	--
10,000	31.4×10^6	0.5	1500.5	257.9	1395.5
25,000	31.4×10^6	1.2	1501.2	184.3	1471.2
50,000	31.4×10^6	2.4	1502.4	43.1	1498.8
75,000	31.4×10^6	3.6	1503.6	31.3	1501.9
88,000	31.4×10^6	4.2	1504.2	26.3	1503.0
100,000	34.9×10^6	4.3	1504.3	22.0	1503.4
125,000	34.9×10^6	5.4	1505.4	18.5	1504.8
150,000	34.9×10^6	6.4	1506.4	15.5	1505.9
175,000	34.9×10^6	7.5	1507.5	13.2	1507.2
200,000	34.9×10^6	8.6	1508.6	11.6	1508.4
250,000	34.9×10^6	10.7	1510.7	9.3	1510.5
275,000	34.9×10^6	11.8	1511.8	8.5	1511.6
288,000	34.9×10^6	12.4	1512.4	8.1	1512.3

Note: Assume constructional stretch has been accomplished through previous loadings.

1. Section Modulus (Area x Modulus of Elasticity) for 2 1/4-inch IWRC hawser is 31.4×10^6 through 20% strength of the wire; 34.9×10^6 over 20% load.
2. Change in scope due to wire elasticity. (ft)
3. Total scope of hawser after stretch. (ft)
4. Catenary depth per formula:

$$C = T/W - T/W\sqrt{1-(WS/2T)^2}$$

5. Distance between tug and tow per formula:

$$D = S(1 - WC/3T)$$

Source: Wire Rope Users Manual, 3rd Edition, Table 17 that develops lower peak tensions for the same change in separation between tug and tow.

Two components of wire "stretch" must also be included when determining the distance between tug and tow: constructional stretch and elastic stretch. *The Wire Rope Users Manual* (Ref. C) estimates constructional stretch as 0.5 to 0.75 percent for 6-strand, fiber-core (FC) wire and 0.25 to 0.5 percent for 6-strand, independent wire rope core (IWRC) wire. Constructional stretch is caused by a virgin rope's helical strands constricting the core during initial loading. The constricted core is compressed and lengthened by the pressure exerted by the helical strands. For fiber core ropes, constructional stretch is pronounced due to the high compressibility of fiber when compared to an IWRC. Constructional stretch properties fade from wire rope early in its life, especially for IWRC ropes. Shortly after a wire rope has been repeatedly loaded, the constructional stretch characteristic is no longer exhibited. Fiber core ropes, however, will retain this property longer, especially if subjected to only light loads.

The elastic stretch of hawsers likewise varies with load. For convenience, elasticity is assumed to be constant through 20 percent loading, with a different figure applying beyond 20 percent loading. For common Navy hawsers, the figures in Table 3-3 can be used where Section Modulus (which incorporates compactness factors and variance of elastic modulus) is expressed as the effective area of the steel in the wire multiplied by the modulus of elasticity of the steel (Section Modulus (lb) = area (in^2) x Elasticity (pounds per square inch)).

For example, a 1,500-foot, 2 1/4-inch IWRC wire with a 25,000-pound load will elastically stretch:

$$\text{Change in length (ft)} = \frac{\text{load(lb)} \times \text{length (ft)}}{\text{Section Modulus (lb)}}$$

$$\frac{25000 \times 1500}{31.4 \times 10^6} = 1.2 \text{ ft.}$$

This formula assumes that constructional stretch has already occurred. Table 3-4 has been developed for a 1,500-foot, 2 1/4-inch IWRC extra improved plow steel (EIPS) wire hawser.

3-4.3.1 Using an Automatic Towing Machine

The automatic payout and reclaim feature of the towing machines installed in most tugs is a very effective means of reducing peak towline tensions. Table 3-5 provides the range of automatic settings available on various tugs. Generally used when water depth precluded an adequate catenary, the towing machine was often taken off "automatic" after sufficient towline catenary had been established in deeper water. Now, however, with questions concerning real effectiveness of a wire catenary in reducing peak tensions, it appears that the automatic feature is equally as important in deep water. Operation in the automatic mode is generally preferred; this, however, is not intended to conflict with the manufacturer's approved operating procedures. For example, in calm seas, the manufacturer's recommended standard operating mode will probably be manual.

Additional information on towing machines and winches appears in 4-5.1 and in (Ref. L).

3-4.3.2 Using Synthetic Towlines

Using synthetic towlines is one of the best means of absorbing dynamic towing loads. The characteristic elasticity of synthetics has many advantages over the other means of reducing dynamic loads. Those advantages include, but are not limited to, the following:

- ***Speed of response.*** When compared to an automatic towing machine (ATM), synthetic lines are capable of instantaneous response. If the dynamic load has a low acceleration, both the ATM and synthetic line absorb the dynamic load comparably. If the load has a high acceleration, however, the ATM may not be able to respond fast enough before a tension spike impacts the towing system.

- ***Passive system***. Once deployed, the synthetic line requires no operator and is non-mechanical. Its shock-absorbing action requires no active input or maintenance by the operator.
- ***Maintenance***. An ATM is a complex machine and while it is not a common occurrence, is subject to mechanical failure. Proper care and diligent maintenance is necessary to ensure dependable operation. Synthetic line is affected by other factors including abrasion, heat, and UV light. By limiting exposure to these factors, a synthetic tow hawser should have a long service life.

Synthetic towlines take two forms: a complete synthetic tow hawser and a "spring" synthetic line inserted in the towing system. The synthetic spring consists of a length of synthetic line placed in the towing system between the steel towing hawser and the chafing chain extending from the tow. A spring works in combination with the catenary produced by the heavier steel components. It can assist in absorbing rapid acceleration peak loads while the catenary adjusts to loads applied more slowly. A synthetic spring should be sized to a comparable breaking strength of the remainder of the towing system. Important restrictions on the use of synthetic tow hawsers and springs found in Section 4-3.2, Section 4-6.5, and (Ref. C). Consult and incorporate these restrictions in any towing system design that involves synthetic line.

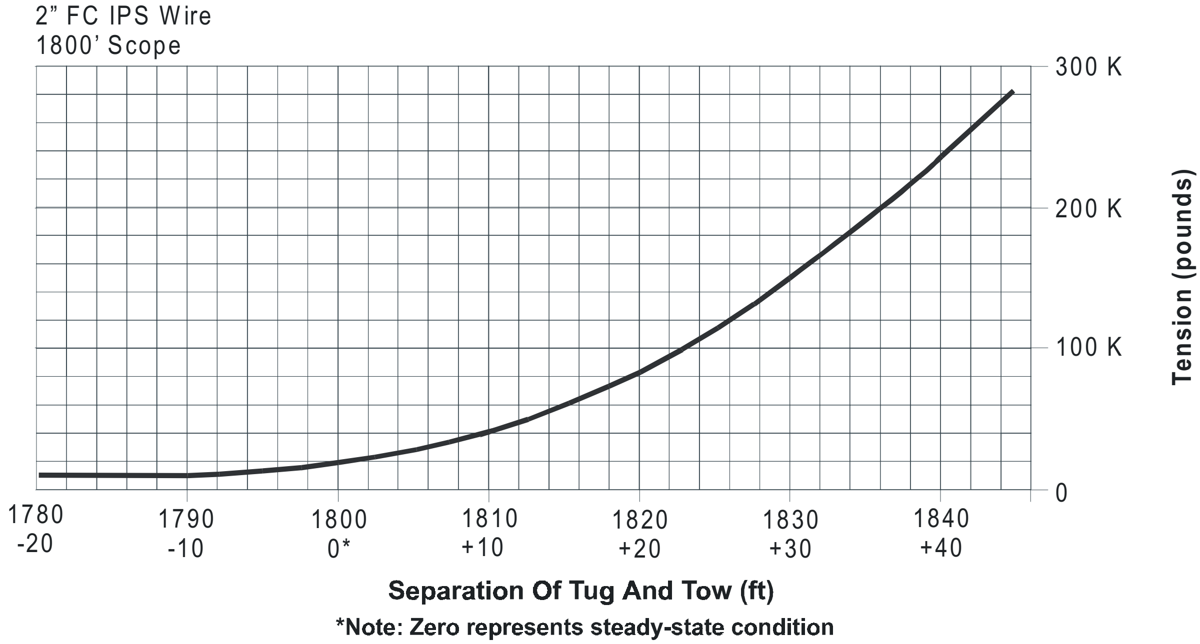
3-4.4 Tug and Equipment Selection

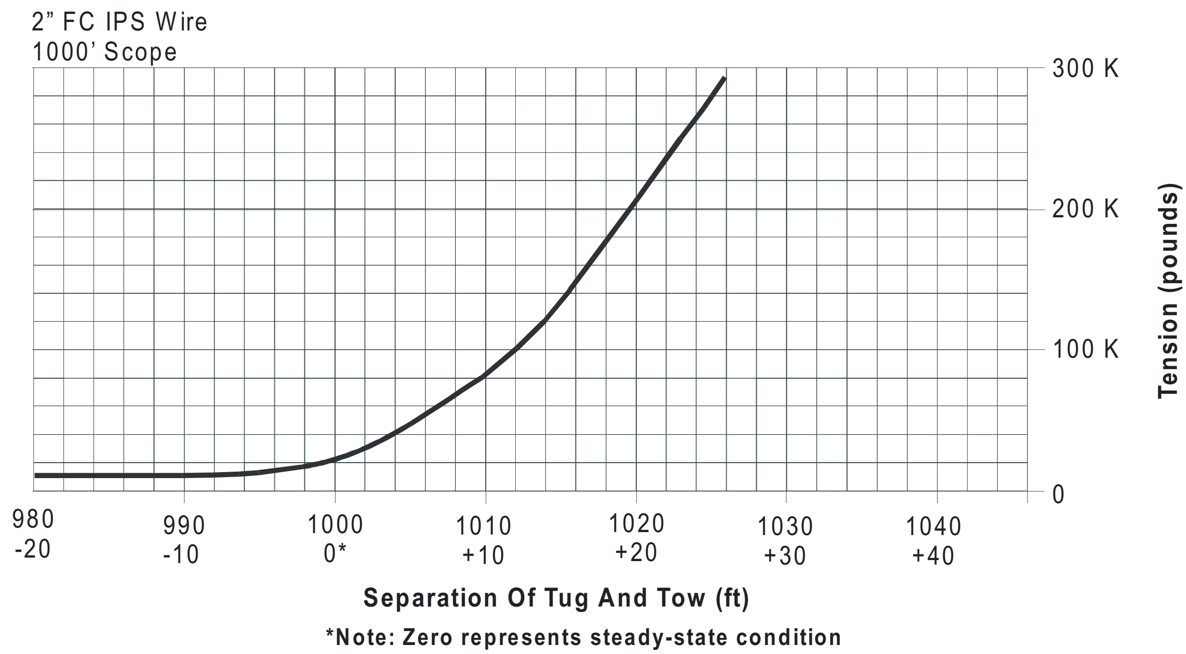
3-4.4.1 Tug Selection

Much too often tug assignments have been based almost completely on availability. A tug must have many other special attributes. It must be staffed with competent personnel and have adequate power for the tow, proper towing gear to connect the tow to the tug, and sufficient endurance to complete the tow.

The principal measure of a tug's power is its ability to exert tensile force on the towline. The maximum force a tug can exert on the towline is defined as the tug's maximum propulsion power delivered at zero tug speed. In the jargon of the towing industry, this maximum tug power/zero tug speed condition delivers a force referred to as "bollard pull." The tug's available propulsion power and hydrodynamic properties of the tug and tow determine the speed of the tow and, therefore, steady forces on the towline. Generally, a tug's power plant and propeller are designed to deliver maximum power and optimum efficiency at a designated towing speed. The greatest thrust (bollard pull) is produced at zero speed, with the towline pulling force diminishing as the towing speed increases. When the tug reaches its maximum free route speed, all its horsepower is used in propelling it. At this point, the available towline pulling force is essentially zero.

Each class of ship should have its own unique set of available tow tension curves that depend upon engine power setting, ship speed, propeller rpm, and propeller pitch (for ships with controllable pitch propeller [CPP] systems). For tow planning, the maximum available tow speed is the figure of interest. Figure 3-3 shows the available tow tension versus ship's speed for U.S. Navy ocean tugs. Comparing a curve to a horizontal resistance value (as calculated in 3-4.1.3) provides the approximate maximum tow speed for an assumed condition. If the maximum speed available does not coincide with the assumed tow speed conditions, additional resistance computations should be performed to achieve a balance between tension required and tension available. A more direct





NOTE
These curves plot the hawser tension vs. tug/tow separation. They demonstrate the much “softer” nature of the longer scope for the same change in separation.

Figure 3-13. Distance Between Vessels vs. Hawser Tension for 1,000 and 1,800 Feet of 6x37 FC Wire.

Table 3-5. Operating Range for Automatic Towing Machines of Various Types of Ships.

Types of Ships	Operating Range (lbs.)
Salvage Ship (ARS 50)	20,000 - 110,000
Fleet Ocean Tug (T-ATF)	30,000 - 110,000

method is to plot a curve of horizontal resistance directly onto a copy of Figure 3-3. The tug and tow curves will intersect at the maximum speed attainable with each tug for assumed tow conditions.

If the available tow speed exceeds the amount needed (usually for small or non-ship tows), the tug will require less than maximum continuous engine power. In this situation, a less powerful tug can be considered. Conversely, if available tow speed is less than required, a more powerful tug or multiple tugs must be selected. In the latter case, there will be two or more towlines, so towline hydrodynamic resistance must be calculated appropriately. Otherwise, the available towline tension of the tugs is additive.

When the available tug is underpowered for the desired tow speed, the most important consideration is whether it has sufficient power to keep the tow out of danger under the most severe wind and sea conditions that can be reasonably expected. For instance, it may be acceptable that a given tug is unable to make headway over the ground, while towing a large ship in a sudden gale in the open sea. The same tug, however, may be considered inadequate for towing the same ship under the same conditions near a lee shore. In the case of a planned tow of a large ship, adjustment to tow dates and careful weather routing are essential. For more severe cases, adjustment of the assignments and schedules of other tugs also may be required to provide the required towing capability.

For emergency or unplanned towing requirements, the tow will be initiated by the first available tug. Procedures outlined herein are useful in determining whether additional towing assets should be diverted to escort or take over the tow. (Ref. K) contains data useful in estimating the power of commercial tugs that may be needed in an emergency.

3-4.4.2 Towing Gear Selection Factors

Once the tow vessel has been optimally sized to fit operational requirements, towing hardware, including the "jewelry" connecting system components, shall be sized to accommodate the anticipated forces for those operational requirements. The mechanical properties of typical components of towing systems are covered in the Appendices of this manual. Examples include wire rope and wire rope terminations ((Ref. B)), synthetic fiber lines ((Ref. C)), chain, shackles and links ((Ref. D)), and line stoppers ((Ref. E)). Engineering design factors of safety for all system components are dis-cussed in 3-4.1.5. Towing gear is discussed at length in (Ref. 4).

Hawser size is generally fixed for a given tug. If a specific size hawser is required by the type of tow, that fact, rather than the availability of tugs, may determine tug selection.

The calculated steady towline tension values are multiplied by the safety factor to obtain the required minimum breaking strength of the wire rope hawser. With the minimum breaking strength known, (Ref. B) may be used to evaluate the wire hawsers carried by candidate tugs. If there is no good match, the assumed tow speed can be adjusted until a match between required hawser strength and available tugs is achieved. For a particular tug, with a specific hawser, the problem may be reversed to find the maximum allowable steady tension.

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Chapter 4

TOWLINE SYSTEM COMPONENTS

4-1 Introduction

This chapter presents guidance on the use of the wide variety of components available for use in towing. Tow planners and tow ships should carefully consider relative advantages and disadvantages of each component when designing a tow rig. Consideration should be given to durability, availability, ease of handling, and other pertinent factors.

4-2 Towline System Components

The towline system is made up of many components. A tow hawser often called the towline or towline connection, is only one component of the towline system. Figure 4-1 illustrates a complete towline system. A towline system includes attachment points, rope terminations, and tension components such as chain pendants, wire rope pendants, and spring pendants. These elements are joined by shackles, links, or other connecting hardware.

A towline system is the tension-carrying link between tug and tow and must be able to withstand steady loads, as well as dynamic peak loads, often called shock loads. The primary materials used in tension members are wire rope, synthetic fiber lines, and chain.

All items must be sized for the towing loads with an appropriate factor of safety (see Table 3-2). Size and compatibility are key considerations.

The following is a list of factors that influence selection of the components of a towing system:

- Strength (static loads, dynamic loads, fatigue)
- Ability to nondestructively inspect
- Elasticity (stretch vs. load over a full range of loads and over the lifetime of material, set or permanent stretch)
- Predictability (strength and compliance)
- External abrasion resistance
- Internal abrasion resistance (related to fatigue life)
- Weight and specific gravity
- Survivability in a specific environment (effects of corrosion, ultraviolet light, sea water, acids, temperature, moisture)
- Ease of handling (surface characteristics: slippery, sticky, pliable, minimum bend radius)
- Stowage (volume shrinkage upon drying, flexibility)
- Adaptability to fittings and terminations
- Compatibility of fittings and terminations

In various towing applications, one or more of these factors may have a predominant influence on the choice of material. Chain, for example, often is selected as a chafing pendant or bridle because of its abrasion resistance and survivability. When used as a leader chain (see Figure 4-1), provides elasticity through catenary action rather than through material stretching. Likewise, polyester may be suitable for a tow hawser or spring, but would not be selected as a chafing pendant. Wire rope is generally favored for use as a tow hawser on ocean tugs because of its strength and reasonably high abrasion resistance, with its flexibility, stowability, and ease of handling also being important.

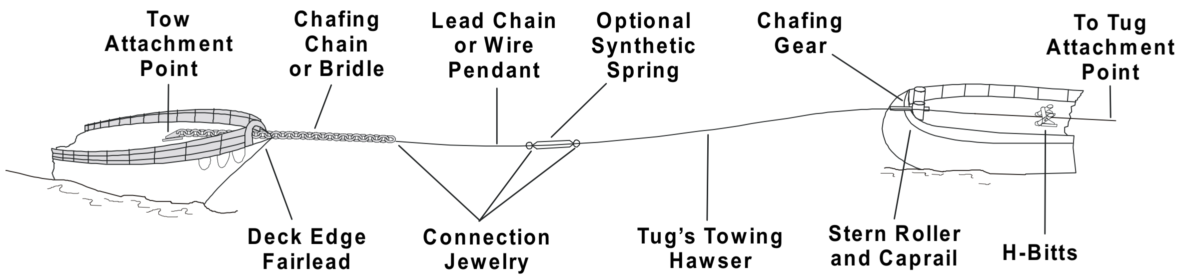


Figure 4-1. Typical Towline Connection Components.

4-3 Main Towing Hawser

The tow hawser is the primary tension element of the towline system. Tow hawsers are normally wire rope or a synthetic line. The end of the hawser that extends to the tow is usually equipped with an end fitting such as a socket, thimble, or spliced eye; if the tug doesn't have a towing machine or winch, both ends of the hawser may have fittings. When the tow hawser is part of a tug's equipment, it is stowed on the drum of the towing machine, or in the case of synthetic line, in a bin below deck. When the tow hawser is part of the towed vessel's equipment, it may be stowed on a storage drum, reel, or brackets, or faked down in a tub, ready for use.

4-3.1 Wire Rope Hawser

Before the development of wire rope in the 19th century, the primary material used for tow hawsers was natural fiber line made from manila, sisal, and hemp. As ships became larger, the diameter of natural fiber lines increased to the point where handling and storage became difficult. Because of its superior abrasion resistance and strength-to-weight and strength-to-size ratios, wire rope rapidly replaced natural fiber lines for towing hawsers. Wire rope was accepted for towing despite being far less elastic than natural fiber lines. At first, elasticity loss was countered by using long spans of hawser, where the weight of the wire rope formed a catenary in the wire and provided a measure of effective elasticity. Later, tow ships often used manila spring pendants, or "springs," in conjunction with wire rope to provide the needed elasticity. Today, synthetic fiber springs perform this function and are common in commercial practice.

For wire rope in new or very good condition and used in conjunction with an automatic towing machine, a minimum **safety factor of 3** is appropriate for routine ocean tows in good weather (see Table 3-2). To be on the conservative side and allow for unforeseen occurrences, a **safety factor of 4** is recommended for routine tows. Other conditions require higher factors, as noted in the table.

4-3.2 Synthetic Hawser

When synthetic fiber line was developed for commercial applications, it began to replace manila rope for towing springs and hawsers on small tugs. Synthetics also gained acceptance as open-ocean towing hawsers, often replacing wire rope. The elasticity of synthetic hawsers easily absorbs tension caused by motion.

One of the first synthetic materials to be used in towing was nylon. The Navy began to experience problems, however, when using nylon line as the peak load mitigation system. Some of the problems were due to nylon being weaker when wet than when dry. Additionally, the safe working load (SWL) and factors of safety for nylon in the marine environment had not been adequately defined.

A better understanding of the strength, service life, degradation, and elasticity of synthetic line has led to limitations in nylon's use as the main towing hawser. Nylon line is only approved for:

- Open-ocean towing of craft with less than 600 long tons displacement or in tow-and-be-towed or emergency towing operations
- Unique or special tows approved by NAVSEA on a case-by-case basis.

NOTE
Appendix C provides the breaking strength values for synthetic line. Manufacturer's tables usually quote values for dry nylon. Breaking strength for wet nylon line is about 15 percent less than for dry line and, thus, the manufacturer's values generally must be decreased by 15 percent for towing or other "wet" uses. Wet strength reductions do not apply to synthetics other than nylon.

A material that is better suited for towing applications is polyester. NAVSEA's continuing investigation into using improved and composite designs of synthetic hawsers has led to the approval for general use of single and double braided polyester lines in all routine and emergency towing applications, except where otherwise dictated. The specifications of the approved polyester lines are provided in (Ref. C). Existing nylon towing hawsers shall be replaced with the approved polyester lines on a size-for-size basis. Synthetic springs are discussed in Section 4-6.5.

Table 3-2 provides factors of safety for synthetic lines being used as a main towing hawser. The steady towline tension value calculated in Section 3-4 shall therefore be multiplied by the safety factor listed in this table to obtain a required minimum strength. Note that the safety factor depends on the tug attachment point and the degree of tension control. (Ref. C) provides data for use in evaluating one or more candidate synthetic lines.

Smaller lines (less than 8 inches circumference), with a greater portion of their fibers exposed to abrasion and the effects of ultraviolet light and other chemical attack, require higher factors of safety. Increase the factors listed in Table 3-2 by adding a value of 2.

4-4 Secondary Towline

A secondary towline shall be rigged on all tows. The secondary towline is intended for emergency, short-term use. It may be of lesser strength than the primary towline (although it does not need to be) and is often made up with synthetic line. Rigging methods will vary, depending on whether the tow is manned or unmanned. A secondary hawser is placed on the tow and is generally led down one side of the deck edge, rigged with a heavy messenger led outboard of the ship's structure, and terminated by a lighter floating pendant with a marker buoy trailing astern of the tow (see Figure 4-2). This system is rigged so that the tug merely recovers a trailing messenger and heaves aboard the secondary towline for connection to the hawser. A secondary tow system can be rigged to tow from either the bow or stern.

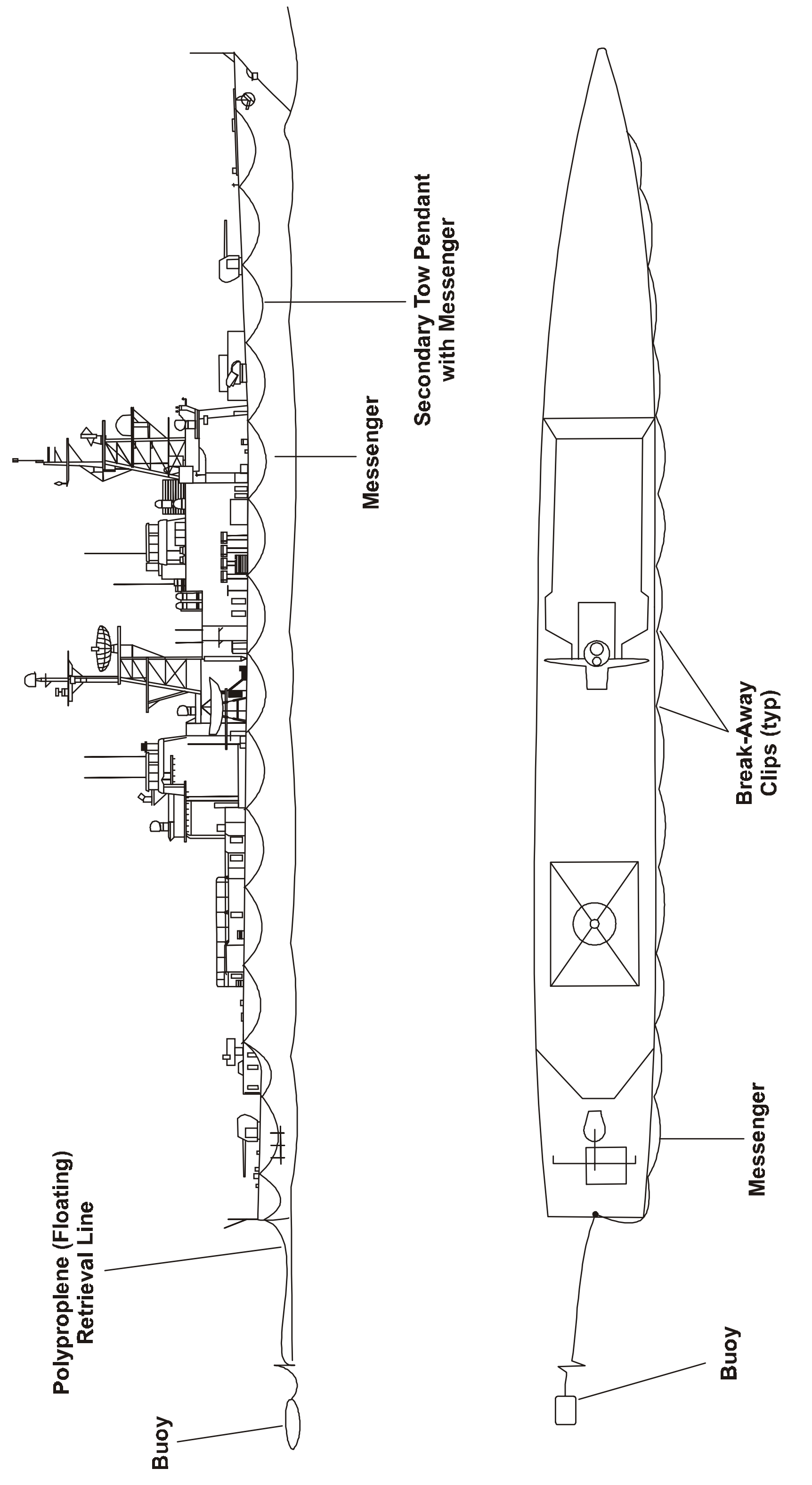


Figure 4-2. Secondary Towline System.

For small tows a primary pendant is rigged using the ship's anchor chain a secondary pendant is rigged from a stern tow pad using the ship's emergency towing hawser with a 200-foot floating messenger and small trailing buoy. When rigging an emergency tow hawser aft, chafing chain should be connected to the tow pad with a safety shackle. **Pelican hooks should not be used**. For large tows or ships that will not tow well from the stern, a secondary tow hawser should be rigged from the bow and fairled down the sides, stopped off in bights, to the messenger.

CAUTION
Bights of wire hanging can be damaged or loosened if the tow goes alongside a tug or a dock.

Secondary wire can be secured with a piece of 3/8-inch round bar. The round bar is tack welded to the deck edge and bent up and around the wire. This allows the wire to be pulled out easily if needed. These clips should be spaced about 5 feet apart. A similar method can be employed when securing chain. (see Figure 4-3) .

All stops should be strong enough to hold in heavy weather but accessible to allow cutting and light enough to be broken without damage to the towing pendant or tow. It must be rigged outboard of all existing structure, including bitts and handrails, and should fall free without turns that will cause kinking as they pull out.

In all cases, a secondary towline will already be connected to an appropriate hard point on the tow and provided with necessary chafing protection. As a minimum for vessels above 600 L-ton displacement, the secondary towing pendant should be 1 5/8-inch wire rope with the necessary chafing gear.

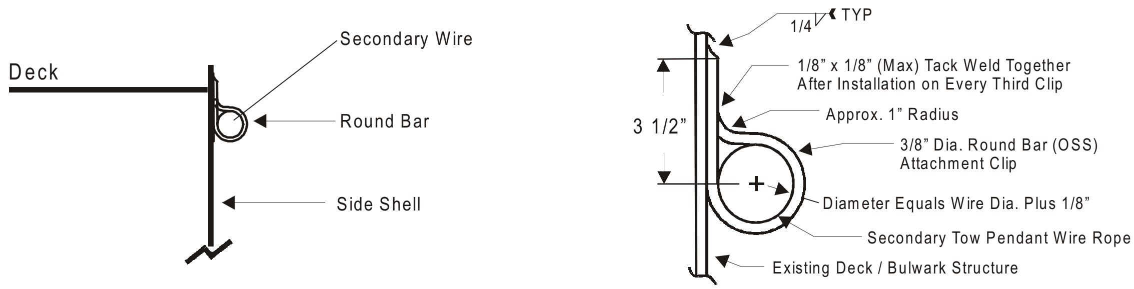
4-5 Attachment Points

This section discusses various types of attachment points on tows and describes the loading various types of attachments may be subjected to. Every possible effort should be made to ensure that an attachment point is subjected to only one type of load in a known direction. Horizontal and vertical padeyes, for example, should be subjected to a force only perpendicular to the axis of the pin. See Section 4-5.3 for more information.

The attachment points on tugs and tows transmit the towing load from the towline to the vessel. Attaching the towline system is of vital importance and must be given careful consideration with regard to seamanship, rigging, and basic engineering mechanics.

Towline attachment points on U.S. Navy tugs are the towing machine or traction winch.

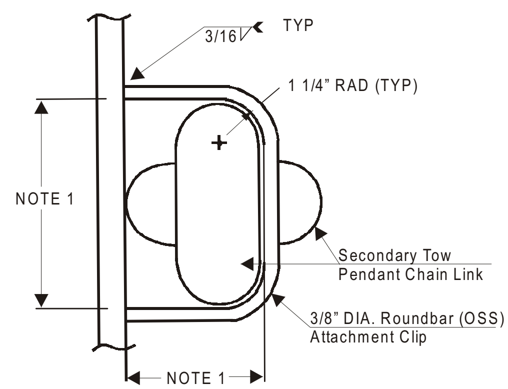
Attachment to the tow may be at a hard point specifically intended for towing, such as a deck padeye, chain stopper, or specialized towing bracket, although many ships do not have an attachment point specifically designed and fitted for towing. Some commercial ships are not designed to be towed, or the tow attachment is located somewhere other than originally designed. Often attachments require use of fittings or gear intended for other purposes, such as single point mooring (SPM) fittings, bitts, anchor chain holding fittings, or the tow's anchor chain. Sometimes, for planned tows, a new attachment point will be installed. The attachment point shall be inspected for planned tows. Non destinctive testing (NDT) shall include visual inspection of the attachment point and surrounding area and a dye-penetrant test of the padeye or bitt attachment points is recommended. If there is any doubt about the strength of the padeye or attachment point, further testing and repairs are required.



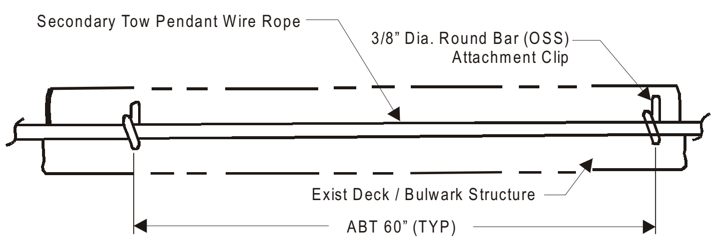
See Right for more detail →

Typical Secondary Tow Pendant Wire Rope Attachment Clip

NOTE
1. Dimensions of chain attachment clips are to be determined by allowing 1/16" clearance all around the chain (i.e., Width plus 1/8")
2. Chain attachment clips are to be spaced approximately 3 feet apart.



Typical Secondary Tow Pendant Chain Clip



Typical Secondary Tow Pendant Securement
Typical Secondary Tow Pendant Messenger Line Securement

Figure 4-3. Secondary Towline System.

For an emergency tow, a makeshift connection, such as a heavy chain wrapped around a strong foundation, may be used. In every case, the material condition of the fittings and structures should be carefully inspected.

For deck fittings designed specifically for towing, operators may assume that the appropriate engineering was performed, if these fittings pass the NDT inspection. If the attachment point is inadequate or does not exist, it must be designed, fabricated, and installed. Activity preparing a tow must arrange for engineering analysis to ensure a safe connection.

An important factor when locating and installing an attachment point is the need for an integrated attachment point and fairlead system. A fairlead ensures that the tow load is applied in the designed direction, i.e., no side loading. Therefore, attention should be paid to both the attachment point and the fairlead. A common failure of the attachment system involves gross structural failure of either the attachment point or fairlead. This problem is especially relevant when towing minecraft, non-oceangoing craft, and wooden, aluminum, or fiberglass vessels. Fairleads on these types of vessels may not be strong enough to withstand towing loads.

Safety factors for attachment points should be designed and built in accordance with the *General Specifications for Overhaul of Suface (GSO) Ships,* U.S. Navy, Sections 582 and 077, Naval Sea Systems Command, S9AA0-AB-GOS-010/GSO (Ref. D). The cri-terion generally applied is that the breaking strength of the line should not exceed 35% of the padeye's bitt, or cleats yield strength.

4-5.1 Winches and Towing Machines

Although wire rope is somewhat easier to handle than wet manila line of equal strength, it cannot be faked out on deck when hauled in. Powered winches and towing machines were a natural evolution, providing the inhaul and storage features for wire rope hawsers, while eliminating the use of bitts and hooks.

All U.S. Navy tugs have automatic towing machines, except for the MSC-operated T-ATFs, which use SMATCO winches. MSC has backfitted automatic towing machines on selected T-ATFs. Each T-ATF requires a ship check for applicability.

The principal functions of towing machines are:

- Acts as a hard point or attachment point for securing the towline to the tug.
- Pays out and heaves in the towline during towing operations.
- Transports or stows the towline as it is heaved in.
- Acts as a quick-release device for disconnecting a towline if necessary during an emergency.
- Acts as an automatic tension control device to limit or relieve peak dynamic loads in a towline system, thereby enhancing the life and utility of the equipment, increasing maximum speed, and increasing safety.
- Monitors and displays tow hawser conditions such as tension and scope.

A towing machine has a power-driven drum that serves as an attachment point and stores unused portions of the wire rope towing hawser. The powered drum is used to control the length of wire towline. Most U.S. Navy towing machines have an automatic control system that automatically pays out line when tension exceeds a set value. More sophisticated machines also have an automatic reclaim capacity, which hauls back the hawser when tension decreases. Towing machines have a free-spooling feature that serves as a quick disconnect system for the towing hawser.

As synthetic fiber line towing hawsers were being introduced in Navy towing, the multi-sheave traction winch was developed (see Figure L-1). In addition to providing a hard point for attachment, the winch has payout and heave-in features for adjusting the towline scope. Because reel-type storage is not practical for synthetic line, the hawser is fairled into a stowage bin located below decks as it comes off the traction winch. Some traction winches are now equipped with automatic controls, that pay out hawser to relieve high towline tensions. This control generally does not provide automatic reclaim on the traction winches. Periodic heave-in, under manual control, may be required to maintain the desired towline scope. Traction winches for wire hawsers are often found on larger commercial ships.

Most towing machines and winches have a "dog" system that positively holds the drum against towing loads. A dog is a pawl or ratchet type system that cannot be released against tension. When towing "on the dog," a towing machine must be started up, engaged and the hawser heaved in slightly to release the dog. Therefore, when towing on the dog, there is no quick-release capability.

Refer to (Ref. L) for a more complete discussion of U.S. Navy towing machines and winches.

4-5.2 Bitts

A bitt is a strong post used for belaying, fastening, and working ropes, hawsers and mooring lines. Bitts usually appear in pairs and are named according to their use.

NOTE
Unless specifically designed, bitts are generally not suited as towing attachment points and are not in the proper position to be used as towing fairleads.

The term bollard is occasionally applied to a bitt, but more commonly is applied to a device on a pier for securing mooring lines.

Bitts on U.S. Navy ships are designed to withstand a load equal to at least three times the breaking strength of the line they were designed to hold. See Section 6-2.6.2 for the safe working loads of specific design strengths of U.S. Navy bitts.

Towing or H-bitts are heavy steel castings or weldments secured to the ship's structure (see Figure 4-4) . Generally located near the tug's pivot point, they provide the hard point that sustains athwartship loads imposed by a towline when it sweeps the fantail. In tugs fitted with towing machines, the H-bitts are used to fairlead the main tow hawser to the drum to prevent transverse strain on the level wind mechanism and are used to stop off the tow wire when necessary. On the ARS 50, the function of the H-bitts is integrated into the deckhouse structure.

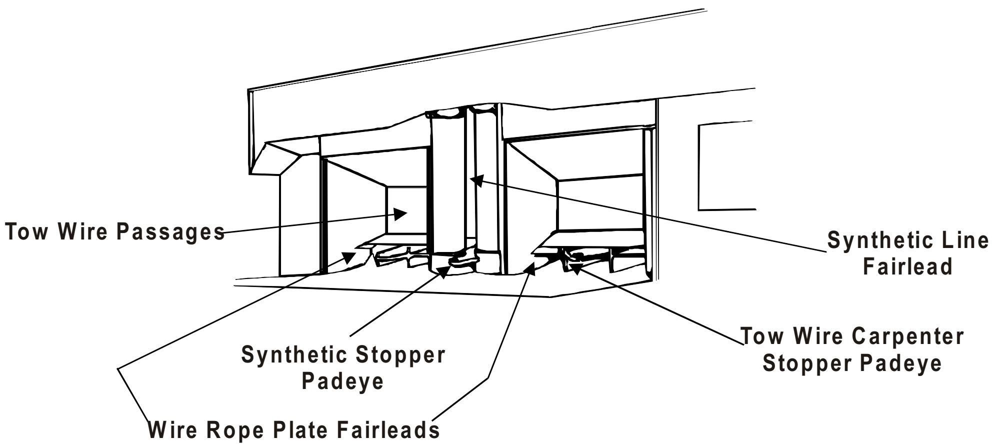
Under normal towing conditions, using the H-bitts for holding the hawser is not recommended; such use is usually restricted to debeaching operations or other instances when isolating the towing machinery from hawser tension is necessary.

4-5.3 Padeyes

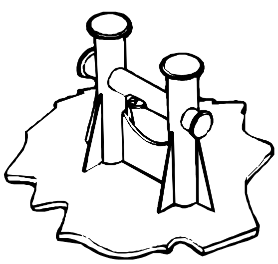
The most frequent means of attaching a towline to the towed vessel is by means of a padeye. Three distinct types of devices collectively are referred to as padeyes. Personnel rigging the connection must understand design features. The three types of padeyes found in towing are:

- Horizontal padeye
- Vertical free-standing padeye
- Towing bracket

Figure 4-5 shows two different styles of horizontal padeyes. Their distinctive feature is that the pin has a vertical axis. The towline, therefore, is free to sweep in the horizontal plane, while constrained in the vertical plane.



Aft End of ARS 50 Towing Machinery Room Looking Forward



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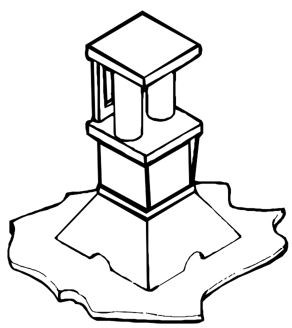

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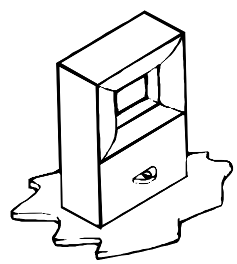

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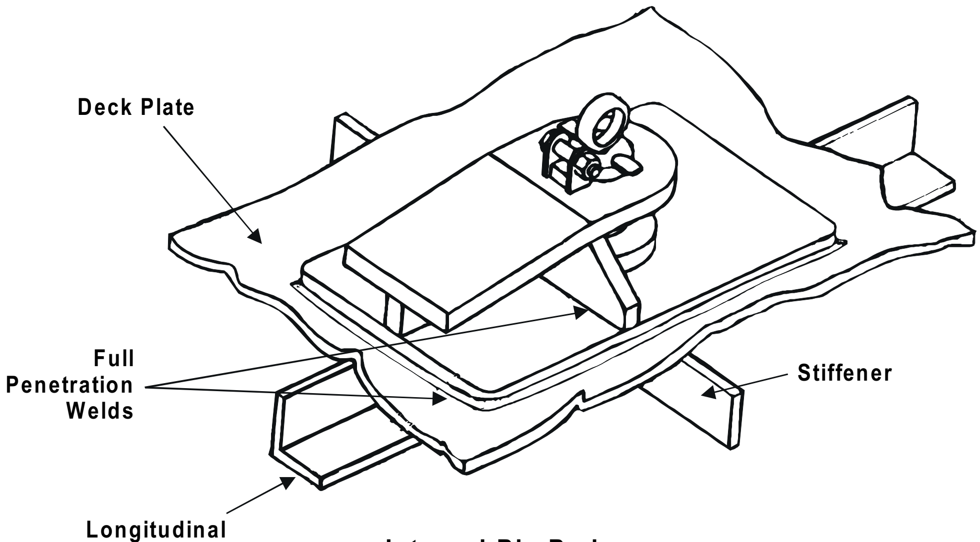
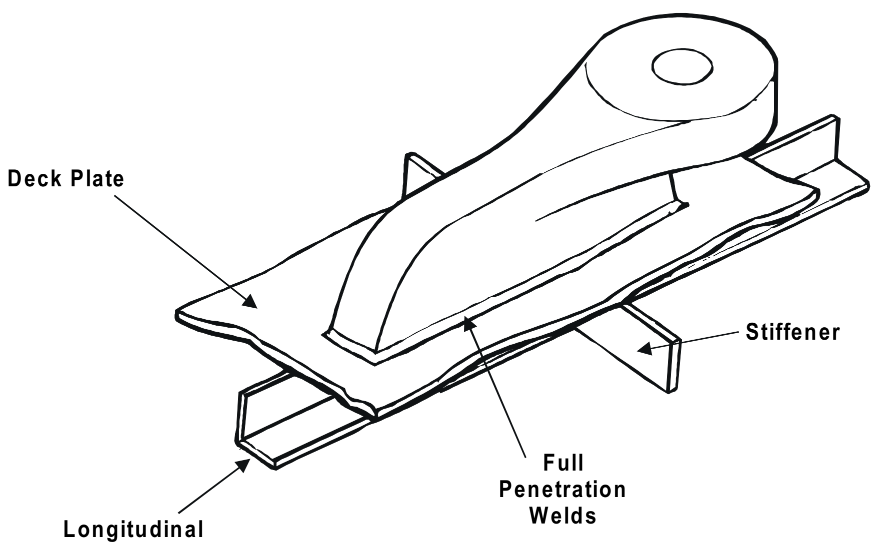
Figure 4-4. Aft End of ARS 50 Towing Machinery Room and Typical Towing Fairleads /Bitts .



Integral-Pin Padeye



Chain Stopper Padeye

CAUTION
Chain stoppers are designed to bear only 60% of the breaking strength of the chain. Chain stopper pad eyes should, therefore, not be used as a single attachment point for pendants or bridles. They should be used only as attachments for chain stoppers.

Figure 4-5. Horizontal Padeyes.

There are two types of horizontal padeyes in use today.

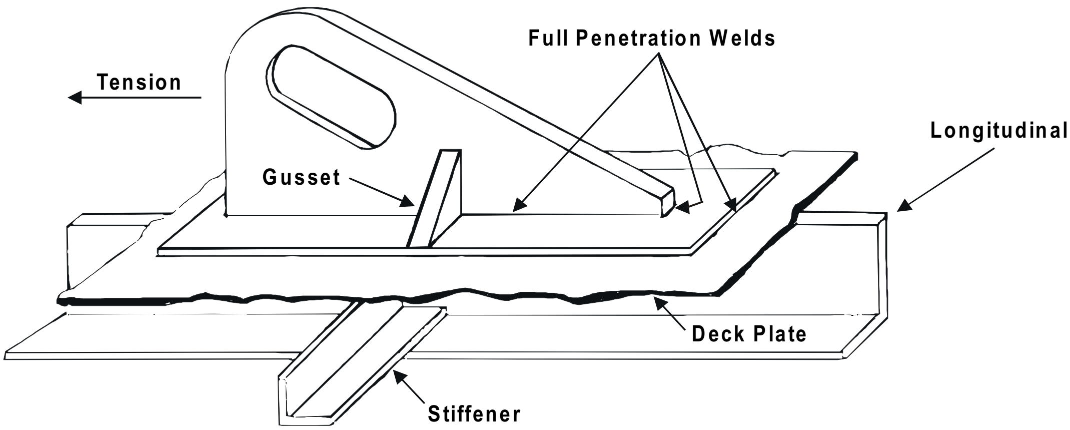
- The integral-pin type comes with its own pin, with the female threads located in the base plate of the padeye (see Figure 4-5, upper sketch). A locking device prevents pin rotation. This style padeye has a lower profile, so the moment arm of the towing load is correspondingly lower to the deck. This allows for lower loading moments and eases the design of the structure. Additionally, the integral-pin padeye allows the open or end link of a chafing chain to be pinned directly to the padeye, requiring no additional connecting jewelry.

- The shackle-style padeye is located on the forecastle of most U.S. Navy vessels (see Figure 4-5, lower sketch). It is the standard fitting for the attachment of chain stoppers to the forecastle deck. When using horizontal padeyes, there is often insufficient space to accommodate the bolt of a safety shackle due to the padeye's low profile. Therefore, U.S. Navy chain stoppers are provided with a specially forged, screw pin shackle that is appropriate for use in a towing rig. Chain stoppers and their associated padeyes are nominally designed for only 60 percent of the anchor chain's breaking strength. The strength of chain stoppers and their associated padeyes must be considered when using them as components in a towing system.

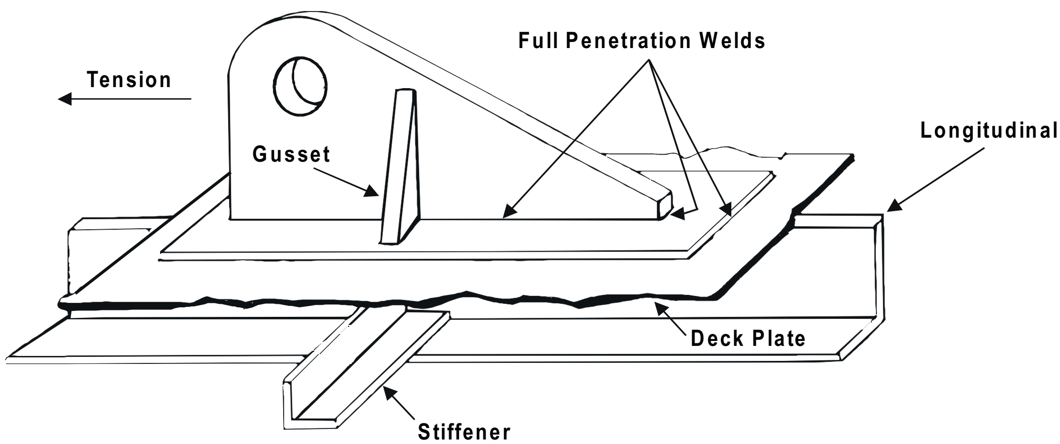
CAUTION
Chain stoppers are designed to bear only 60% of the breaking strength of the chain. Chain stopper padeyes should, therefore, not be used as a single attachment point for pendants or bridles. They should be used only as attachments for chain stoppers.

The vertical free-standing padeye comes in two basic designs as shown in Figure 4-6 . The difference is in the shape of the eyehole. The eye of a shackle-pin type padeye is a cylindrical hole through the plate designed to accept the pin of a connecting shackle. In the dipped-shackle type padeye, the hole is elongated and the bearing area of the hole is rounded so that the bow of the shackle can properly bear against the end of the slot. In this case, the shackle's pin is presented to the chafing pendant.

The vertical free-standing padeye is less resistant to lateral loads than the horizontal padeye. The free-standing padeye must be used with a towing fairlead strong enough to withstand the lateral loads of the towline, to minimize the risk of tripping the padeye. The width of the shackle-pin type padeye plate should occupy 75 to 80 percent of the jaw width of the shackle, to prevent it from racking and creating loads that tend to open the jaw of the shackle.



Dipped-Shackle Type



Shackle-Pin Type

Figure 4-6. Vertical Free-Standing Padeyes.

The vertical free-standing padeye may have a higher attachment point than the horizontal padeye. This makes for larger loading moments on the structure itself and on the attachment system to the ship deck or frame structure. This in itself is not a disadvantage if the design is proper and those who rig the system understand it.

CAUTION
If time and the situation permit, a detailed analysis of the padeye and connection should be made to avoid unexpected failure of either.

4-5.4 Padeye Design

Figure 4-7 provides an acceptable padeye design for situations where no suitable connection point exists. Given the predicted towline tension and a specific plate thickness, the chart provides the minimum hole diameter and the minimum distance from the hole to the edge of the plate. Given the same predicted tension and a specific thickness for the continuous fillet weld, the chart also determines how long the padeye must be.

To design a padeye using this chart, follow these steps:

a. Estimate the towline tension that the padeye will meet. In this case, use the approximate towline tension as determined from the results of the calculations in Appendix G. In Figure 4-7, this number is called the load or force (F). Locate this level using the numbers on the far right-hand side of the chart.

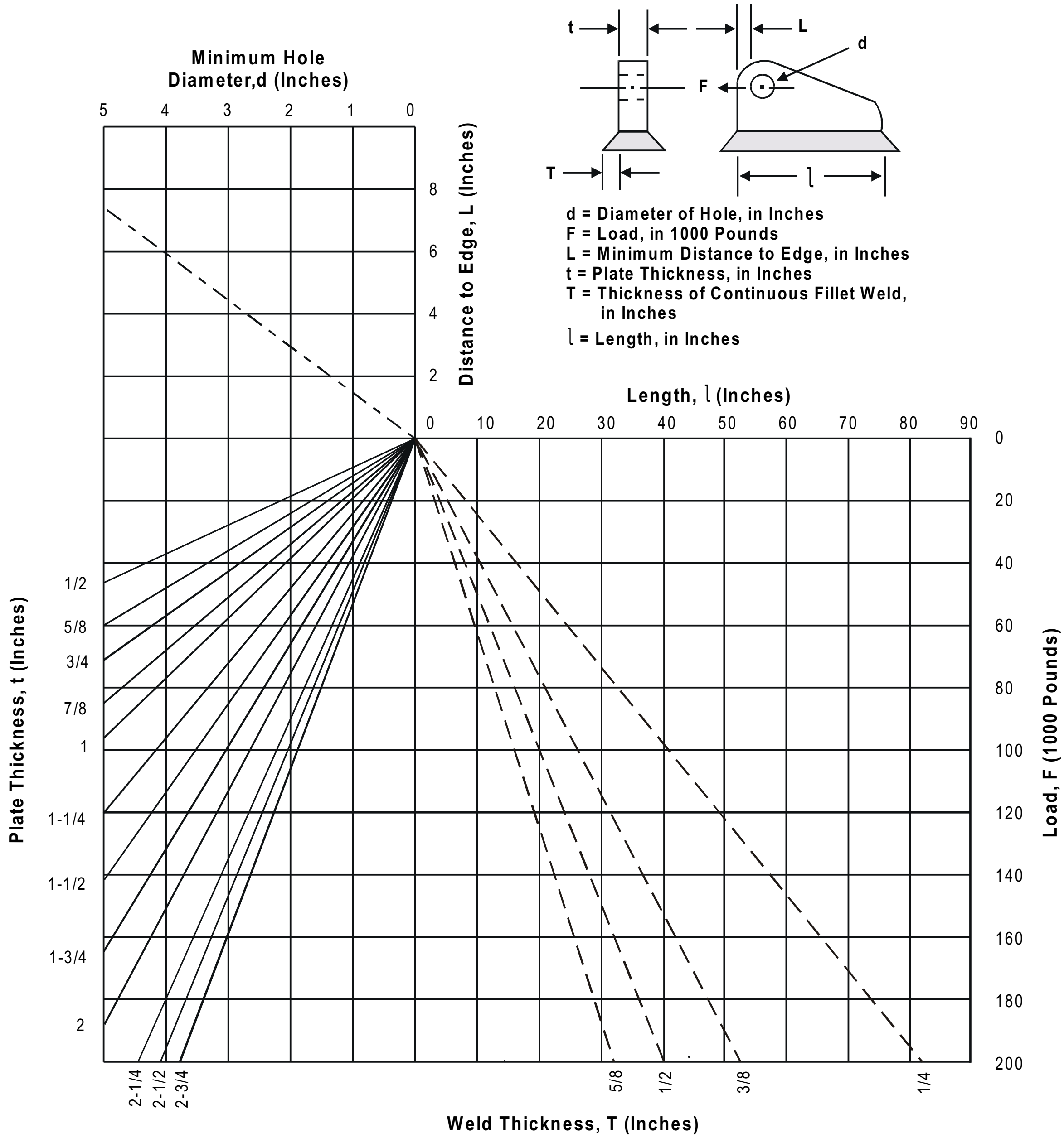
b. Choose a particular plate thickness (t). Each thickness is represented by a solid diagonal line. These lines are labeled in the lower left-hand side of the chart. Find the point where the plate thickness (t) intersects with the predicted load (F).

c. To find the minimum hole diameter (d), draw an imaginary line from the intersection point straight up to the top of the chart. The diameter measurements are displayed across the very top of the chart.

d. To find the minimum length from the hole to the edge of the plate, find the point where the diameter measurement (d) intersects with the broken diagonal line that appears in the upper left-hand portion of the chart. Look on the right-hand side of the chart to find the minimum distance to the edge (L). This minimum distance applies in all directions around the hole, including above and below.

e. To determine the minimum length for the padeye, choose a particular thickness for the continuous fillet weld (T). Each thickness is represented by a dashed diagonal line. These four lines are labeled on the bottom of the chart on the right-hand side. Find the point where the thickness (T) intersects with the predicted load (F). To find the padeye length (l), draw an imaginary line from the intersection point straight up to the top of the chart. The length measurements are displayed across the very top of the chart and are expressed in inches.

For example you are tasked with planning a tow using an automatic tow machine with a new towing hawser. Per calculations you estimate the towline tension (F) to be 80,000 pounds and the maximum plate thickness available to fabricate a towing padeye is 1 1/2 inches thick (t). Determine the diameter of the hole (d) required and the distance (L) the hole must be from the leading edge of the plate. By using Figure 4-7 we can determine the diameter of the hole (d) required. Entering the left side of Figure 4-7 find the line corresponding to the plate thickness (t). Trace the line upward until it intersects with the estimated towline tension of 80,000 pounds from the right side of Figure 4-7. Draw a line vertically from this intersection to the top of Fig-



NOTE
Padeye material should be ASTM-36, ABS Grade A, or similar.

Figure 4-7. Minimum Padeye Design Requirements.

ure 4-7. Where this line intersects the top of Figure 4-7 determines the minimum hole diameter (d). In this case, a minimum hole diameter (d) of 2 3/4 inches is required. We can also determine the minimum distance from the leading edge of the hole to the edge of the plate (L) by using the vertical line previously drawn and determining where it intersects with the dashed diagonal line crossing the top of Figure 4-7. Going right from this intersection to the right of Figure 4-7 determines the minimum distance to the edge of the plate (L). In this case the minimum distance (L) to the edge of the plate is 4 inches. Assuming the fillet welds are 1/2 inch thick (T), what length (I) padeye is required? We can determine the length of the padeye by finding the line on the bottom of Figure 4-7 that corresponds to the weld thickness (T). Trace this line upward to the left until it intersects with the estimated towline tension from the right of the figure. Draw a vertical line from the intersection to the top of Figure 4-7. Where this vertical line intersects the top of the figure determines the minimum distance to the edge of the plate (I). In this case the minimum distance to the edge of the plate (I) is 16 inches.

The example is satisfactory for 80,000 pounds of tension. To verify that the hole is of sufficient size, check the size of the shackle required. If an automatic tow machine is used, Table 3-2 shows a factor of safety of 3 is required or a 240,000-pound proof-load shackle (2 1/4-inch Grade B shackle). The pin for this shackle is 2 1/2-inches thick and will just fit the hole in the padeye. If the tow were to be performed without an automatic towing machine, but with a chain pendant, Table 3-2 would require a shackle factor of safety of 4. (Ref. D) and Tables D-7 through D-9 show that the minimum required Grade B shackle size is 3 inches, with a 3 1/4-inch pin. The 1 1/2-inch available plate can be used with a larger hole, taking care to maintain the minimum distance to the edge of the padeye (L) required by the load and plate thickness.

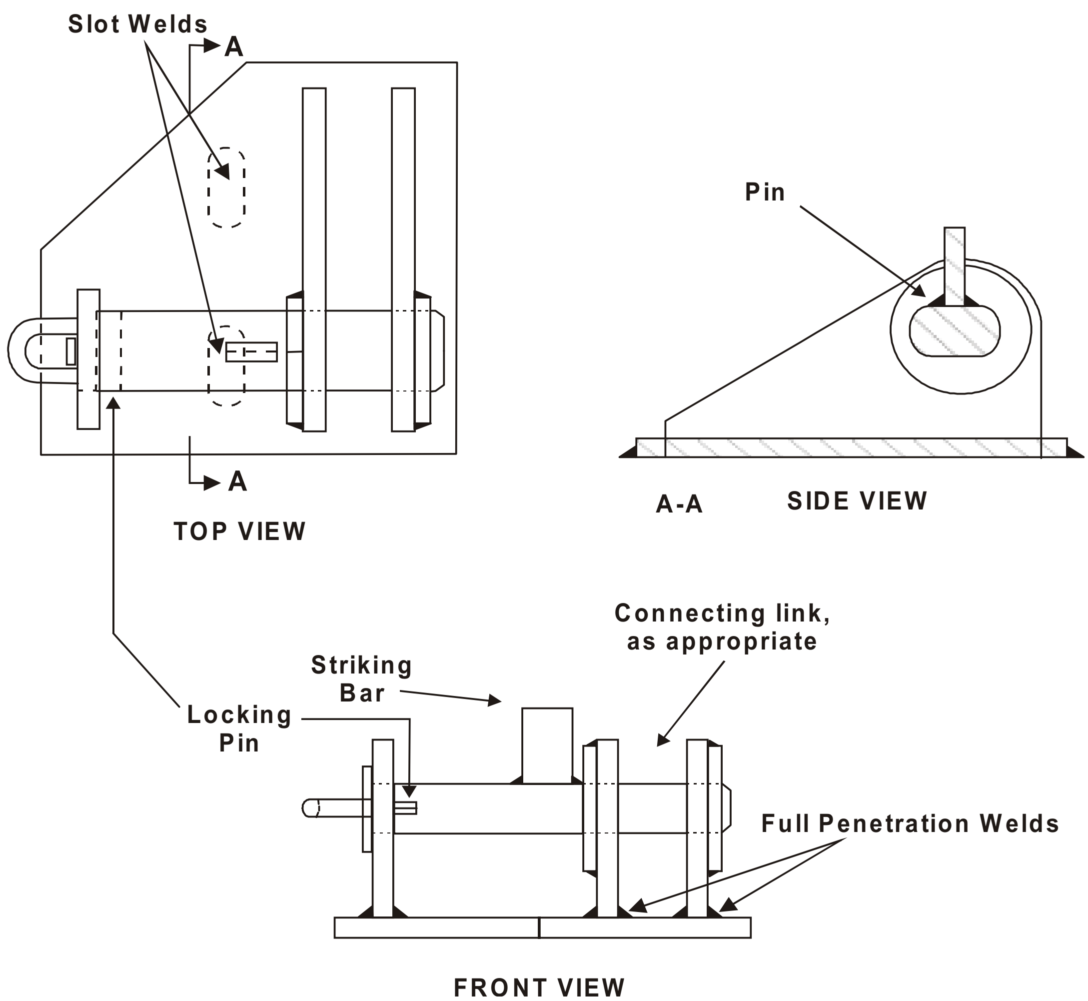
CAUTION
This method yields a design with a minimum factor of safety of 3 for all failure modes. For a stronger padeye, use a higher assumed load. For instance, if a padeye with a failure load of 300,000 pounds is desired, use 100,000 pounds as the design load. The below-deck structure must be checked or altered to transmit towing stresses to the ship's structural members. Simply welding the padeye to the deck plating is not enough.

4-5.5 Deck Structure

When designing and locating padeyes, it is extremely important to examine the below-deck structure. Towing padeyes produce large local loads that cannot be supported by deck plating alone. It is necessary to locate padeyes atop both longitudinal and transverse members to adequately distribute loading to the surrounding structure, particularly if the padeye is likely to be subject to side loads. The longitudinal member should be aligned directly under the main plate of the padeye. The transverse member location is somewhat less critical but should be located as close to the padeye as possible, preferably directly underneath.

4-5.6 Smit Towing Bracket

The Smit Towing Bracket consists of two vertical plates, similar to a pair of free-standing padeyes, with an elliptical pin fitted between them (see Figure 4-8) . The pin is fitted with a keeper key or locking pin and can be released in an emergency. The principal advantage of the Smit Towing Bracket is the ease of breaking the tow connection, even under significant load. This is accomplished by removing the locking pin and driving the striking bar to port with a sledge, allowing the



CAUTION

Chain smaller than about 3 1/4” will require a pear-shaped link or an anchor shackle to connect to the standard Smit bracket. Check dimensions carefully.

Figure 4-8. Smit Towing Bracket.

main pin to slide out of the pear-shaped link. The design uses no shackle. This style of towing attachment, like the vertical free-standing padeye, is susceptible to tripping loads and is dependent upon the fairlead chock.

The standard Smit Bracket design is manufactured in two sizes. The larger size will accept the standard end link of a 3-inch chain. Smaller chains will require a large safety anchor shackle or a pear-shape link. This link may possibly be found aboard the ship outfitted with such a towing bracket.

CAUTION
The large and small Smit Brackets are designed to accept the standard end link of 3-inch and 2-inch chains, respectively. They will directly accept the common link of considerably larger chains. Check dimensions carefully in designing the tow connection.

The smaller standard size Smit Bracket is designed to accept the end link of 2-inch chain, or the common link of 2 3/4-inch chain.

Sometimes the Smit Bracket design is adapted to other dimensions. In all cases, the dimensions must be checked carefully to ensure that properly sized jewelry is available to make the connection.

4-5.7 Towing Hooks

Towing hooks rarely are seen in the United States, but may be found on foreign tugs, especially European tugs. They are heavy steel hooks mounted on vertical pins that allow them to swing. Each hook is shock-mounted by using a heavy compression spring and fitted with a quick-release device that trips the hook, much like a chain stopper. The compression spring provides a small amount of dynamic load relief for the towline system.

4-5.8 Chocks

Most tows make the towline connection on deck. Whether using a bridle arrangement or a single point connection, the selection of the point where the towline (or bridle legs) crosses the deck edge is critical to protect both the towline and the towed ship's structure. These robust points include bullnoses, closed chocks, and roller chocks with a generous radius (see Figure 4-9). Planned tows often will involve installation of a special fairlead, because the radii of chocks and other fittings designed for mooring are generally not sufficient for towing. Emergency tows generally must make do with whatever is available, remembering that towline chafing and structural damage to the tow are probable. In this case, the towline component crossing the deck edge will usually be a chain, heavier in size than otherwise would be required for strength alone.

4-5.9 Fairleads

Fairleads are used to lead mooring lines around obstructions and align them properly with winches or capstans. Fairleads are located to accommodate lines from both sides of the ship. Fairleads usually have rollers to reduce line wear.

4-6 Connecting Hardware (Jewelry)

Connecting hardware or towing jewelry used to rig the tow system include a variety of shackles, chain detachable links, special fittings such as flounder plates, splices and end terminations for wire and synthetic line. This hardware is used to connect the various portions of the towline system to each other and to the tow (see Figures 4-10 through 4-14). Components of different sizes are connected by using offset plate shackles and pear-shaped detachable links.

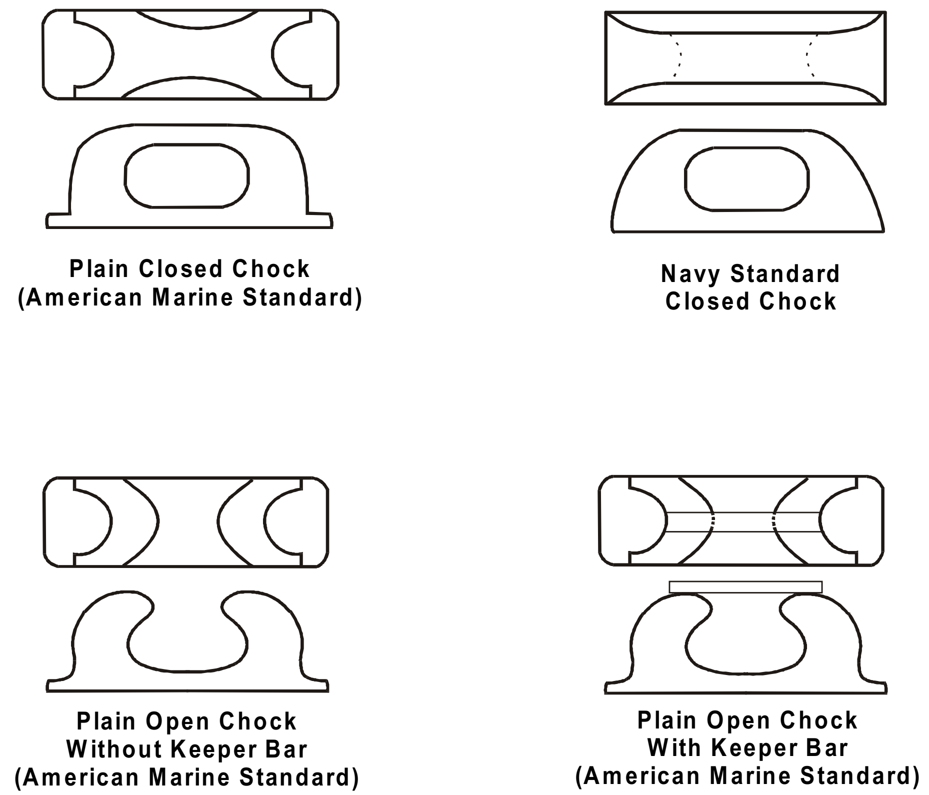


Figure 4-9. Types of Chocks.

4-6.1 Shackles

General purpose Navy shackles are described in detail in RR-C-271D, Amendment 1, Federal Specification, Chain and Attachments, Welded and Weldless (Ref. E) and in (Ref. D). There are two types, two grades, and three classes of shackles. Of these twelve categories, only four can be used as towline connectors. These are as follows:

- Type I Anchor Shackles
  Grade A - Regular
  Class 3 - Safety Bolt and Nut

- Type I Anchor Shackles
  Grade B - High Strength
  Class 3 - Safety Bolt and Nut
- Type II Chain Shackles
  Grade A - Regular
  Class 3 - Safety Bolt and Nut
- Type II Chain Shackles
  Grade B - High Strength
  Class 3 - Safety Bolt and Nut

Examples of chain and anchor shackles are shown in Figure 4-10.

CAUTION
Special forged shackles, when used with chain stoppers and carpenter stoppers, use carefully machined screw pins and are permissible in towing. Such pins must remain accessible for inspection and service while in use.

Navy shackles are permanently and legibly marked in raised or indented lettering on the shackle's body identifying the manufacturer's name, trademark, shackle size, and recommended Safe Working Load (SWL). SWL of both Grade A and Grade B Navy safety shackles is suitable for sizing hardware for lifting purposes. However, SWL cannot be used in towing. Proof loads for a shackle must be used vice SWL. Recommended factors of safety listed in Table 3-2 and Section D-14 describe appropriate methods for sizing shackles for towing.

CAUTION
Screw-pin shackles, other than the special forged shackles for stoppers, must never be used for connections in towing rigs. The pin could back out due to the constant vibration set up by the hydrodynamic actions on the towline.

Although screw-pin shackles are a commonly used type of marine shackle and afford a quick and simple means of connecting and disconnecting, the screw pin shackle should not be used for connections in a towing rig. Due to the cyclic loading associated with towing, it is possible that the pin could back out. Excessive vibration or alternate athwartship movement coupled with the surging of the towline may cause screw pin shackles to come undone.

CAUTION
Shackles and other fittings frequently come with cotter keys or pins. **Cotter keys are not used in towing.** Replace cotter keys with locking bolts with two jam nuts. The head of the locking bolt and the jam nuts shall be appropiately sized to ensure the head of the locking bolts and the Jam nuts are in contact with the nut of the safety shackle.The locking bolt can be peened over if desired.

CAUTION
Never weld on forged steel shackles. The welding process can weaken the shackle.

Navy shackles are made of forged steel; welding to forged steel shackles can reduce the strength of the shackle by as much as 30 percent. Shackles should never be welded on, nor should pins be secured by welding. The nuts on safety shackle pins are secured by a small locking bolt, with two jam nuts to secure the pin nut. The locking bolt can be peened over if desired. This belt shall be appropriately sized to ensure the head of the locking bolt and the jam nuts are in contact with the nut of the safety shackle. This belt should not exhibit looseness of play. If change out or breaking the shackle connec-

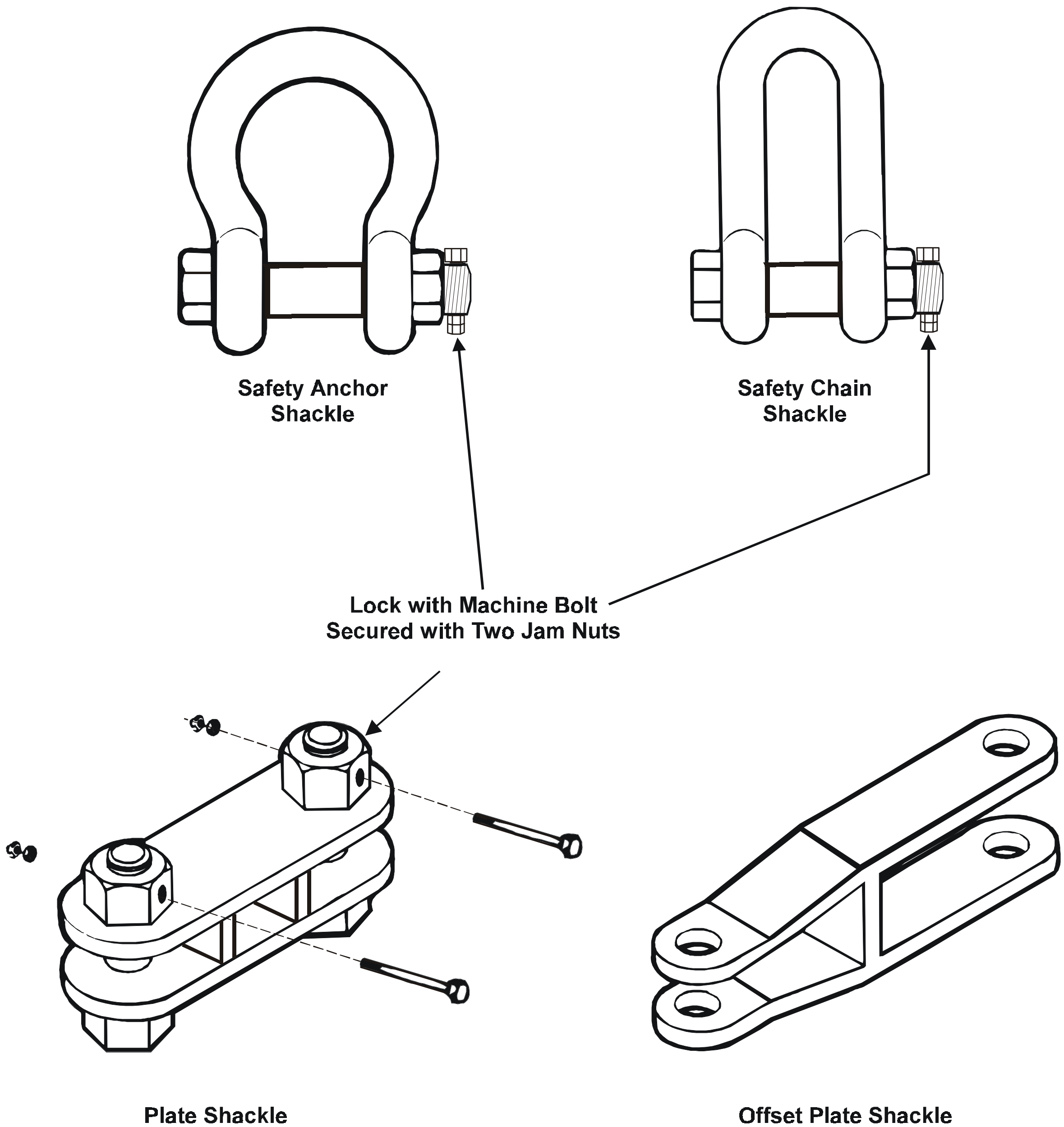


Figure 4-10. Shackles.

tion are anticipated during the tow it is good practice to procure additional properly sized locking bolts prior to getting underway. Cotter keys should not be used in towing.

4-6.2 Other Connecting Links

It is often difficult to pass a safety shackle through the opening in a link of chain. Alternative connecting devices when rigging chain and wire pendants, bridles, include:

- Plate shackles (see Figure 4-10)
- Detachable links (Navy and Kenter type)
- Detachable anchor connecting links (pear-shaped or detachable end link)

Plate shackles shown in (Ref. I) (Figure I-16 through Figure I-18) are commonly used to make connections to the flounder plate and to connect chain and wire pendants.

Detachable links are similar in shape to chain links, but can be disassembled into several pieces (see Figures D-1 through D-3). This allows the link to be used as a connection between chain and other components. Pear-shaped links have one end that is smaller than the other; they are used to attach components of different sizes.

CAUTION
Never weld detachable links. The welding process can weaken the links.

NOTE
When inspecting chain, inspect the detachable links to determine whether they have been properly assembled. The key slot must be in the proper place and the match marks must be identical and matched. This is necessary because detachable links are hand-fitted to ensure proper assembly and full strength. All assembled links should be visually inspected and sounded.

The practice of welding detachable links closed to assure security of the towing rig is one that continually plagues towing commands. This practice should never be permitted. It is much safer and more cost-effective to use a hairpin to secure the tapered pin in the link. This ensures that the link will not come apart and simplifies the eventual disassembly and re-use of the link. Details for modifying detachable links for use with hairpins are contained in (Ref. D).

Detachable links should not be used in instances where they might be subjected to bending or twisting.

4-6.3 Wire Rope Terminations

Three types of wire rope terminations are normally used in Navy towing applications: swaged, spliced, and socketed (see Figure 4-11)

The wire rope swaging process attaches fittings to wire rope by means of cold plastic flow of metal under extremely high pressures. The process uses hydraulic presses in con-

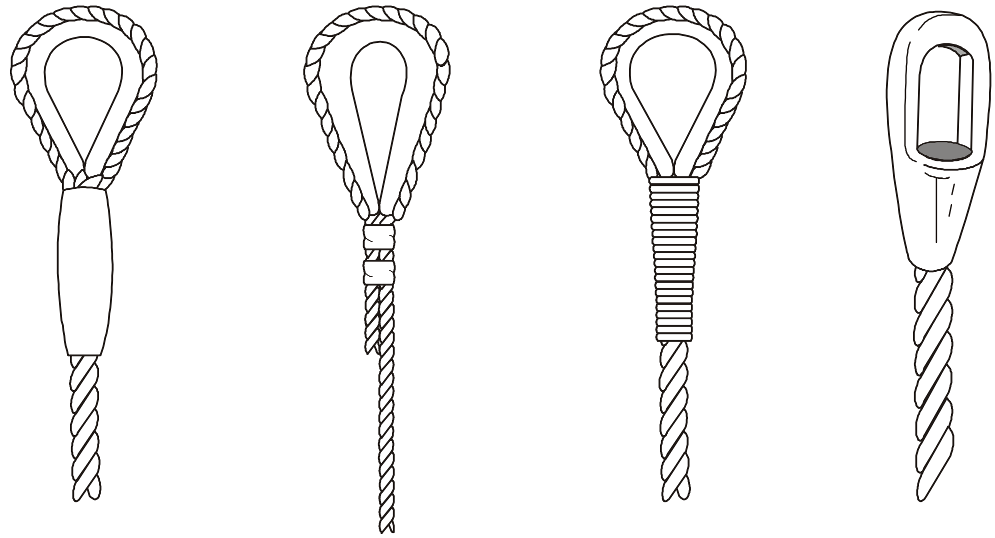


Figure 4-11. Types of Wire Rope Terminations.

junction with suitable dies. The swaged fittings are usually made of special alloy steels. An advantage of this process is low cost and high efficiency.

Swaged eyes are more common than spliced eyes. Existing swaging technology is so highly advanced that virtually all types of wire rope terminations can be made. Properly made swaged eyes develop 85 percent of the strength of the wire. Swaged terminations are applied only to wire rope with wire rope cores. A fiber rope core wire can be swaged by replacing the fiber core at the termination with a strand of wire.

The second type of wire rope termination, the hand-spliced eye, has less strength than the breaking strength of the wire. For instance, 1 5/8-inch to 2-inch hand-spliced eyes have 75 percent of the breaking strength of the wire, while 2 1/4-inch and larger wires have an efficiency of 70 percent. (See Table B-3 for more details.) Nonetheless, hand-splicing enjoys continued popularity because of field repair capability.

A subset of a wire splice is the use of wire clips. This is the preferred over the hand-splice because it can withstand 80 percent of the wire's breaking strength if completed properly. Both the hand-splice and the wire clip termination have less strength than the breaking strength of the wire and should be used only in an emergency (such as damage to or loss of the normal end fitting). See Table 4-1 and Naval Ship's Technical Manual (NSTM) S9086-UU-STM-010, Chapter 613, *Wire and Fiber Rope and Rigging* (Ref. F) for the proper placement and number of wire clips.

The third type of termination, the poured zinc or Spelter socket, is very common and is prepared in accordance with NSTM, Chapter 613 (Ref. F). This termination will withstand 100% of the rope's breaking strength if prepared properly. The end of the rope is seized and the strands are unlayed all the way to the

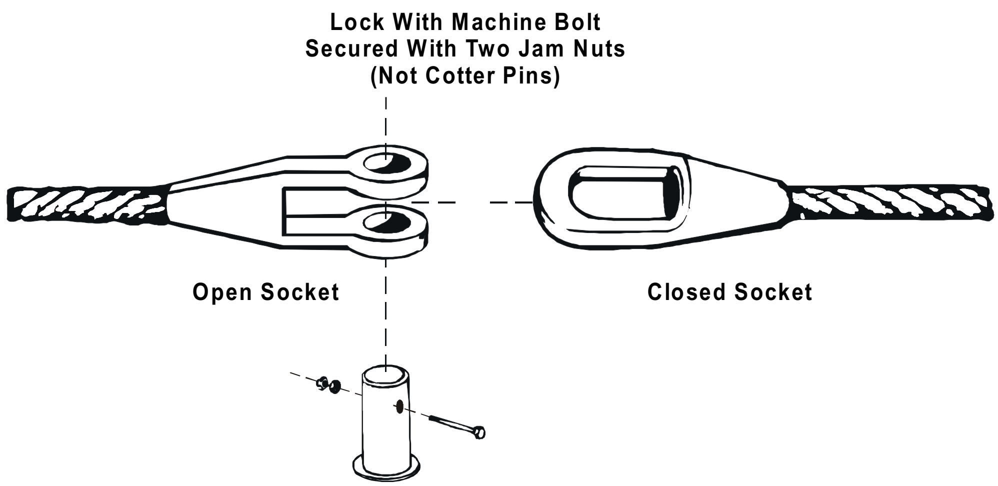


Figure 4-12. Towline Termination.

individual wires. This broomed end is inserted into the socket and secured in place with the poured zinc. Epoxy-type poured sockets are not suitable for towing purposes.

CAUTION

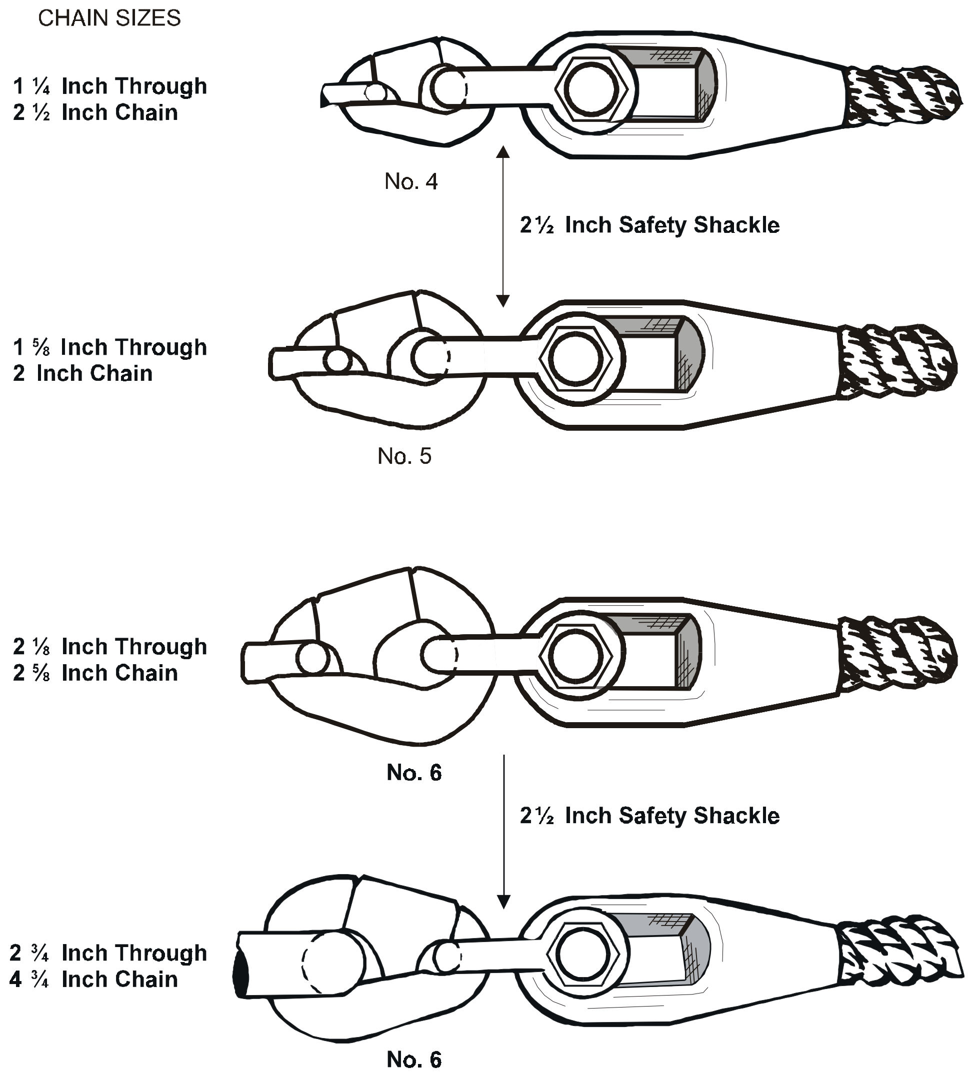
Whenever a poured socket is installed on a wire rope, the condition of the lubricant in the portion of the rope near the socket should be checked and new lubricant applied to dry areas.

Sockets are of two types, open and closed (see Figure B-8). The open socket is fitted with a locking bolt and secured by a locking bolt with two jam nuts. Frequently used. on towing hawsers, the closed socket forms an eye with a solid bail (see Figure 4-12). Figure 4-13 demonstrates using a safety shackle and three standard pear-shaped detachables to connect the standard hawser termination to a wide range of chain sizes.

4-6.4 Synthetic Line Terminations

In general, the same methods are used for splicing synthetic lines as for natural fiber line. When splicing a synthetic fiber line, however, exercise care to maintain the stranded form. If this is not done, the strand will collapse and form a bundle of tangled yarns. Also, since the felting action (tendency to mat together) of synthetic fiber is considerably less than that of natural fibers, more tucks are needed to produce a safe splice. This is generally true for lines of plaited construction. For guidance in splicing single or double braided lines, consult the manufacturer's recommendation or contact NAVSEA 00C.

The traditional standard end fitting for manila was a tear drop wire rope thimble. With the advent of high-strength synthetics, however, the eye of the line could stretch sufficiently to allow the thimble to capsize out of the eye. In



NOTE
Three different pear-shaped detachable links will satisfy all normal chain connection requirements.

Figure 4-13. Pear-Shaped Detachable Links.

addition, the higher strength of the synthetic line caused thimbles to crush and fail. To resolve these problems, a variety of solid thimbles have been developed and have become the standard end fittings used on synthetic line. Figure 4-14 shows the approved Navy standard thimbles.

4-6.5 Synthetic Spring

A spring is a line made of material exhibiting elastic behavior. In towing, a spring absorbs shocks due to dynamic loading of the towing system; this is one reason that the ocean towing industry first became interested in nylon and other synthetic fiber lines. Nylon replaced manila in hawsers and spring pendants because of its superior elasticity and because it is smaller, lighter, and easier to handle than manila of similar strength. Polyester has replaced nylon (see Section 4-3.2) in most synthetic line towing applications. (Ref. C) contains more information on synthetic springs and specifications for lines made of polyester fiber that are approved for use as tow hawsers and springs.

A synthetic spring is sometimes inserted between the towing pendant and the tug's hawser for dynamic load mitigation. Seen most frequently in commercial towing, the spring usually is a length of synthetic fiber rope, spliced together, arranged into a grommet (see Figure 4-15).

A grommet is fabricated by splicing a line to form one continuous loop. The two sides of the loop are pulled together around two thimbles, and seized with small stuff to form the grommet or strap shown in Figure 4-15. The line used to make the grommet must be sized so the assembled grommet will have a total safe working load that is equal to or greater than the design load for the towing system.

Although the line is doubled in the grommet, its strength is not twice that of a single line. There are losses in strength in the splices, so that the assembled grommet is only 0.9 times as strong as twice the original breaking strength. For this reason, the line used for the grommet must have a basic breaking strength equal to at least 5/9 of a single line spring in order to have the same total strength when fabricated into a grommet.

An alternative to the grommet arrangement is the synthetic spring consisting of a length of line with a standard eye splice in each end. Each of these eyes will normally employ a thimble. Since the spring is not doubled, the line diameter must be greater than that used in the grommet, but should be easier to handle.

At present, there is no agreement on the method to calculate the proper length of a synthetic towing spring. Commercial operators generally use a spring of 200 to 400 feet in length. For additional guidance on sizing a synthetic spring, contact NAVSEA 00C.

For a 2-inch IPS fiber core hawser towing on the brake a grommet made from 10-inch circumference double-braided polyester would be required. This would be determined by applying the required factor of safety for wire from table 3-2 which is 4, when used with synthetic spring. Therefore the maximum steady working load is 288,000 ÷ 4 or 72,000 pounds. For a synthetic spring (polyester), the factor of safety is 6. Thus a single polyester spring, capable of handling 72,000 x 6 or 432,000 pounds is required. Use in a grommet configuration will require a strength of 432,000 x 5/9 or 240,000 pounds. So, a 10-inch circumference double-braid polyester line, with a specified breaking strength of 277,000 pounds, will be required for this grommet. The grommet's weight per foot in air is approximately equal to that of the wire (6.74 vs. 6.72 lbs/ft), however, the grommet will be far more bulky

4-6.6 Bridles

If the tow has a configurational, operational, or directional stability problem that makes a

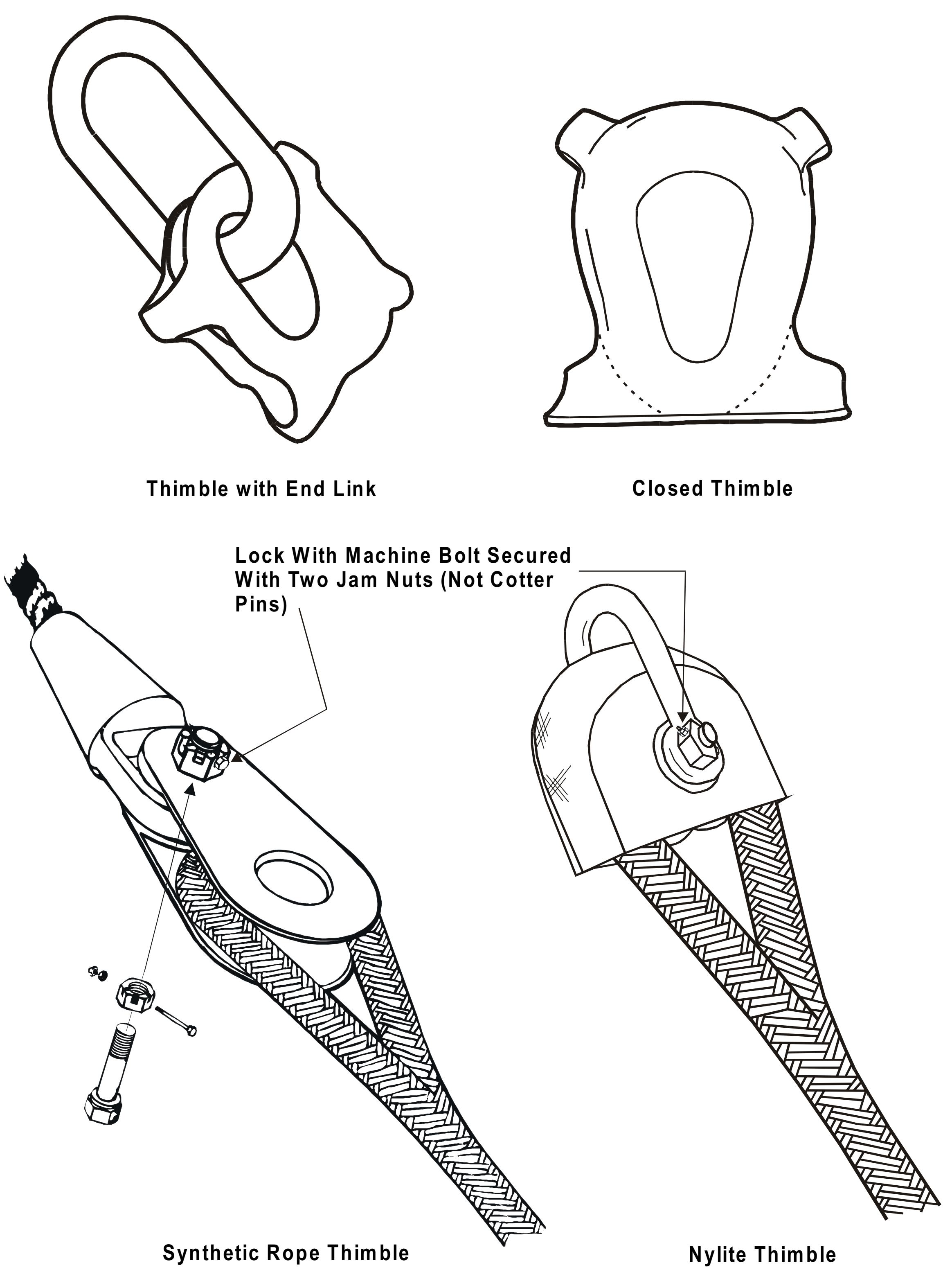


Figure 4-14. Synthetic Line End Fittings.

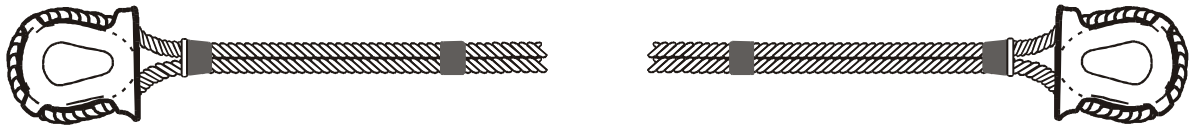


Figure 4-15. Synthetic Line Grommet.

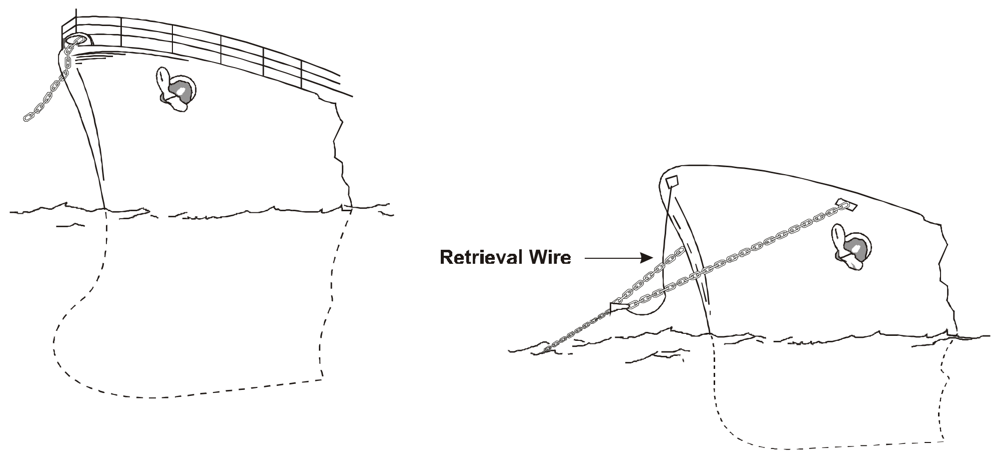
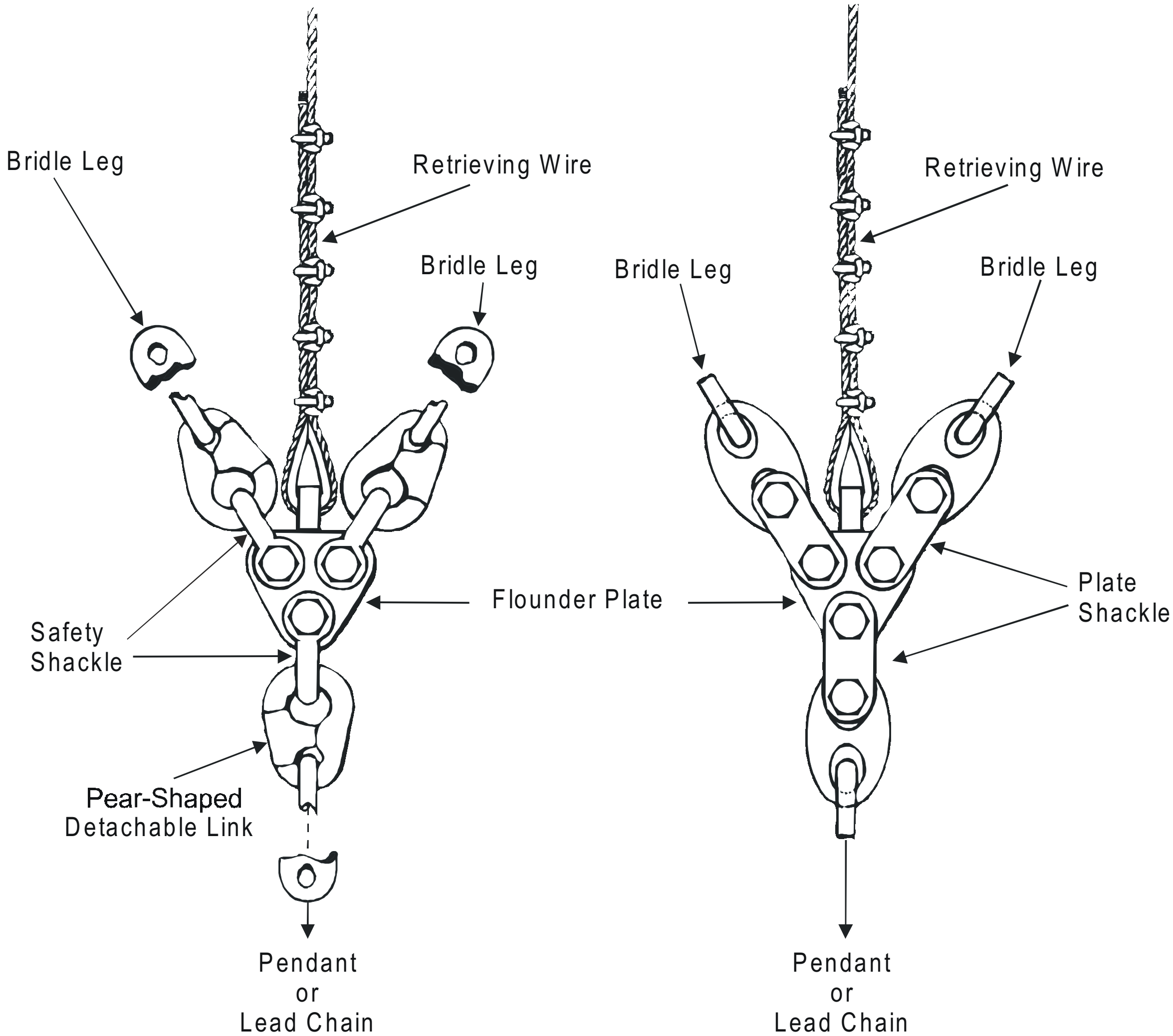


Figure 4-16. Towing Rigs.

single pendant inadequate, a bridle should be rigged (see Figure 4-16 and Figure 4-18). Barges with square bows are rigged with bridles because of the stabilizing effect produced by pulling from both legs of the bridle. Some barges have a hull form and/or appendages that increase the directional stability of the barge; these barges may be rigged with a pendant, rather than a bridle, attached on centerline. Chain is the preferred material for bridles in deep ocean towing and often complements or substitutes for the wire pendant. Chain's advantage over wire comes from its greater weight per foot, which deepens the catenary, and from its superior resistance to chafing. As a rule of thumb, the size of the chain to use for bridles and pendants should be at least equal to the size of chain used to anchor the tow. An exception is for larger ships, where the 2 1/4-inch beach gear chain carried by Navy towing/salvage ships is appropriately sized for the power and hawser size of these tugs.

The flounder plate, or fish plate, is a component of a typical towing bridle. A flounder plate is designed to distribute the towing force of a tug's hawser to the separate legs of a bridle. The deployment of flounder plates on typical towing rigs is described in detail in (Ref. I). Flounder plate design is detailed in Figures I-15.

For service craft up to 500 tons, the bridle must be equal in size to the ship's anchor chain, but not less than 1 1/4-inch. For craft greater than 500 tons, a minimum of 1 5/8-inch chain shall be used. Ships do not need chain larger than 2 1/4 inches when towed by



NOTE
See (Ref. A) for additional examples of bridle sizes of components.

Figure 4-17. Chain Bridles Using Plate Shackles and Safety Shackles.

U.S. Navy tugs. More powerful commercial tugs will require larger chain bridles. Non-magnetic chain and attaching hardware shall not be used for towing bridles. The length of each leg of the bridle from the towing attachment point to the flounder plate after rigging is completed must be equal to or greater than the horizontal distance between the attachment points. The bridle apex angle, defined as the angle between the two bridle legs as measured from the flounder plate vertex, shall be less than 100 degrees, with an optimal angle between 30 and 60 degrees (see Figures I-1, I-2, I-3 for an illustration).

All towing bridles, when rigged correctly, must have a backup securing system. This is normally accomplished by using wire rope of appropriate size (able to lace through chain links) and taking sufficient bights of wire from a second securing point (bitts, heavy cleats, etc.) and lacing the wire rope through the after end of links in the chain bridle (no less than four bights). Size and number of bights of wire should equal the strength of the chain used in the bridle. If a towing pad is used to connect the bridle to the tow, the backup wires must be laced through the portion of the chain that is forward of the towing pads. The securing point should be aft of the towing pad to prevent snap-loading. If a set of mooring bitts is used as a securing point for the bridle on the tow, the wire should be laced thorough the chain links that remain astern of the bitts after the three or more "figure eights" are secured on the bitts. There must be a sufficient number of wire clips (see Table 4-1) on each bitter end of the backup wire, aligned in the same direction (See (Ref. I) and (Ref. J) for tow rig design plans.)

It may not always be possible or practical to rig a backup system (i.e., submarine towing). In these cases, additional analysis of the main towing attachment may reduce the risk. Where possible, the attachment should be designed to a breaking strength well in excess of the other components.

On some ships with large bows (e.g., CV, AD, AOR, or AFS) it may be necessary to rig a one- or two-shot chain pendant between the bridle flounder plate and the towing hawser. Both bridle legs should be the same size and length and should be checked by counting the links when rigging is complete. All detachable links in the bridle legs and chain pendant must be locked with a hairpin (see Section 4-6.2).

Because chain and wire bridles and pendants are often subjected to wear and abrasion during towing, it is recommended practice to "over design" to allow for wear, particularly for long tows. Tables in (Ref. B) and (Ref. D) provide the breaking strength and weight per foot of various types of wire and chain. These tables can be used together with the calculated towline tensions and factors of safety obtained from Table 3-2 to determine whether the available selected wire or chain is sufficiently strong.

Sometimes a heavy wire is used as a bridle for short tows or emergency situations, but special care is required to minimize chafing of the wire and damage to the structure from the wire's extremely hard material. If the hard point is a considerable distance from the fairlead, a fairly short length of chain, sufficient to ride in the fairlead, may be used to save weight and sometimes to simplify the final connection to the tow, such as when using bitts as the hard point.

4-6.7 Pendants

A pendant is often used between the tow and towing hawser to facilitate the rigging problem of connecting heavy components. This is called a "lead" or "reaching" pendant. The lead pendant usually is wire rope and should have the same breaking strength as the main hawser unless it is intended to be the safety link, in which case it will be of lower strength (see Section 4-7 for information on the "safety link" concept). The pendant may be up to 300 feet long to permit connection/disconnection on board the tug, while maintaining a safe standoff under heavy weather conditions. Often, the arrangement of the tension member that extends outboard of the bow of the tow is such that chafing could occur. If a wire rope pendant is used in this case, it must be carefully protected from chafing, or a portion of it must be replaced with chain to provide chafing protection.

Chain pendants frequently are employed when using a single-leg attachment between the hawser and tow. This attachment generally runs through a centerline bullnose, chock, or fairlead near the tow's centerline. A chain extending forward from the apex of a towing bridle is also called a lead chain. The purpose of the lead chain is to add weight to the end of the towline system. This improves the spring in the system by increasing the towline's catenary. Sometimes the chafing/lead chain is the tow's anchor chain, which can be veered to the desired total length. During emergency tows of merchant ships, the tow's anchor chain is frequently used as a tow pendant.

A wire lead or reaching pendant is frequently used with a chain pendant to simplify connecting up the tow.

4-6.8 Retrieval Pendant

A retrieval pendant is a wire rope leading from the deck of the tow to the end of the towing pendant or flounder plate. The retrieval pendant facilitates bringing the tow gear back onto the foredeck of the tow so it will not drag the seafloor or foul the ship's appendages when the tow is disconnected. The retrieval pendant often is handled on the deck of the tow by a hand-powered winch or a deck capstan. It must be capable of being handled by the riding crew or by a boarding party put aboard the tow. The wire must be strong enough to lift the flounder plate, bridle, and/or pendant, but it is not intended to be exposed to towing loads. Examples of retrieval pendant rigging are shown in Figures 4-16 and 4-18 and throughout (Ref. I).

To size a bridle retrieval pendant, use a 4:1 safety factor for lifting bridle weight but no less than 5/8-inch wire rope.

4-6.9 Chain Stoppers, Carpenter Stoppers, and Pelican Hooks

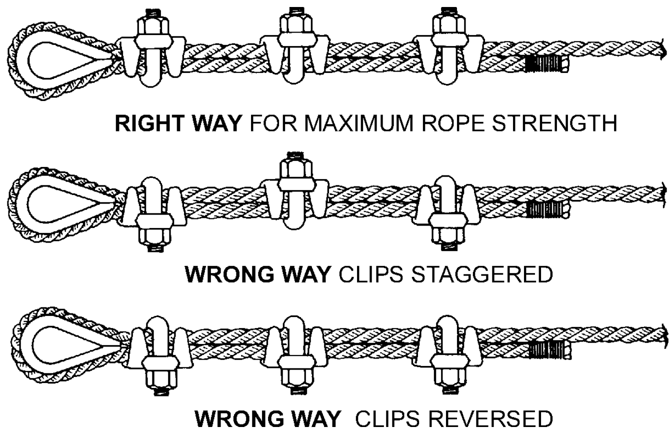
The term "stopper," as used in seamanship, describes a device or rigging arrangement that is used to temporarily hold a part of running rigging or ground tackle that may come under tension. There are many types of stoppers and methods of attaching them to the tension members. Most stoppers cannot be released under load and require the held line to be heaved in to slack the stopper and allow its removal. Some stoppers, however, such as the pelican hook and carpenter stopper, can be released when under load.

In towing applications, the stopper is usually connected to the deck pad by means of chain shackles. It is used to hold a towing pendant on deck during the hookup and breaking of a tow. A chain stopper is sometimes employed as a quick-release device (see Figure 4-18). Stoppers are nominally rated to hold a minimum of 60 percent of the breaking strength of the chain or wire for which they have been designed. This must be considered in their use. It is important not to confuse chain stoppers with pelican hooks. Pelican hooks are significantly weaker than chain stoppers of the same nominal size and are unable to grasp the chain in the desired manner.

Pelican hooks can be used to grasp chain through a long link attached to the bitter end of a chain. They cannot grasp a chain in the middle like a chain stopper can (see Figure 4-18). They can be used as quick release devices, although they do not have the holding strength of chain stoppers.

Carpenter stoppers are used when it is necessary to develop a grip on a wire rope and hold

Table 4-1. U-Bolt Clips.



Recommended Method of Applying U-Bolt Clips to Get Maximum Holding Power of the Clip. The following is based on the use of proper size U-Bolt clips on new rope.

1. Refer to the Table 4-1 (part 2) in following these instructions. Turn back specified amount of rope from thimble or loop. Apply first clip one base width from dead end of rope. Apply U-Bolt over dead end of wire rope with live end resting in saddle. Tighten nuts evenly, alternating form one nut to the other until reaching the recommended torque.
2. When two clips are required, apply the second clip as near the loop or thimble as possible. Tighten nuts evenly, alternating until reaching the recommended torque. When more than two clips are required, apply the second clip as near the loop or thimble as possible, turn nuts on second clip firmly, but do not tighten. Proceed to Step 3.
3. When three or more clips are required, space additional clips equally between first two - take up rope slack - tighten nuts on each U-Bolt evenly, alternating form one nut to the other until reaching recommended torque.
4. Prior to use, apply a load to test the assembly. This load should be of equal or greater weight than loads expected in use. Next, check and retighten nuts to recommended torque.

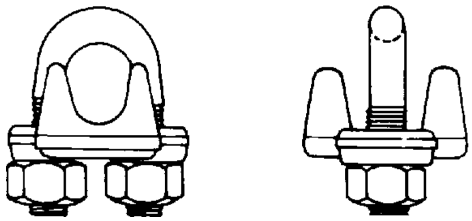
In accordance with good rigging and maintenance practices, the wire rope and termination should be inspected periodically for wear, abuse, and general adequacy.

Inspect periodically and retighten to recommended torque.

A termination made in accordance with the above instructions, and using the number of clips shown in part 2 of this table, has an approximate 80% efficiency rating. This rating is based upon the nominal strength of wire rope. If a pulley is used in place of a thimble for turning back the rope, add one additional clip.

The number of clips shown in part 2 of this table is based upon using right regular or lang lay wire rope, 6 x 19 classification or 6 x 37 classification, fiber core or IWRC, IPS or EIPS. If Seale construction or similar large outer wire type construction in the 6 x 19 classification is to be used for sizes 1 inch and larger, add one additional clip.

Table 4-2. Applying U-Bolt Clips.



Clip Size	Minimum Number of Clips	Amount of Rope to Turn Back (Inches)	Torque Ft./Lbs.	Weight (Lbs. per 100)
1/8	2	3 1/4	4.5	6
3/16	2	3 3/4	7.5	10
1/4	2	4 3/4	15	20
5/16	2	5 1/4	30	30
3/8	2	6 1/2	45	47
7/16	2	7	65	76
1/2	3	11 1/2	65	80
9/16	3	12	95	104
5/8	3	12	95	106
3/4	4	18	130	150
7/8	4	19	225	212
1	5	26	225	260
1 1/8	6	34	225	290
1 1/4	7	44	360	430
1 3/8	7	44	360	460
1 1/2	8	54	360	540
1 5/8	8	58	430	700
1 3/4	8	61	590	925
2	8	71	750	1300
2 1/4	8	73	750	1600
2 1/2	9	84	750	1900
2 3/4	10	100	750	2300
3	10	106	1200	3100
3 1/2	12	149	1200	4000
If a pulley (sheave) is used for turning back the wire rope, add one additional clip.				
If a greater number of clips are used than shown in the table, the amount of turnback should be increased proportionally.				
The tightening torque values shown are based upon the threads being clean, dry, and free of lubrication.				
Above values do not apply to plastic coated wire rope.				

it to the breaking strength of the wire (see Figure 4-19). Advantages of the carpenter stopper include its quick application and release, ability to develop full tension without damage to the wire, and low maintenance requirements.

WARNING
Old-style carpenter stoppers with smooth covers are condemned and should not be used. These old models are made of cast metal and are subject to explosive brittle fracture upon impact. Serious injury to personnel may result from flying fragments.

CAUTION
A carpenter stopper should not be used unless it is specially designed for the lay, helix, number of strands, and diameter of the specific wire rope. The stopper and the wire should both be clean and free from sand or other abrasives.

Three types of carpenter stoppers have been used in the U.S. Navy:

- The “old WWII” style
- The “improved 1948” style
- The “modified-improved 1968” style

Only the last style listed is approved. It can be identified by four heavy ribs on the hinged cover and will have a Boston Naval Shipyard test date of 1968 to 1973 or be manufactured by Baldt after 1973.

Refer to (Ref. E) for more information on the use of stoppers.

4-6.10 Chafing Gear

Chafing gear is usually used to reduce wear on both the hawser and the tug’s structure. Chafing gear includes materials such as mats, battens, strips of leather, canvas, grease, worming, parcelling, roundings, and serving (see Figure 4-20). Material specifically manufactured for chafing gear is also available and works very well. These materials lessen or prevent towline chafing and are applied at the point where the towline crosses the stern rail or other structure.

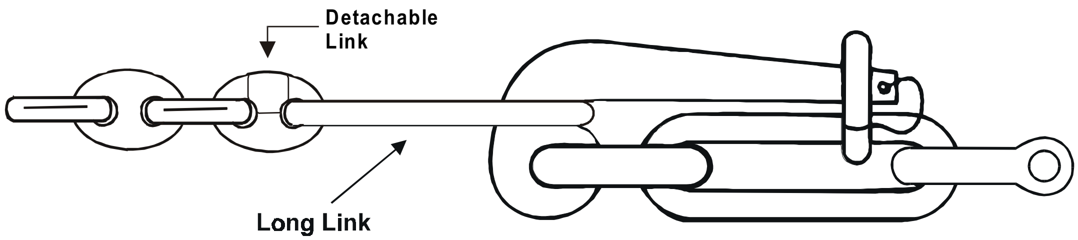
Another method to control chafing is to periodically adjust the scope of the wire to reduce the wear on any one point. The amount of time between adjustments will depend on the behavior of the tow and the sea state. This is called “nipping” the wire or “freshening the nip.”

4-7 Fuse or Safety Link Concept

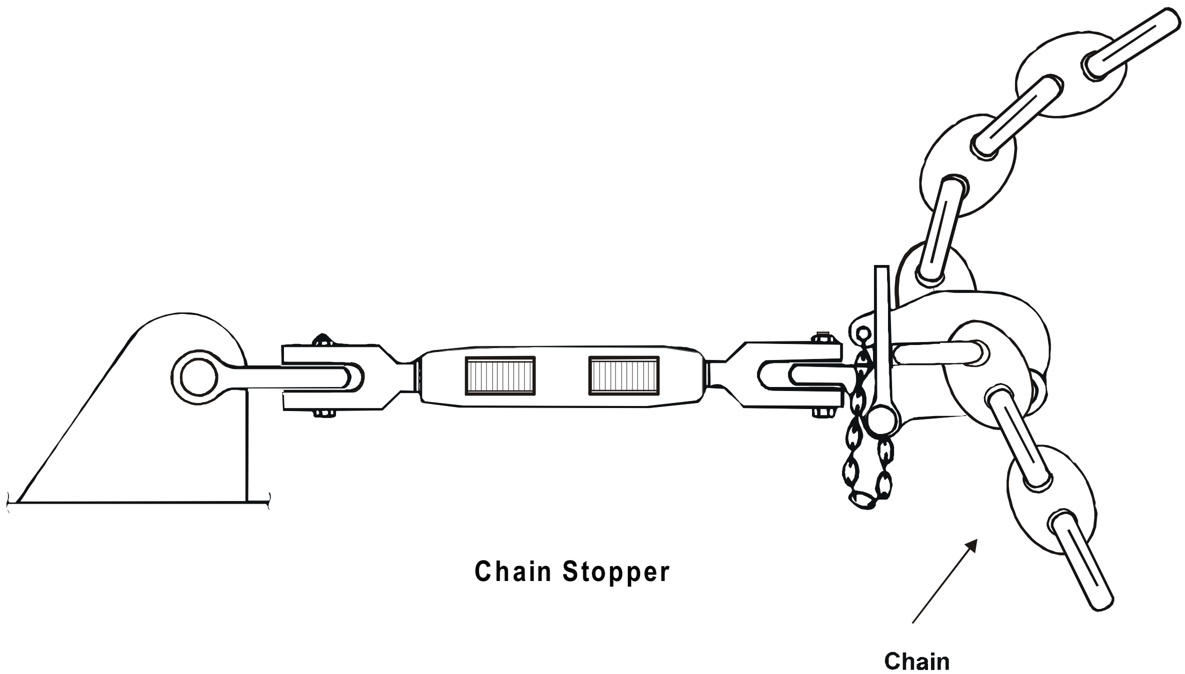
A safety link, sometimes called a fuse pendant, is the point or component in every towing rig most likely to fail at a predicted load. A safety link is analogous to a safety valve or a circuit breaker. The safety link’s primary characteristic is its predictability; it ensures a known location and mode of towing system failure in event of an overload. The safety link should not fail under the anticipated tensions of a planned tow. Tow preparing activities should identify the safety link of the system and provide that information to the officer responsible for the tow so that design limits are not exceeded.

Since every rig will have a weakest point, it is often prudent to intentionally incorporate a safety link to protect a critical portion of the tow system, usually the hawser, from a possible overload. A wire rope pendant is usually selected as the safety link, and is sized to have a 10 to 15 percent lower breaking strength than the main tow hawser. If a towing system overload occurs, the failure will not damage the tow hawser and it can be reconnected.

The breaking strength considers the hydrodynamic resistance of the towline, which creates



Pelican Hook



Chain Stopper

WARNING
Do not confuse pelican hook with chain stopper.

Figure 4-18. Pelican Hook and Chain Stopper.

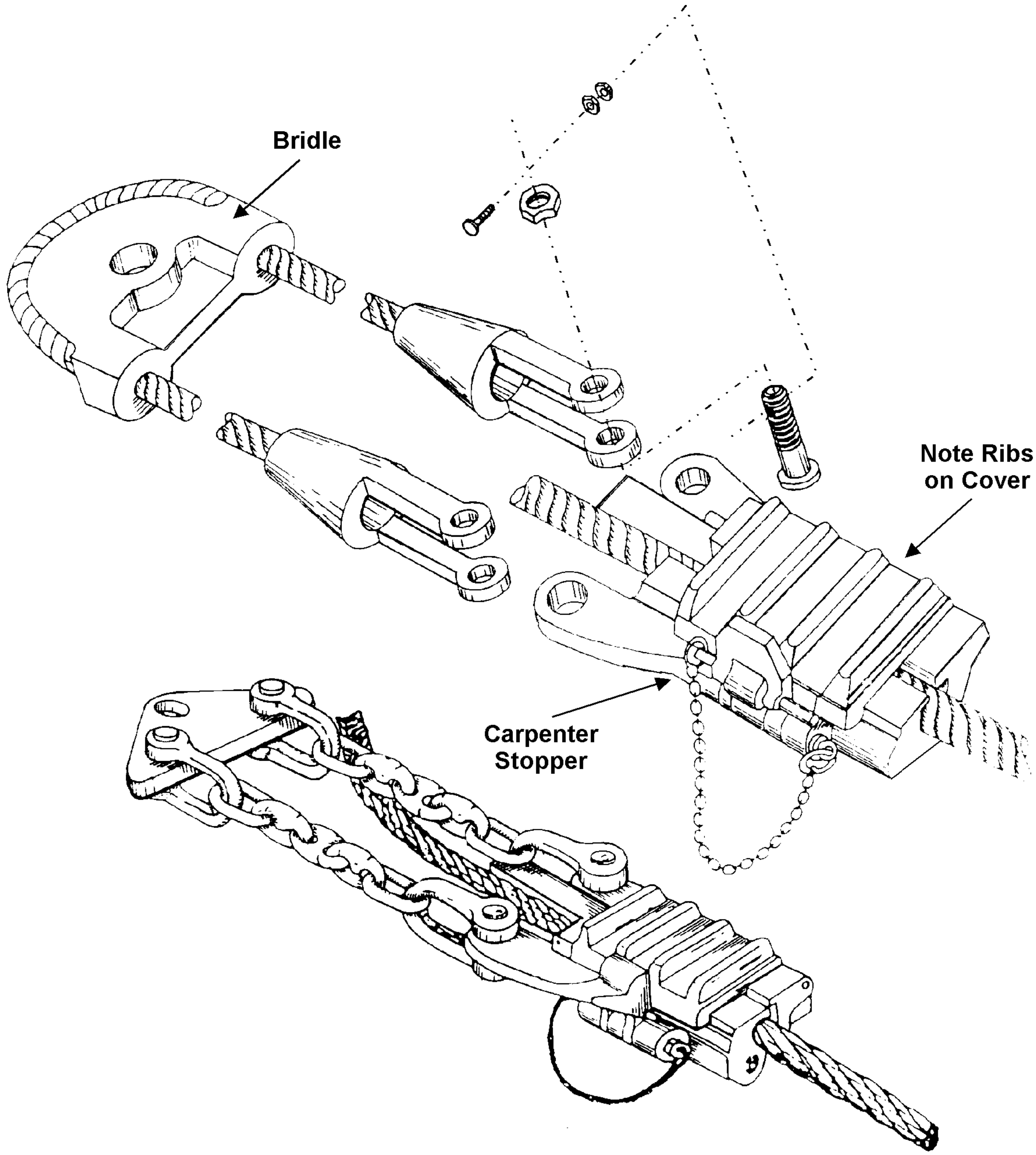


Figure 4-19. Carpenter Stopper.

a higher tension at the tug end of the hawser. Such pendants should never be subjected to chafing or other unusual service.

CAUTION
Since the safely link is the weakest point in the tow system, this will determine the safe working load. Tow planners must ensure the safety link is capable of withstanding all expected loads.

4-8 Line Handling Devices

WARNING
Motions of the tug and tow can cause the towline to change positions rapidly and without warning. Personnel must be aware of the potential danger of a sweeping towline and remain clear of all areas that may be within this sweep.

Towing requires extensive manipulation of line. Virtually all of the line used in towing operations is far too heavy to be handled by anything other than machines and unique devices that have evolved in towing practice. The following sections detail the function of line handling devices used in towing.

4-8.1 Caprails

CAUTION
Whenever the surface of a caprail becomes rough, steps should be taken to repair or replace it to protect the hawser. Caprails should be kept free of any nicks or burrs.

The caprail is the riding surface on top of the bulwark (see Figure 4-21). The tow hawser bears on the stern caprail as it passes astern of the tug and enters the water. Caprails are installed in several configurations. They can be fabricated from pipe or plate. On newer tugs, they have large radius surfaces contoured to the tug's deck layout. It is important to keep the caprail smooth and free of nicks and burrs that damage both synthetic and wire hawsers. In current design practice, the bearing surface of the caprail is hardened to a minimum Rockwell C hardness of 40 to 50.

4-8.2 Towing Bows

Towing bows are transversely installed beams or pipe that bridge the caprails on the afterdeck of the tug (see Figure 4-22). Their function is to keep the towline clear of all deck fittings and to furnish a protected area below the sweeping tow hawser where personnel can pass safely.

4-8.3 Horizontal Stern Rollers

Horizontal stern rollers minimize chafing during heave-in and payout (see Figure 4-20). A stern roller is a large-diameter roller, set in the stern bulwarks on the centerline and faired to the caprail. The roller rotates with the movement of the wire, constantly changing the contact point. This movement spreads the wear from the wire. Because it is also hardened, it resists scoring and thus provides a smooth surface on which the wire rides. The ARS 50 Class is not equipped with horizontal stern rollers. Instead they have a large-radius, hardened steel transom that minimizes wear on the hawser.

Chafing gear should be used even if stern rollers are available. When towing with a constant towing scope, chafing comes from port/starboard movement of the wire. Horizontal stern rollers do not reduce chafing in this manner.

4-8.4 Capstans and Gypsy Heads

Capstans rotate on vertical shafts and are used for line handling, but not as towing machines (see Figure 4-23). The prime mover of a cap-

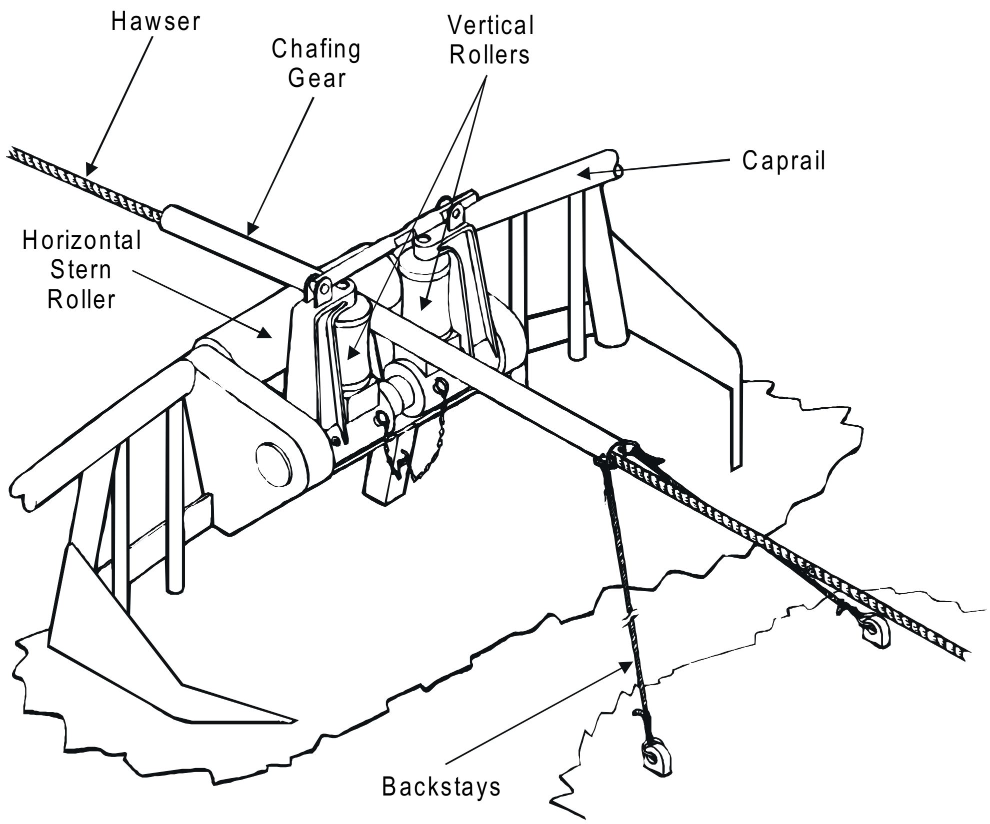


Figure 4-20. Chafing Gear and Stern Rollers.

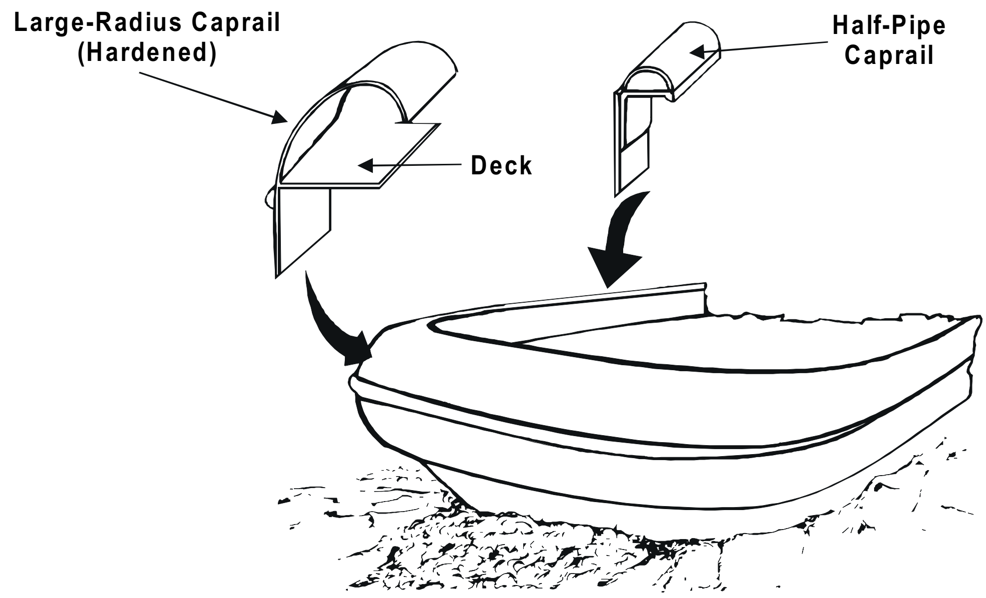


Figure 4-21. Caprails.

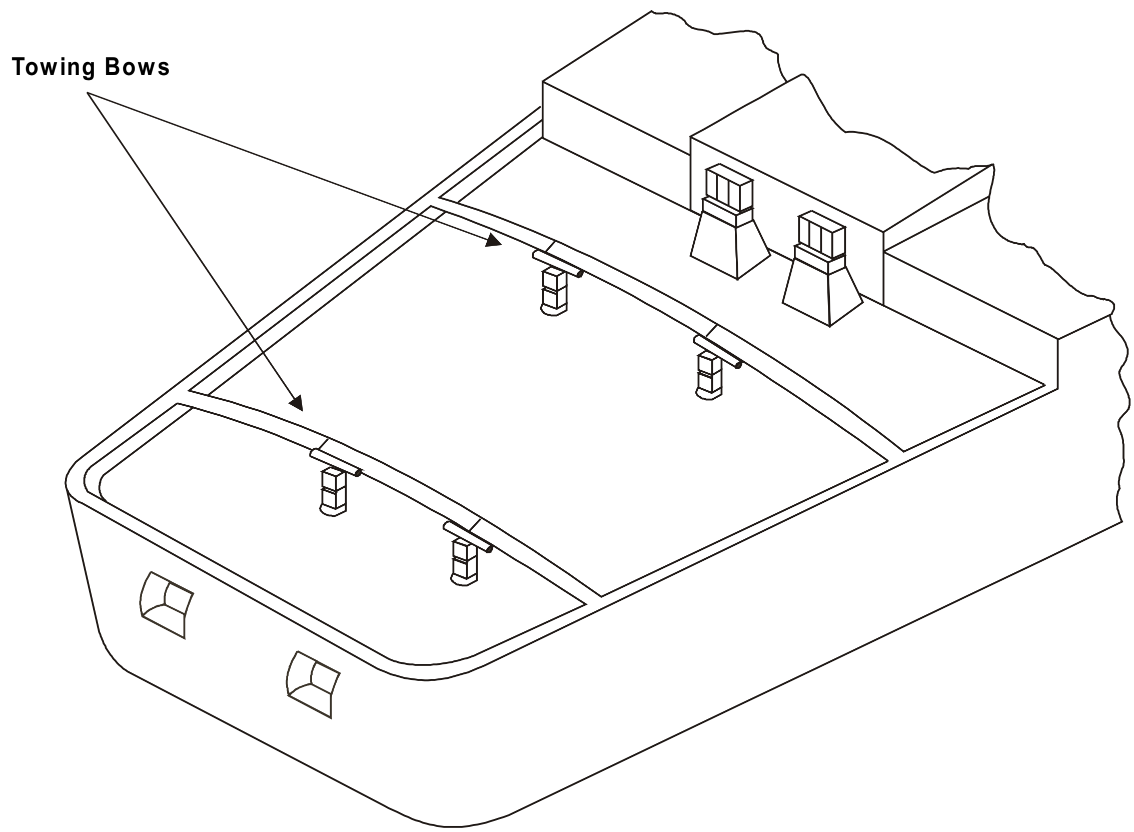


Figure 4-22. Towing Bows.

stan is often located below deck. This permits the capstan to be mounted so that the line travels relatively close to deck level. A gypsy head, which is similar to a capstan, rotates on a horizontal shaft and is usually powered as an auxiliary of a winch. Gypsy heads, like capstans, are used for line handling, but not for towing.

4-9 Sweep Limiting Devices

Sweep limiting devices restrict the horizontal sweeping of the wire across the fantail.

WARNING
The vertical stern rollers and Norman pins onboard the ARS 50 Class ships will drop when a load of 50,000 pounds or more is applied to mid-barrel height. The resulting uncontrolled sweeping of the towline may injure personnel or damage equipment.

4-9.1 Vertical Stern Rollers

Vertical stern rollers tend the towline during heave-in and payout, and during long-distance straight towing by preventing the wire from sweeping across the deck and rail. On newer ships, the stern rollers or pins are normally operated hydraulically from a remote location (see Figures 4-24 and 4-25). Onboard the T-ATFs, the hook-shaped items on either side (just outboard of each vertical roller) are hydraulically operated "capture hooks," often used instead of the vertical rollers to provide lateral restraint for the towline. On the ARS 50 Class, the vertical stern rollers drop when the side force at mid-barrel height exceeds 50,000 pounds.

CAUTION
Using vertical rollers may put the tug "in irons," seriously limiting the tug's maneuverability.

The presence of the towline in the stern rollers limits the maneuverability of the tug because it moves the tow point from the H-bitts back to the caprail.

NOTE
Stern rollers should be properly maintained and lubricated to ensure rotation and smooth surface conditions. Rollers can become frozen and their surface areas grooved and scored from towline wear. Such conditions directly contribute to the abnormal wear of the towline.

Vertical stern rollers act as a fairlead for the towing machine. The long distance between the stern rollers and the towing machine enables the tow hawser to naturally reel itself on to the drum and the level wind performs only light duty. The stern rollers are normally used to capture the hawser and to assist when picking up or disconnecting a tow. The vertical rollers may limit the amount of lateral movement that the tow hawser receives as the tow yaws from port to starboard.

Vertical stern rollers are designed only as a fairlead device and cannot structurally withstand loads of the magnitude of which the H-bitts is capable. Strong side loads commonly seen in towing situations could very easily carry the assembly away. On the ARS Class, the rollers will fold down to their stowed position at the lateral load of 50,000 pounds ap-

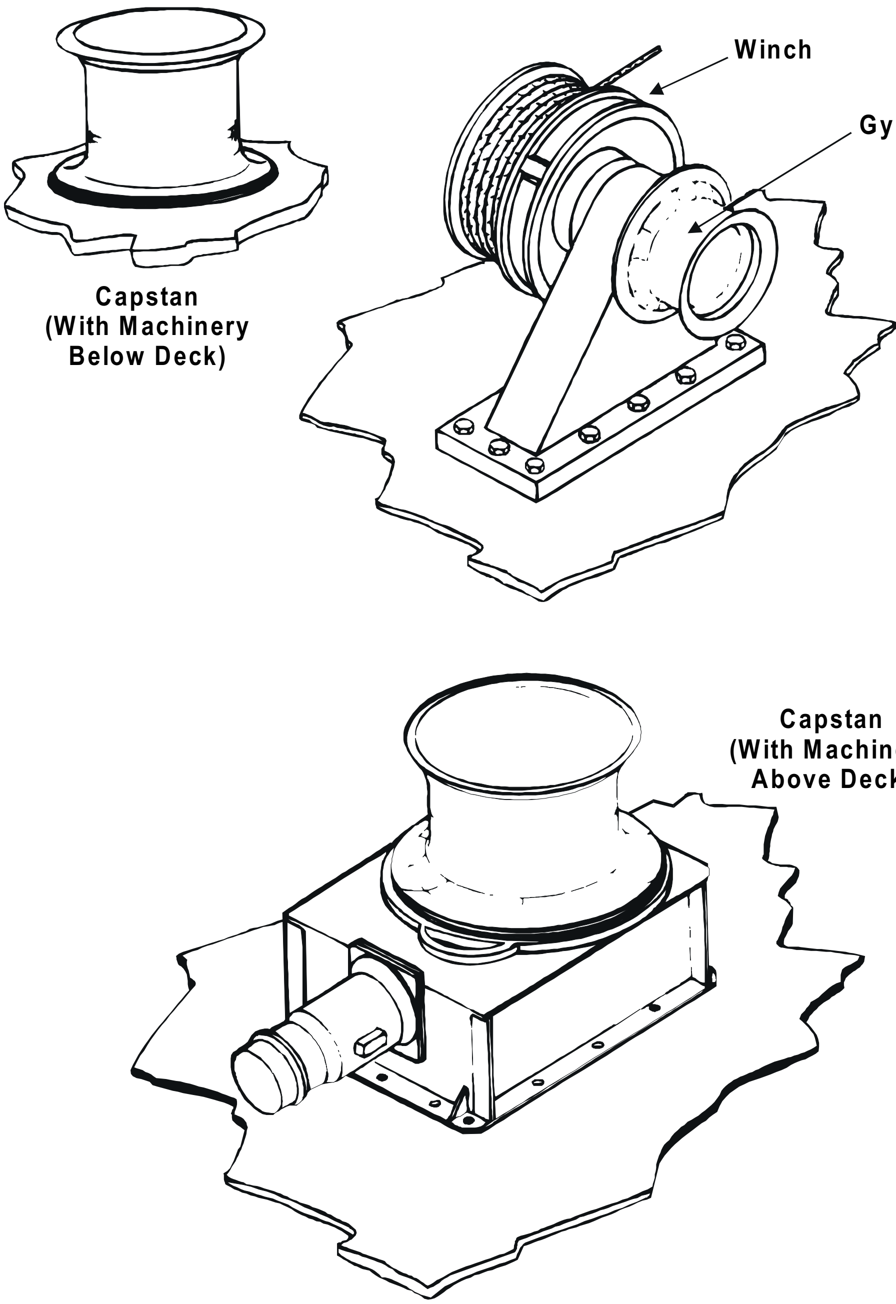


Figure 4-23. Capstans and Gypsy Head.

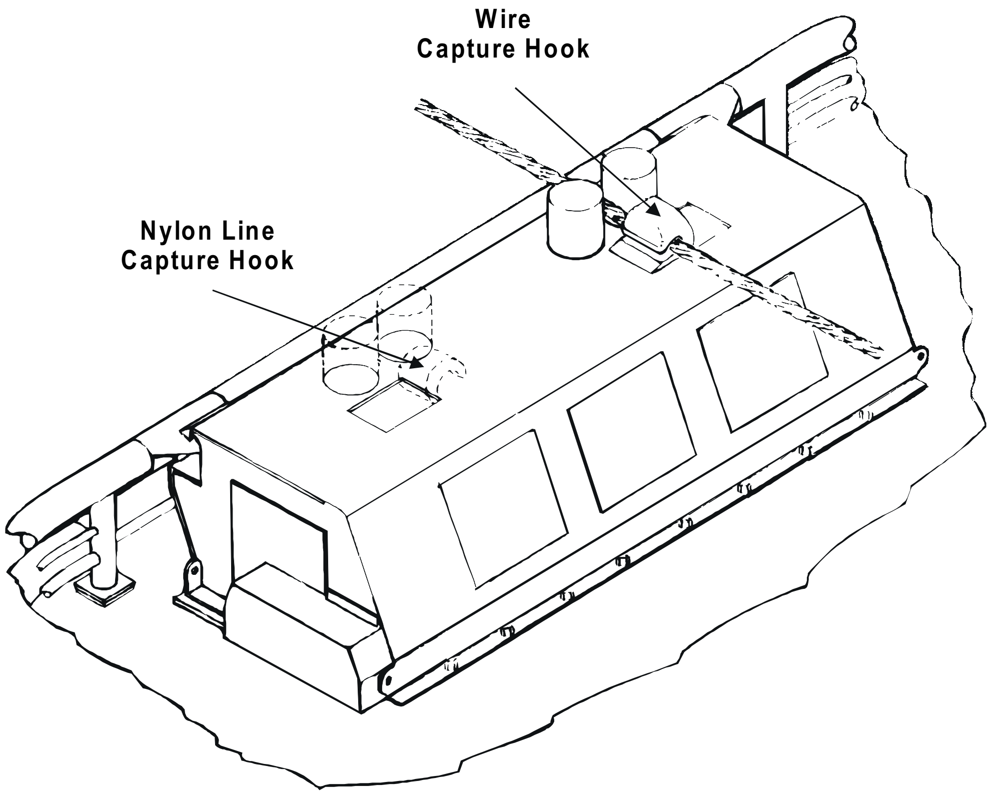


Figure 4-24. Stern of T-ATF 166 Class.

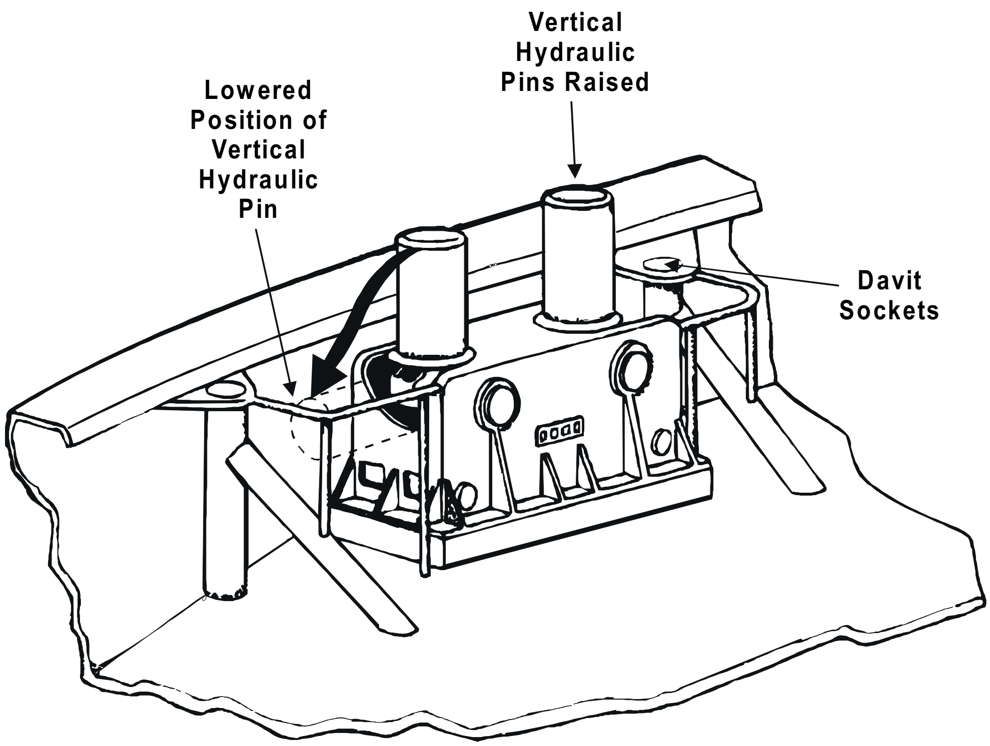


Figure 4-25. Stern Rollers (ARS 50 Class).

plied at mid-roller height. The towline is usually restrained in a stern roller assembly only under light sea conditions. The vertical stern rollers should always be dropped when maneuvering in restricted waters or rough seas.

When the towline rides against a vertical stern roller, it is being bent over a small radius. This causes towline fatigue and possible failure at a lower load. Chafing gear is required on the towline when it is scheduled for long periods in the stern roller. Slacking off a few inches, or "freshening the nip" regularly, is a good practice to reduce wear on the wire. Wire grease is often used to reduce chafing at these hard points. This is especially true when using a capture hook (as on a T-ATF) because there is little room for chafing gear.

4-9.2 Norman Pins

The primary function of Norman pins is to limit the arc of sweep across the stern (see Figures 4-26 and 4-27). Norman pins also help keep the hawser out of the propellers during slack wire conditions. Ocean tugs generally are provided with sockets along their aft bulwarks into which Norman pins are fitted. Some tugs have two sets of Norman pins, with one set that may be inserted into the stern caprail.

Retractable or movable Norman pins have various designs, ranging from simple, removable round stock or pipe to remote controlled, hydraulically operated devices. On older ships, the round pins could be removed from any socket and moved to another location. This necessitated personnel moving about on the fantail and thus being subject to hazards;

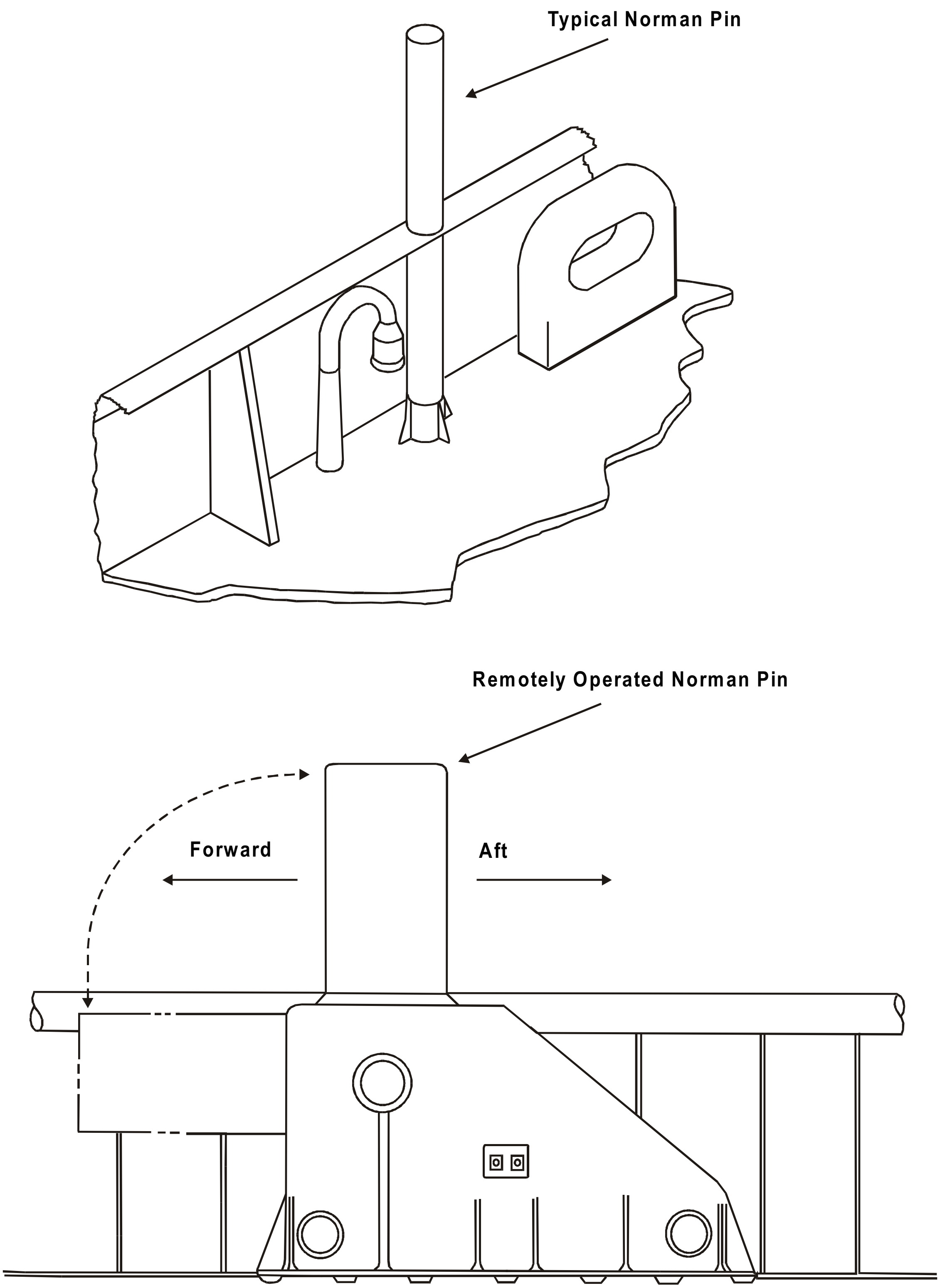


Figure 4-26. Norman Pins.

with remote control, the procedures are now safer. Newer tugs and salvage ships, such as the ARS 50 class, have remote controlled, hydraulically operated Norman pins in fixed locations. On board the ARS 50 class, the Norman pins are set to drop when the lateral force at mid-barrel height exceeds 50,000 pounds. The hazard potential is formidable. When the pins start inclining toward the horizontal, the wire (with 25 tons force propelling it) can jump the pin and sweep forward.

Current design practice requires that the wire bearing surface of the Norman pins be hardened to a minimum Rockwell C hardness of 40 to 50.

4-9.3 Hogging Strap

CAUTION
A hogging strap may be necessary to prevent the towline from jumping the stern rollers when towing a high-bowed ship at short stay. A hogging strap may be subject to excessive vertical loads. Care should be taken not to part the strap. Failure of a hogging strap may result in the loss of tug control or ranging up by the tow.

The hogging strap limits the relative movement between the towline and the stern in both vertical and horizontal planes (see Figure 4-28). Movement in the vertical plane is caused by the stern of the tug dropping faster than the towline or by a tow ranging up. A hogging strap can be attached to the towline with a shackle or a special saddle-like fitting. The limitation of the shackle is the high concentration of load it imposes on the hawser to which it is attached. Saddle-like fittings are preferred because they have larger radii; this increases the area of contact and distributes the load over a wider arc.

Because the hogging strap transfers the tow point aft from the H-bitt, it can cause reduced maneuverability.

4-9.4 Lateral Control Wire

A lateral control wire is similar in configuration to the hogging strap, but it has the added feature of variable scope. Instead of a fixed-length strap holding the towline to the deck, a snatch block is secured to the deck and the lateral control wire is led through it to a deck winch, lateral control winch, or capstan. In this manner, the line can be fully slacked to let the towline sweep free or can be taken in to give either partial or full snugging like a hogging strap. The lateral control wire is helpful in keeping the towline out of the propellers during slack wire conditions.

A dedicated lateral control winch, limited to approximately 2,000 pounds straight line pull, is available on the ARS 50 Class ships.

Like the hogging strap, the lateral control wire moves the tow point aft and can limit maneuverability.

4-10 Cutting Gear

Most Naval ships are equipped with oxy-acetylene cutting equipment. Additionally, some tugs and most salvage ships are equipped with hydraulic cutters.

WARNING
Wire rope stretches far less under load then most natural and synthetic fiber lines. If it fails under high loads, wire rope has a smaller zone of danger to bystanders if loose ends "snap back." The elongation under load is sufficient, nonetheless, to be dangerous. The recoil can be extremely violent and all personnel should stay well away from any potential recoil path.

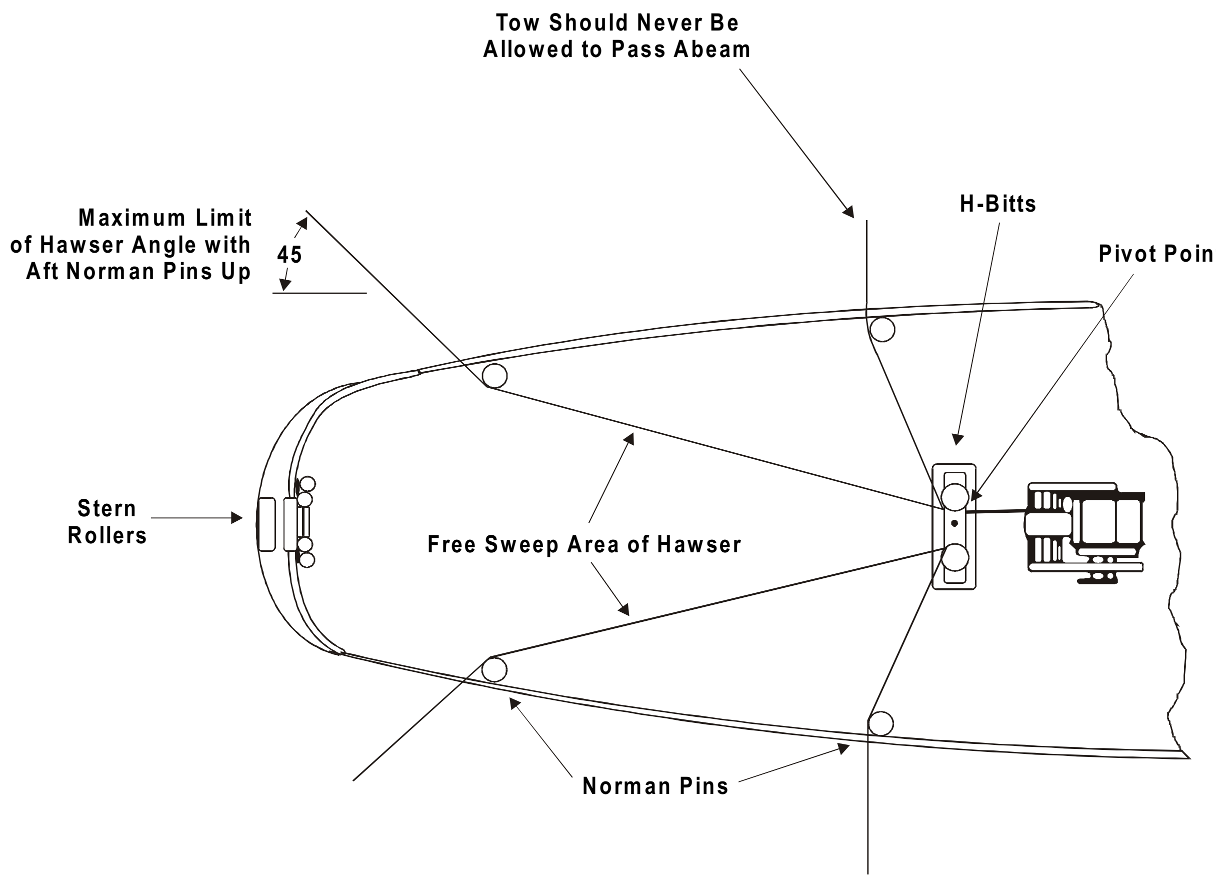


Figure 4-27. Norman Pin Use.

For cutting chain, the oxyacetylene or exothermic cutting equipment is most suitable; hydraulic cable cutters may be better for cutting wire. Personnel safety is paramount when cutting any member of the tow assembly; therefore, every effort should be made to reduce the tension. This is particularly true when cutting wire and synthetic lines. The greater the distance between the person doing the cutting and the cutting point, the greater the safety factor. Securing the cutting torch to a boat hook is a good practice. Seizing a wire hawser on both sides of the intended cut is also a prudent measure. Cutting a synthetic line with an axe is hazardous and should not be done under tension. The use of stoppers to control snap-back decreases the hazards involved when cutting any chain, wire or synthetic line.

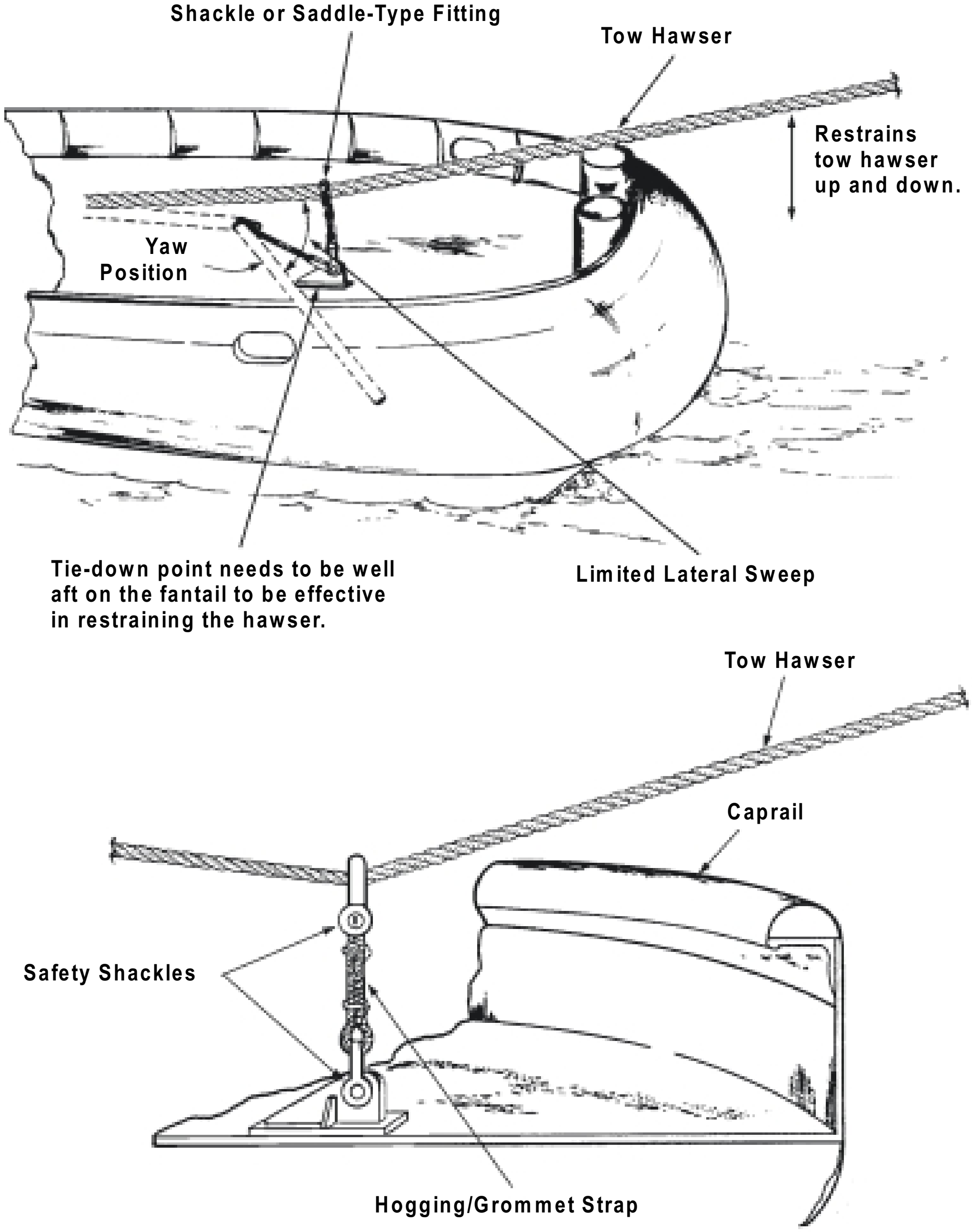


Figure 4-28. Rigging of Hogging Strap on Ships without Horizontal Stern Rollers.

Chapter 5

TOW PLANNING AND PREPARATION

5-1 Introduction

Because each tow is unique, the planning, preparation, and execution have to be carefully worked out each time. Tow preparations must be meticulous, uncompromising, and farsighted. Fleet Admiral Nimitz provided a valuable guide for any ship operation when he said:

> *"The time for taking all measures for a ship's safety is while still able to do so. Nothing is more dangerous than for a seaman to be grudging in taking precautions lest they turn out to be unnecessary. Safety at sea for two thousand years has depended on exactly the opposite philosophy."*

Incidents involving loss of tows have demonstrated an absolute need for a thoroughly professional approach to towing. Tows have been damaged and lost by inattention to the basic principles of proper planning and preparation. The plan must cover all aspects of the tow and anticipate worst case scenarios. Planning a tow includes training personnel, practicing basic procedures, and devising safe evolutions.

This chapter discusses tow planning and preparation in general terms.

5-2 Lessons Learned

As Naval towing has evolved, several obvious lessons have been learned. A list of these lessons first appeared in the first Navy towing document, COMINCH P-03, and are as valid and meaningful today as they were in 1944 when the document was published. The document noted that in the planning and task analysis for towing operations, avoid the following situations when possible:

- Keeping tugs waiting while tows are being prepared or disposed of after the mission has been accomplished. In this connection, when the draft of the towing tug is too great for the depth of the water at either terminal, advance arrangements should be made to deliver or to take over the tow before the arrival of the deep sea tug.
- Employing large tugs to do work that available smaller and less powerful or less seaworthy tugs can do.
- Employing small tugs to undertake work beyond their capacity.
- Employing tugs designed or especially suited for combat zone duty in rear areas. Large salvage tugs are well suited for combat towing and for emergency salvage or fire fighting in combat areas.
- Employing tugs that cannot survive moderate damage in forward combat areas. Survival factors include stability, reserve buoyancy, and subdivision, as well as being armed to ward off attacks by enemy planes.
- Routing tugs with large tows over areas where the water is too shallow for the hawser's catenary. Arrangements should be provided for shortening the towline where necessary. Tows are frequently lost or involved in difficulties due to the towline fouling on submerged objects.
- Unnecessarily employing tugs for standby duty on salvage or rescue operations. Tugs should not be ordered to stand by unless there is a definite possibility that their services may be needed and they are capable of rendering the service likely to be required.

- Diverting rescue tugs from areas where tugs equipped with rescue facilities, such as salvage or fire fighting, may be required.
- Employing tugs for tows that could be undertaken by other craft scheduled to make the same passage, or by a ship that could be more easily made available than a tug.

5-3 Staff Planning

The underlying issue of staff planning is sequencing all the required aspects of preparing the tow. Orchestrating preliminary, operational, and post mission requirements is a fleet or group staff planner's mission. Care must be taken in planning a tow to select the proper gear and deciding on a route and departure date. In doing so, a tug may avoid adverse weather conditions that might subject the towing systems to loads that exceed its safe working load.

5-3.1 Towing Ship Selection

In an ideal world, the staff planner would be able to match tug characteristics to the type of tow to perform the tow in a cost effective manner. Because the fleet has been reduced in size, planning appears to be easier because the potential combinations of choices is fewer with fewer towing assets. In reality, planning is more difficult because the staff planner often cannot properly match the size and resistance properties of the towed vessel to the horsepower and bollard pull of the towing vessel. Fleet planners are sometimes forced to improperly size the ocean tug to the tow. Consequently, the only vessel available to tow a small, low resistance hull may be the largest and most powerful ocean going tug in the fleet. In many cases, routine tows not requiring the capabilities and manning of a fleet salvage tug can be contracted through MSC. This reserves the fleet salvage tug for operations for which it is best suited.

5-3.2 Operational Considerations

5-3.2.1 Support

The staff planner must determine what support will be required for the tow at the point of origin, en route, and at the point of debarkation. Included in support considerations are industrial support required for preparing the towing rig, temporary berthing and messing for riding crews, refueling, provisioning, return of any special issue equipment, tasking orders, and the logistics of tug assist for getting underway and disconnecting. Many of these functions may be passed to the towing ship Commanding Officer.

5-3.2.2 Manned Tows

The tow sponsor is responsible for providing riding crews for the towed vessel. While direct financial support for riding crew transportation, messing, and berthing also resides with the tow sponsor, there are aspects of a riding crew that have to be integrated into the planning process for the towing ship. Staff planners will determine:

- If there is a need for joint training of the riding crew with the towing ship's crew for a special tow
- If the riding crew will be berthed on the towing vessel
- How long before the tow departure the riding crew will have to be temporarily assigned to the towing ship.

5-3.2.3 Tug Selection

When selecting a tow ship and support crew, consideration must be given to any anticipated complications of the tow. For instance, if damage control or salvage may be required, (towing a rescued vessel) experienced salvage personnel are essential. A fleet salvage vessel should be selected or a similar vessel supplemented with a salvage crew. Commercial tow ships have limited manning, and although capable, may be insufficient in number to perform all required tasks without additional personnel.

5-3.2.4 Unsuitable Tows

Many ships are unsuitable to be towed in the open ocean. Table 5-1 lists vessels that are not recommended for open ocean towing, along with supporting rationale as to why they do not qualify. Of course, any vessel can be towed, but the vessels listed in Table 5-1 cannot be towed without serious risk. These craft can be made safer by correcting the disqualifying condition, but in their normal operational configuration, they should not be towed in the open ocean.

5-3.3 Selecting the Navigation Track

The transit course should be determined using pilot charts as an aid. Locations along or near the track where a lee can be found should be noted. These can be utilized, when practicable, to effect inspection, repair the tow, or take shelter in heavy weather. Routine navigational issues must be reviewed in the context of having a vessel in tow. Pilot charts, navigational charts and Fleet guides must be consulted for any restrictions for towing in general, as well as the particular tow. The Navigator shall be familiar with charts of all areas to be crossed, including potential safe havens. He shall account for geographic features such as lees of headlands, effects of river outflows, and tidal currents to determine the relative safety of a particular haven. When entering a safe haven, the Navigator shall be aware of water depths where the tow wire may snag, and stand ready to recommend shortening the towline as required.

An early consideration in selecting the navigation track is the predicted weather en route. Frequent contact should be made with the Naval Meteorological and Oceanographical Center (NMOC) to maintain an up-to-date weather picture, and adjusted track accordingly. Anticipated heavy weather could require selecting a larger, more powerful towing asset. The towing command will use the Optimum Track Ship Routing System (OTSR) to predict the weather along the planned navigational track and make any changes to the track that adverse weather dictates. A longer course on a favorable weather track should be selected in favor of a shorter one with unfavorable weather. Little time is gained by taking a shorter track through bad weather.

Once the navigation track has been selected, calculate total distance and estimate fuel required for the type of tow. If refueling is required either at the tow termination or en route, contingencies must be formulated early in the planning process.

It should be clearly understood in advance by any vessels taking the towed vessel into its berth how close to shore the ocean tug expects to remain connected. The towing vessel must hand off the tow to harbor tugs and pilots and pilot's vessels at some point before mooring. If there is confusion, an accident may occur. Conversely, it should be understood how far from shore the harbor tugs are prepared to retain charge of the tow. Both parties should advise of any weather and sea condition limitations on their abilities. If possible, a meeting of all vessel captains involved (tow ships and harbor tugs) should be conducted prior to getting underway. All transfer procedures and special requirements can be worked out at this time.

5-4 Towing Responsibilities

Primary commands involved in a towing operation are the tow sponsor and the towing command. Frequently the sponsor will task and fund an assisting command to perform some of the tow preparations. This section details the definitions, interrelationships, and

Table 5-1. U.S. Navy Craft Not Recommended for Open-Ocean Tows.

CRAFT CLASSIFICATION	REASONS FOR NON-RECOMMENDATION
LCU, YCU Landing Craft LCM8, LCM6 Landing Craft YFU, UFB, LWT	Low freeboard. Light construction of bow door locking mechanism. Structure can be strengthened to reduce risk.
YFNG, YFNX Lighter, YNG Gate Craft, YSR Sludge Removal Craft	All have deck-mounted equipment which requires installing special protection before towing.
YPD Pile Driver, YD Crane LSMR	All tend to be top-heavy (have high center of gravity) and may also have poor watertight integrity. Topside high weights may require removal and stowage prior to open-ocean towing to attain adequate stability. All require special preparations.
YSD (formerly Seaplane Derrick), YM Dredge	Low freeboard and high weights reduce sea-keeping ability. Weights may require removal and stowage to improve stability at sea.
YTL Small Harbor Tug PTF Patrol Boat	Hulls considered too small for open-ocean tows. Should be transported as deck cargo.
Mini-ATC, LCPL MK2, MK3, MK4, MK5 personnel boats	Low freeboard. Light construction with poor watertight compartment and weak to no attachment points for towing.
MK1, MK2 65’ utility boats, MK4 50’ utility boat, MK3, MK4 40’ utility boats	Low freeboard. Deck mounted equipment.

specific responsibilities of the parties involved in a towing operation.

5-4.1 Sponsoring Command Responsibilities

The sponsoring command is the command requiring a tow, and is responsible for preparing the tow for sea. Basic responsibilities of the sponsoring command include:

- Reviewing applicable Type Commander and Fleet CINC numbered instructions and operational orders
- Preparing the tow
- Assembling towing rig
- Completing Certificate of Seaworthiness (see Appendix H)
- Determining when there is a riding crew requirement
- Designating a receiving activity
- Returning all towing equipment, including towing bridle, to preparing activity or tow originator once the tow has been completed.
- Towing machine/towing winch certification
- Tow hawser certification
- Commercial vessels (U.S. Coast Guard Inspected) - Master's Towing Certificate

5-4.2 Towing Command Responsibilities

The towing command is the command that performs the tow. The Commanding Officer or Master is responsible for:

- Determining sailing date and time
- Determining the transit route
- Selecting towing rig and determining trim conditions
- Inspecting and accepting the tow
- Maintaining and protecting the tow during transit
- Delivering the tow and obtaining a receipt from a receiving activity

5-4.3 Assisting Command Responsibilities

An assisting command is often a naval shipyard, private shipyard (through the cognizant Supervisor of Shipbuilding, Conversion & Repair, SUPSHIP) or Naval Station. Assisting command responsibilities may include:

- Designing a towing hawser system
- Installing temporary towing hard points on the tow
- Installing temporary alarms or electrical systems on the tow
- Supplying a riding crew
- Providing temporary messing and berthing for a riding crew at ports of embarkation and debarkation

5-5 Review Instructions and Operational Orders

An important preliminary step in any tow is a review of pertinent instructions that govern the type of towing to be performed. Fleet and Type Commander instructions are provided for general towing procedures and periodic reporting procedures to be followed during the tow. Specific guidance may also be provided for a particular type of tow, such as NAVSEAINST 4740.9 (Series) for towing defueled, nuclear powered submarines. Operational tasking, such as a Letter of Instruction sent via naval message, will also be provided to any vessel performing a tow. All governing instructions should be reviewed for applicability to the unique tow being performed.

5-6 Riding Crew Requirements

A riding crew can add immeasurably to the general safety of the tow. The Navy command requesting a tow should make a recommendation after considering personnel safety and the value of the tow. Safety considerations must be based on the crew's influence on tow safety rather than the tow's influence on crew convenience. Value of the tow can be either its replacement cost; value of its safe and timely delivery; or cost of consequences of loss from a tactical, strategic, or public relations standpoint.

Rescue tows should have personnel on board, if possible, to make the tow connection and to respond to changes in the tow's material condition. A riding crew can also respond to emergencies such as fire, flooding, hawser or bridle chafing, and towline loss. The tow must be adequately supplied and equipped to support a riding crew. Crew accommodations should include berthing, messing, and sanitary facilities, all of which must be properly ventilated.

Under normal conditions, most planned point-to-point tows are undertaken without a riding crew. All tows can be unmanned if properly planned.

Riding crews shall be limited to personnel required for maintenance and security during the voyage.

Approval to assign a riding crew must come from the Fleet Commanders-in-Chief (CINCs) in accordance with existing directives. Factors governing a decision to assign a riding crew include:

- Safety of the riding crew
- Reduction of risk of towed ship loss by assigning a riding crew
- Material condition of the tow
- Flooding alarms and other monitoring devices installed on board

See section 5-7.1 for more considerations.

5-7 Preparing the Tow

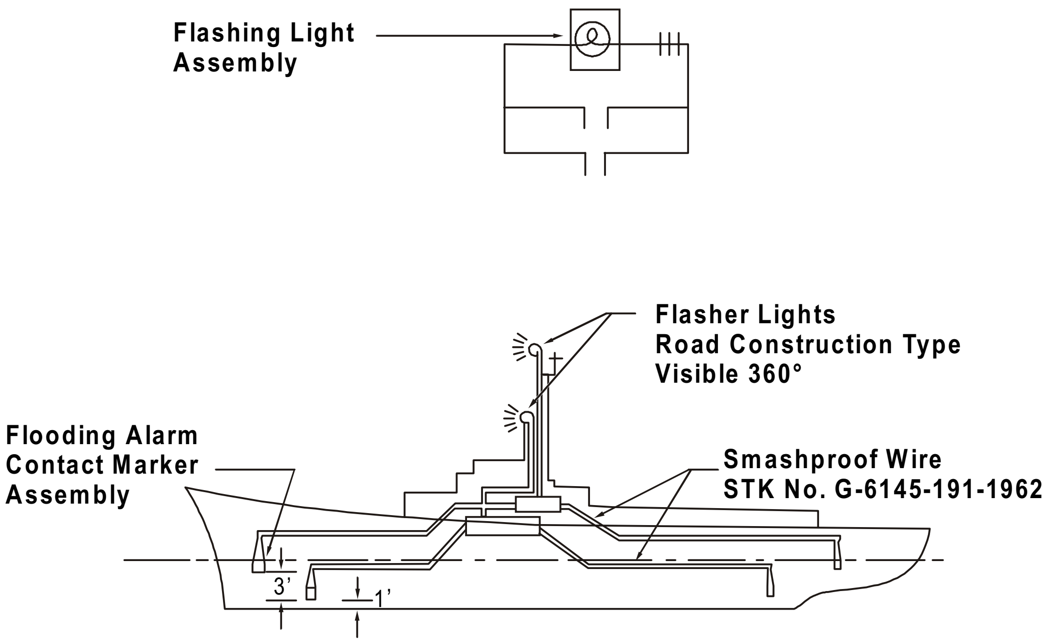
A tow's hull design may require taking numerous steps in preparing to tow. Examples include cranes, pile drivers, dredges, dump scows or other equipment designed for operation in sheltered waters. Preparing the tow may include removing high weights, securing booms, dredge ladders, and other deck structures; adding or removing ballast or adjusting trim; stiffening the hull and performing other functions. Heavy welded brackets must be used to secure heavy movable objects and a tow should always be secured for the worst sea conditions. Expect large angles of roll and pitch and secure all heavy objects accordingly.

Hulls not considered seaworthy for open-ocean tows should be transported as deck cargo or on board a floating dry dock, semi-submersible vessel, or LSD type ships.

5-7.1 Installing Flooding Alarms, Draft Indicators, and Other Alarms

All unmanned tows shall be equipped with flooding alarms. Flooding alarms indicate to the towing ship that there is a problem with the tow, allowing corrective action to be taken before the tow sinks. The tow preparing activity is responsible for installing flooding alarms. Unmanned tows must be equipped with high and low alarms rigged with multiple bulbs, and independently wired flooding alarm lights in all major compartments closest to the keel.

A schematic diagram of an acceptable flooding alarm is shown in Figure 5-1. No attempt has been made to provide detailed specifications or installation instructions because these vary with the type and size of the tow. The number and location of the electrode blocks or alarm switches to be installed in an unmanned tow are determined by the activity preparing the tow and agreed to by the towing command. Installation should be sufficient to



NOTE
This sample diagram is not intended to restrict or limit the number of alarms considered necessary to provide adequate protection to all important watertight spaces.

Figure 5-1. Example of a Flooding Alarm Schematic.

provide coverage of major hull subdivisions. Alarms should be securely rigged and properly serviced to ensure performance and reliability.

5-7.1.1 Flooding Alarm Sensor Mounting Requirements

There are a variety of alarm types. An electrical contact alarm that closes its circuit when water makes contact is a workable alarm most of the time. If used in the engine room, however, oil in the bilge may coat the wires as flooding progresses and render the alarm useless. Carefully consider the practicality of each proposed alarm location. Innovation is advisable.

Refer to the following guidelines when installing flooding alarm sensors:

- Installing flooding alarms may require piercing watertight decks and bulkheads. Penetrations should be as high as possible. Every attempt should be made to use watertight penetrations, or to minimize the size of the penetration.
- Low level alarm sensors shall be installed one foot from the lowest point in the compartment, assuming that the ship is in a bow up position while waterborne.
- High level alarm sensors shall be located three feet above the low level alarm sensors.
- Float type switches are recommended. However, if using sensing probes for flooding alarm sensors, they shall be securely mounted on a suitable nonconductive, nonporous material such as Melamine. Plywood is not a suitable material; C-clamps are not suitable securing devices.
- Areas where flooding alarms are to be installed shall be certified gas-free to prevent explosion and fire from electrical contact sparking.
- When placing alarms in a wide flat-bottomed compartment. It may be beneficial to place an alarm both port and starboard.

5-7.1.2 Wiring and Power Supply Requirements

- Wire the flood alarms so that any low level alarm will activate the low level lights and that any high level alarm will activate the high level lights. Existing ships wiring may be used to support this installation.
- Batteries should be sized to support all flood alarms for continuous 24-hour operation. Sufficient electrical power shall be provided for all lights and alarms for the duration of the tow so there is no need to board the towed ship to change power supplies. Power for the flooding alarm system should be separate from the power source for the navigation lights.
- Secure and protect all wiring from any chafing, and protect all topside wiring from weather damage.
- Where practical, install a wiring board to act as a compartment indicator. It must be wired so that a low level alarm in a given compartment will activate an indicator that identifies the flooding compartment.
- NAVSEA has developed a towing alarm system that utilizes a radio link from the towed ship to a console on the tug. This system allows the tow ship to determine the location of the flooding without boarding the tow. Indications of low battery power and ground faults from alarm wires are also indicated. This system has been packaged for at sea use and includes all power sources, lights, alarms, and wiring. This system is available for issue from the ESSM warehouse.

5-7.1.3 Alarm Lighting Requirements

- At least two high alarm and two low alarm lights shall be installed. The high level alarm lights shall be positioned four feet above the low level alarm lights. The alarm lights shall be mounted topside to be visible from the ships in company.
- The high level alarm strobe lights shall have an amber lens.
- The low level alarm strobe lights shall have a white lens.
- Flooding alarm lights should be checked to ensure their visibility during daylight hours. The lights shall be visible from 360° and at a minimum distance of 2,000 yards during bright daylight.

5-7.1.4 Audible Alarm

An audible alarm can be used to provide notification during fog or heavy rain. This alarm must be loud enough to be heard by ship's personnel while underway. Items such as fog horns can be a considerable power drain. It is recommended that these be rigged for intermittent operation (a few seconds of sound; every few minutes) to avoid needing excessive batteries.

5-7.1.5 Requirements for Other Alarms

Depending upon the tow, its equipment and cargo, other alarms such as fire, radiological, or combustible gas may also be required. Specifications will be provided to the activity preparing the tow. Wiring and powering requirements should apply to all additional alarms.

5-7.1.6 Draft Indicator Requirements

The tow should have large, special waterline marks to allow a towing ship to check trim of the tow visually by day and by searchlights at night. Marks should be painted on the bow, stern, and midships on both sides, in highly visible paint. These marks need not be painted below the waterline, but they must give the tow ship a clear indication of a change in the tow's trim. See Figure 5-2 for samples of waterline marks.

5-7.1.7 Towed Vessel Propeller Preparation

A towed vessel's propellers can be a valuable tool or an unpleasant obstacle during a tow. In either case, they require special attention. Tow planners must decide whether to remove propellers, lock them in place, or allow them to free-wheel. The procedure of free-wheeling propellers is not recommended, but cannot always be avoided.

5-7.1.8 Removing Propellers

For long-distance tows, fixed-pitch propellers may be removed to decrease towing resistance. For some hull forms, however, the added drag of locked propellers may be desirable for better directional stability. Tow planners must also consider the economic feasibility of removing the propellers.

It is helpful to consider the vessel's future when determining disposition of it's propellers. If the vessel is being transferred, but not decommissioned or drydocked, it will probably be best not to remove the propellers, as there would likely be considerable cost for re-installation. This high cost may offset any fuel savings gained by the reduced resistance.

If the vessel is being prepared for tow at a site that may find use for a propeller destined for scrap (spares for sister vessels) it may be beneficial to remove propeller prior to towing.

A propeller creates considerable resistance in either a locked or freewheel configuration. This resistance adds a large contribution to the directional stability of the tow, particularly in the absence of rudder control. If the propeller is removed, the directional stability of the tow should be examined. A water brake or similar device may be added if stability is expected to be a problem.

Controllable pitch propellers may be left installed if set in "maximum forward" pitch, where they offer the least resistance to towing. They may also be set in a "zero pitch" condition for added drag if desired.

5-7.1.9 Locking Propellers

When propellers remain in place and are not allowed to free-wheel, lock the shafts by an installed shaft-locking device or by another suitable method as illustrated in Figure 5-3.

5-7.1.10 Allowing Propellers to Free-Wheel

If any type of propeller must be allowed to free-wheel due to the condition of the towed vessel's propulsion train, propulsion machinery must be disconnected from the shafts or adequate lubrication provided.

CAUTION
Do not allow main reduction gears to rotate unless they are properly lubricated. This requires full lube oil pressure.

A means for lubricating the shaft bearings must be provided. The stern gland on the shaft will normally be water-lubricated. Provision for this must be made while at the same time ensuring that the water does not flood the space.

5-7.1.11 Stern Tube

There should be no leakoff at the stern tube. Equip the tow with extra packing for the stern gland to allow emergency repair during transit. The gland should be tightened so there is no leakage with at least two inches of room before its tightest position. Use locknuts to prevent backing off.

5-7.2 Ballasting or Loading for Proper Trim

Proper trim is important because it can affect stability, towing characteristics, and speed. Shifting ballast, fuel, cargo, or equipment on board can bring about desired trim.

Follow these guidelines when adjusting the tow's trim:

- Trimming by the stern has proven to be a stable and directionally true towed ship load condition. A trim of one foot by the stern for each 100 feet of the tow's length has proven a good trimming rule; deep draft tows use somewhat less than one foot per 100 feet.
- Completely fill all tanks or leave them empty to ensure there is no adverse free-surface effect.
- Ensure all normally dry compartments are dry to avoid adverse stability effects of free surface areas and to provide greater reserve buoyancy.
- Ensure bilges are free of oil and water to ensure that bilge flooding alarms are not tripped by sloshing water. Oil in the bilge is a fire hazard and could foul alarm electrical contacts.
- Close all sluice valves to prevent liquids from flowing between adjoining tanks.
- Ballast landing craft or craft with blunt or raked bows to prevent heavy pounding. Pounding can be very destructive to the vessel's bottom and other structural members. Preventing or reducing pounding also reduces shock loads on the towing rig.
- Ensure the tow has zero list.

5-7.3 Ballasting for Proper Stability

Stability of the tow, in the case of an unmodified or undamaged Navy commissioned ship, can be determined by reviewing Chapter II(a) of the ship's Damage Control Book. Similar information for commercial ships should be

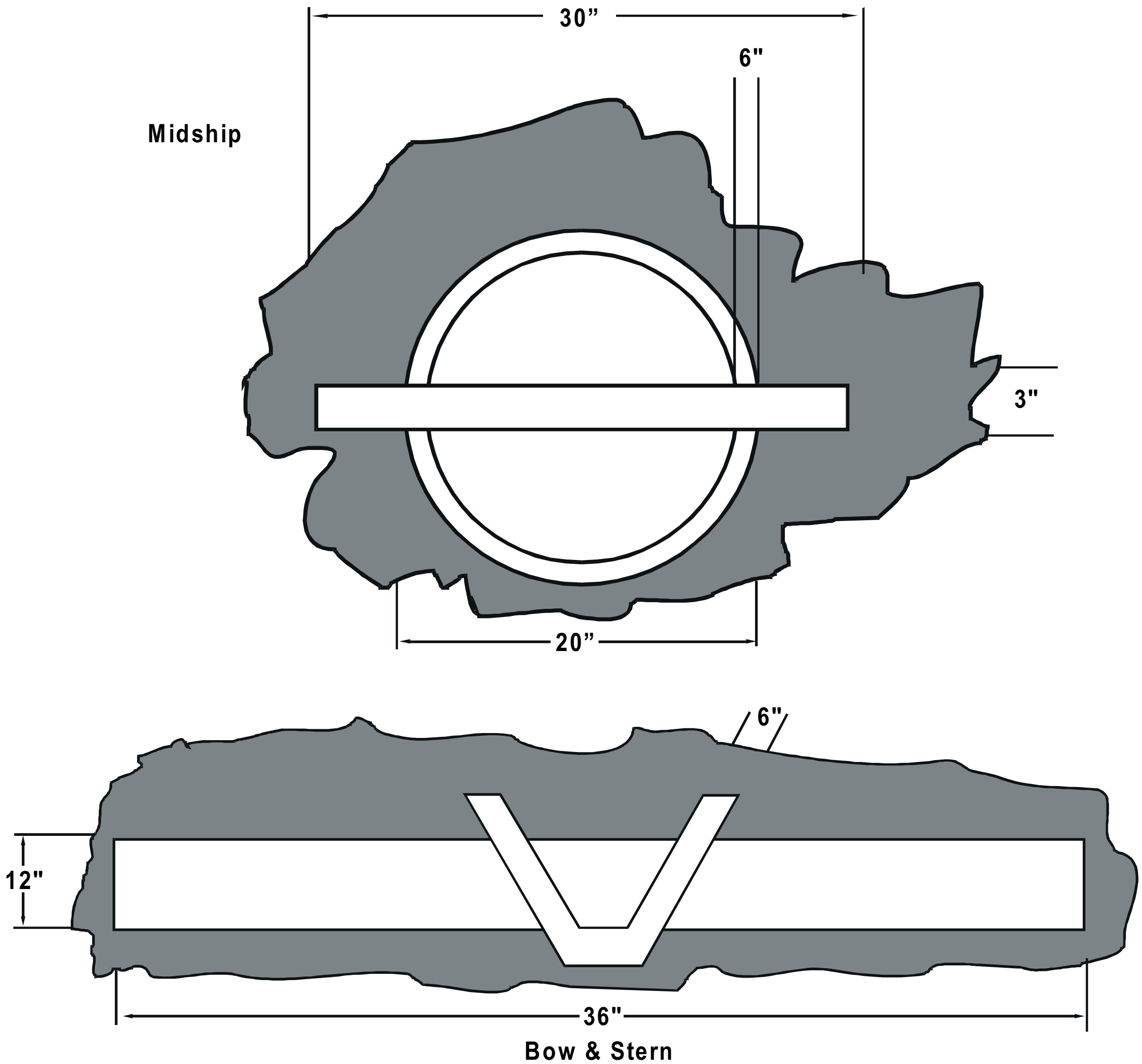
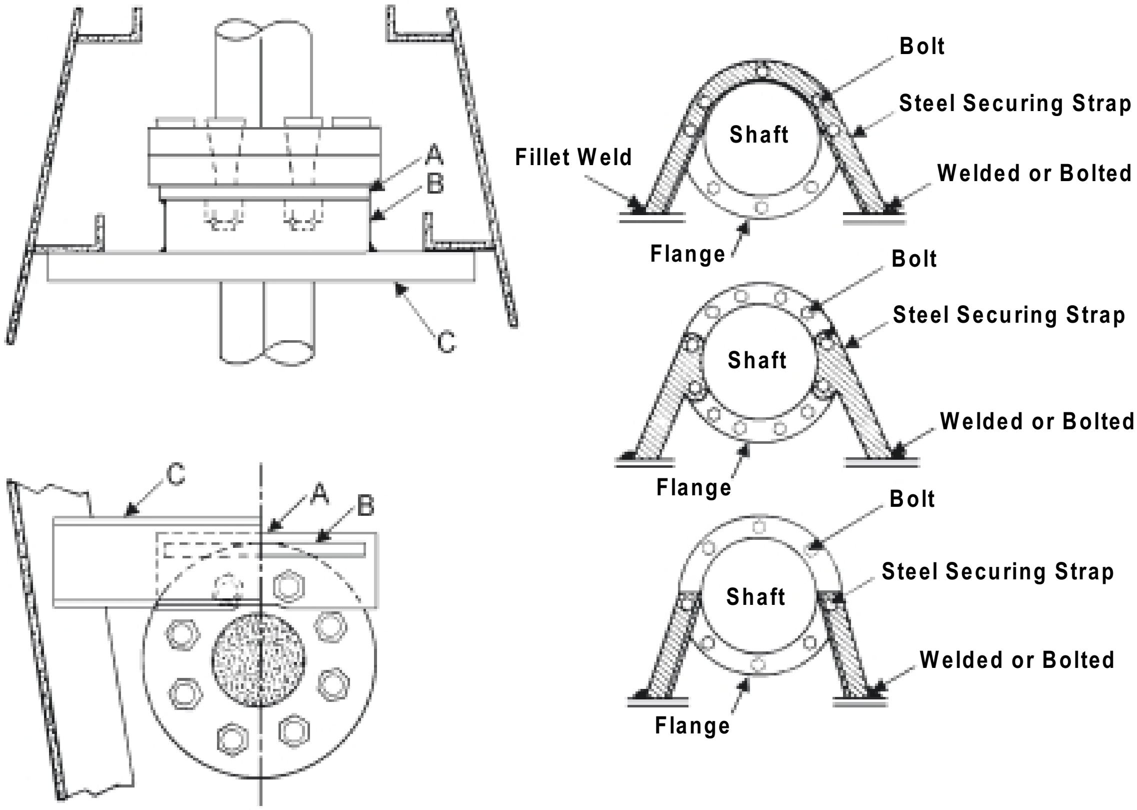


Figure 5-2. Special Draft Markings.



A. Heavy plate, 3/4″ to 1″ cut to accommodate two (2) of the coupling bolts.

B. Intermediate, horizontal plate cut to accommodate and welded to "A" and "C" with full fillet.

C. Deep channel or angle beam, welded to the nearest hull frames with full penetration fillet weld.

Figure 5-3. Securing the Propeller Shaft.

available in the ship's Trim and Stability Booklet, as well as in the Deadweight Survey. When formal documentation of the ship's stability is not available, stability may be approximated by timing the ship's roll period. This method is reasonably accurate and is used by the U.S. Navy, U.S. Coast Guard, and regulatory bodies to confirm the accuracy of inclining experiments and other similar stability determinations. For small craft, timing roll period is the approved method for determining stability.

The roll period can be estimated accurately enough even in fairly calm water by watching the masthead. Time several successive rolls (from extreme port to starboard back to extreme port is one period), then divide the total time by the number of rolls observed to obtain a good estimate. To determine the adequacy of the roll stability, compare the time period with the value calculated from the following formula:

$$T = 2\sqrt{\mathrm{Beam(ft)}}$$

where:

T=Time in seconds.

For adequate stability, the time in seconds for a ship to roll from port to starboard and back to port must be equal to or less than the calculated time (T) in seconds. For example, for a ship with a beam of 100 feet, the time observed for the ship to complete a roll period must be less than the 20 seconds calculated. If the observed time is longer than the calculated value, stability generally is considered inadequate. Equally important is frequent checking for a change in the tow's roll period. Even if overall criteria are satisfactory, investigate promptly any significant increase in period, since this suggests flooding and/or additional free surface.

Each commissioned ship in the U.S. Navy has a Damage Control Book containing specific measures for improving a ship's stability. This book also contains stability characteristics for various loading conditions that meet the Navy's stability criteria.

For small craft and barges that do not have a Damage Control Book, follow a few general guidelines when attempting to improve stability:

- Completely fill any slack tanks
- Lower and secure or off-load high weights
- Secure any large hanging weights and add ballast.

In addition to improving stability, completely filling tanks or adding ballast will decrease freeboard.

5-7.4 Two Valve Protection

Tows of inactivated Navy vessels imply that the preparing activity has met the requirements of Naval Ship's Technical Manual (NSTM) S9086-BS-STM-010, Chapter 50, *Readiness and Care of Inactive Ships* (Ref. G). This NSTM calls for installing hull blanks for all sea chests that don't provide two valve protection to the ship's interior. However, tow inspectors should still be attuned to potential flooding conditions on inactivated vessels.

For unmanned tows of other vessels, a towing vessel's tow inspection team should pay added attention to machinery room or low lying spaces for potential flooding conditions such as single valve protection. Two valve protection consists of either two valves wired shut or one valve and a blank flange. Sea valves must be wired shut with steel wire to protect all sea openings from the sea.

Attention should be paid to any loose connections or badly deteriorated spots in the drain piping which originates above the waterline and terminates within 20-feet of the waterline. If this piping shows excessive rust or other damage, this may represent a potential flooding path in the case of severe weather. These pipes should be repaired to ensure any drainage flows overboard.

5-7.5 Inspecting the Tow for Structural Damage

Every tow should be inspected to ensure that its structure is capable of withstanding the effects of towing. If there is any question about the vessel's structural integrity or if the structure shows signs of extensive deterioration or damage, a qualified structural engineer should be consulted.

In emergencies, such as salvage and rescue towing, structural reinforcement and load distribution may be accomplished with additional structure or shoring. See Figure 5-4 for typical timber framing practice. Protection against slamming damage may be effected by pressing up the bow section of the hull with water. This action may require counter-flooding or shifting of cargo. If the tow is to be rigged for towing by the stern (secondary or emergency rigging), these areas should receive similar attention.

Inspection may reveal damage or deterioration of frames, bottom or weld seams. Particularly when this occurs in the forward one-fifth of the vessel's length, the vessel should be dry-docked or ultrasonically tested, and necessary repairs made. While in dry dock, check bottom, side, decks and inner bottom. All defective welds and plating should be repaired or replaced.

5-7.5.1 Barge Hull Thickness

CAUTION
Many barges and barge-like vessels tend to be more susceptible to damage and deterioration than conventional ship type vessels. They should therefore be inspected for hull strength prior to towing.

Table 5-2 lists minimum thicknesses based on barge length and frame spacing, for typical barges. Bottom plate thickness in the forward one-fifth of the vessel must meet these minimum values for safe towing.

These values are the minimum thicknesses required to meet 1991 American Bureau of Shipbuilding (ABS) 10, *Rules for Building and Classing Steel Barges* (Ref. H). If actual thickness is less than 75% of these values, consider reinforcement. The values in Table 5-2 are for the forward section; thicknesses in the mid-section can be seen in Table 5-3. Again, a 75% criteria should be applied. Reinforcement should be considered if there are any signs of serious corrosion or excessive out of plane damage (buckling, frame tripping, etc.)

To avoid special dry docking before towing, barges, cranes and other service craft should be thoroughly examined during routine maintenance. Plate thickness and weld inspections should be conducted regularly during scheduled dry docking, or by ultrasonic inspection in water.

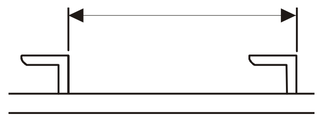
5-7.6 Locking the Rudder

CAUTION
Do not use temporary lashings or other makeshift measures to lock the rudder of a towed ship. Lock the rudder amidships for towing.

Because a drifting rudder will cause the tow to behave erratically, the rudder should be generally locked amidships. The method used to secure a rudder depends upon the tow's steering gear.

- **Yoke or tiller arm steering gear.** Structural steel can be welded across the tiller arm to suitable ship's structure on either side. (An independent engineering evaluation is required to ensure that both securing device and ship's structure are adequate). Figure 5-5 depicts an example of such an arrangement.

Table 5-2. Minimum Plate Thickness for Forward One-Fifth of Barge Bottom.



Frame Spacing (inches)

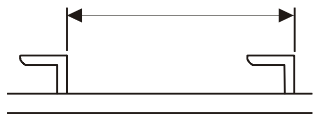
Barge Length	18	21	24	27	30	33	36
100 ft.	0.250	0.271	0.292	0.313	0.334	0.355	0.376
120 ft.	0.261	0.282	0.303	0.324	0.345	0.366	0.387
140 ft.	0.272	0.293	0.314	0.335	0.356	0.377	0.398
160 ft.	0.282	0.303	0.324	0.345	0.366	0.387	0.408
180 ft.	0.293	0.314	0.335	0.356	0.377	0.398	0.419
200 ft.	0.304	0.325	0.346	0.367	0.388	0.409	0.430
220 ft.	0.315	0.336	0.357	0.378	0.399	0.420	0.441
240 ft.	0.326	0.347	0.368	0.389	0.410	0.431	0.452
260 ft.	0.336	0.357	0.378	0.399	0.420	0.441	0.462
280 ft.	0.347	0.368	0.389	0.410	0.431	0.452	0.473
300 ft.	0.358	0.379	0.400	0.421	0.442	0.463	0.484
320 ft.	0.369	0.390	0.411	0.432	0.453	0.474	0.495
340 ft.	0.380	0.401	0.422	0.443	0.464	0.485	0.506

NOTE

Intermediate values may be obtained by linear interpolation. Above thicknesses are for new plates as shown on plans. Shoring should be used if the plating thicknesses are 25% below these values.

All thickness dimensions are given in inches.

Table 5-3. Minimum Plate Thickness for Mid-Section.

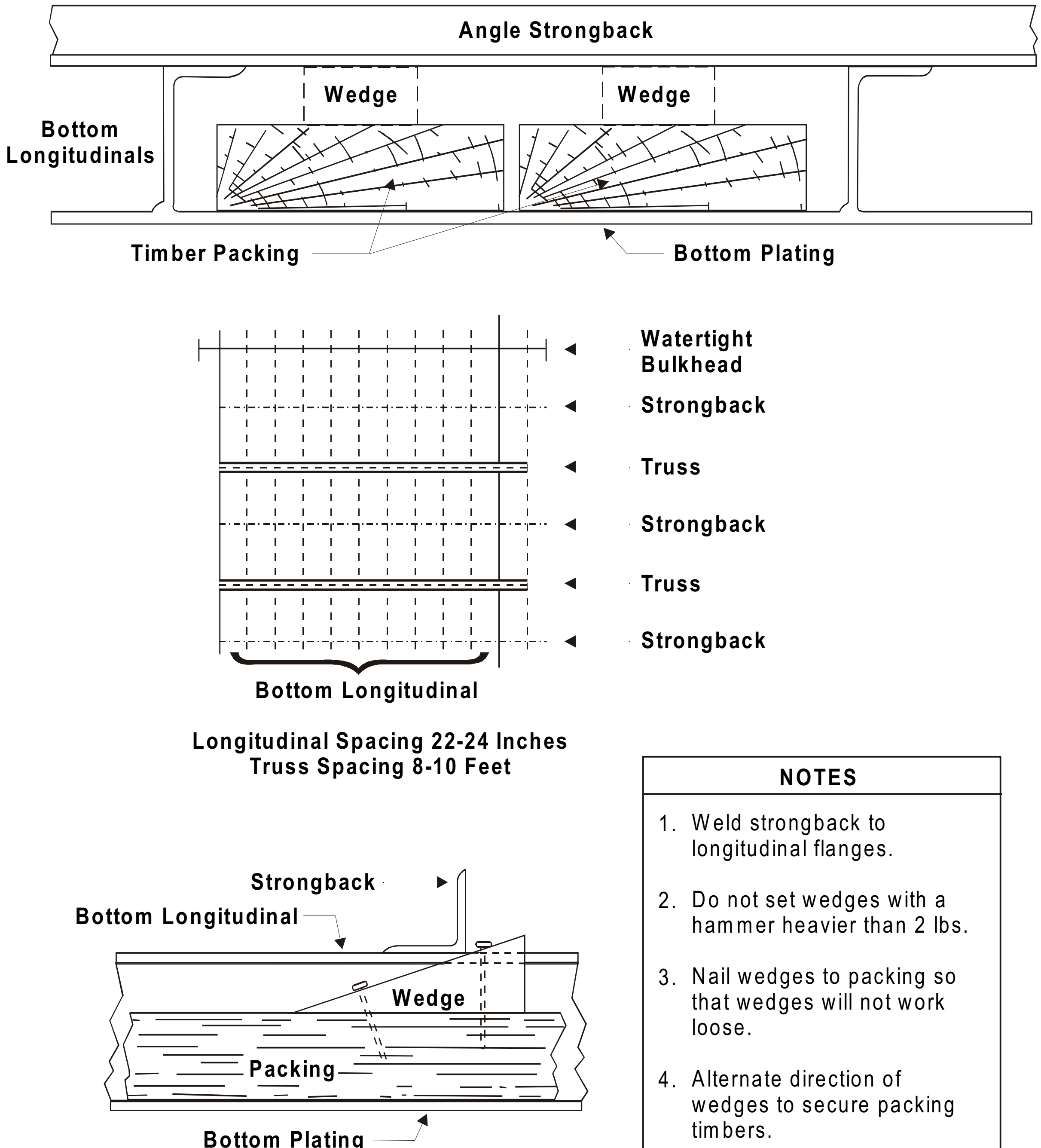


Barge Length	Frame Spacing (inches) 18	21	24	27	30	33	36
100 ft.	0.286	0.316	0.346	0.376	0.406	0.436	0.466
120 ft.	0.299	0.329	0.359	0.389	0.419	0.449	0.479
140 ft.	0.312	0.342	0.372	0.402	0.432	0.462	0.492
160 ft.	0.326	0.356	0.386	0.416	0.446	0.476	0.506
180 ft.	0.339	0.369	0.399	0.429	0.459	0.489	0.519
200 ft.	0.352	0.382	0.412	0.442	0.472	0.502	0.532
220 ft.	0.365	0.395	0.425	0.455	0.485	0.515	0.545
240 ft.	0.378	0.408	0.438	0.468	0.498	0.528	0.558
260 ft.	0.392	0.422	0.452	0.482	0.512	0.542	0.572
280 ft.	0.405	0.435	0.465	0.495	0.525	0.55	0.585
300 ft.	0.418	0.448	0.478	0.508	0.538	0.568	0.598
320 ft.	0.431	0.461	0.491	0.521	0.551	0.551	0.611
340 ft.	0.444	0.474	0.504	0.534	0.564	0.594	0.624

NOTE

Intermediate values may be obtained by linear interpolation. Above thicknesses are for new plates as shown on plans. Shoring should be used if the plating thicknesses are 25% below these values.

All thickness dimensions are given in inches.



NOTES

1. Weld strongback to longitudinal flanges.
2. Do not set wedges with a hammer heavier than 2 lbs.
3. Nail wedges to packing so that wedges will not work loose.
4. Alternate direction of wedges to secure packing timbers.

Figure 5-4. Reinforcing Bottom Plating in Barges.

- **Vane type steering gear.** Extend an emergency wrench (or wrenches) with a heavy channel or beam to reach a strong ship structure. Use full penetration welds on both the wrench and the ship structure (see Figure 5-6).

- **Hydraulic steering gear.** The rams can be secured by positioning the rudder amidships and securing the hydraulic system in an attempt to maintain a hydraulic lock. Sheet rubber is wrapped around the piston and split pipe is cut to the proper length so the ends bear against the cylinders and/or yoke. The split pipe should be secured in place with bands. Both rams should be secured in this fashion. Welding a plate or structural member to the yoke and to the foundation or ship's structure adds security. Refer to Figure 5-6.

Regardless of the securing method, an independent check (by an industrial facility, structural engineer, or mechanical engineer) of the rudder securing method should be accomplished to ensure they are strong enough to withstand the forces generated by the rudder. Forces on the rudder, even at low speeds through the water may be very large due to wave impact and other sea action. These loads will be transmitted through the steering gear and absorbed by the ship's structure.

It may not be possible to use any of the illustrated arrangements, as in the cases of rescue and towing at sea under unfavorable weather conditions. A temporary means may then be employed. Chain falls or come-alongs may also be used in conjunction with tiller arms or quadrants. Where practical, chain should be used instead of wire rope. Ram hydraulic systems may be isolated in some installations to assist rudder locking. These methods are only temporary; a permanent locking arrangement should be installed.

For a manned tow, if the steering machinery is operable and reliable, a decision may be made to steer the tow.

5-7.7 Installing Navigational Lights

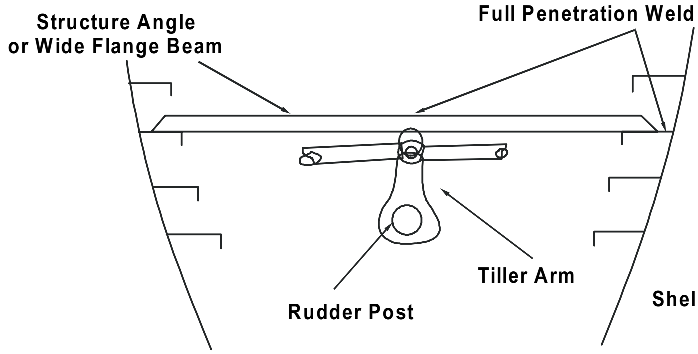
The preparing activity must ensure a tow is equipped with proper navigational lights. Specific requirements concerning the correct positioning, number and color of lights are contained in Code of Federal Regulations (CFR) Part 81-72 COLREGS, *Implementing rules* (Ref. I).

Navigational lights should have a solar switch built in to increase battery life and meet COLREG requirements. Alternately, a single solar switch can be added to the system. Towing lights generally have a 10 foot leader wire for attachment to batteries. If that length is insufficient, Navy type DHOF-4 cable is suitable for connections. Ensure that all wiring is well secured and protected from damage by the elements.

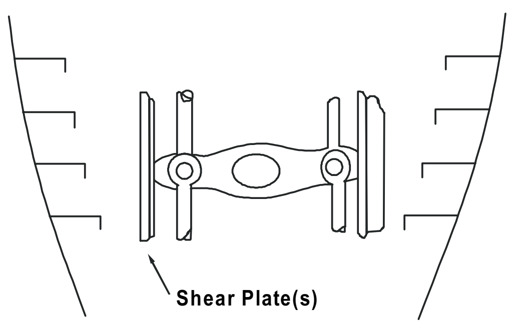
Table 5-4 lists battery capacity requirements for one 60-watt, 12-volt DC sidelight or stern light for tows of various durations. Individual batteries for each light may be used to eliminate the power loss in long cables. Standard Navy 12-volt lead-acid batteries protected by steel containers provide the necessary ampere-hour capacity.

5-7.8 Selecting the Rig

Tow rig selection is best based on past performance and the unique needs of the upcoming tow. Although most Navy tows are simple, single-tug, single-unit operations, some tows are considerably more complex, consisting of a single tug with multiple towed units. Occasionally the displacement of the towed unit requires using more than one tug. The following factors should always be considered when selecting a towing rig:



Fore & Aft Tiller Arm



Athwartship Tiller Arm

NOTE
To maximize lever arm, it may be necessary to use shear plate(s) to secure tiller arm to deck. See Figure 5-6 for typical shear plate example.

Figure 5-5. Securing the Rudder.

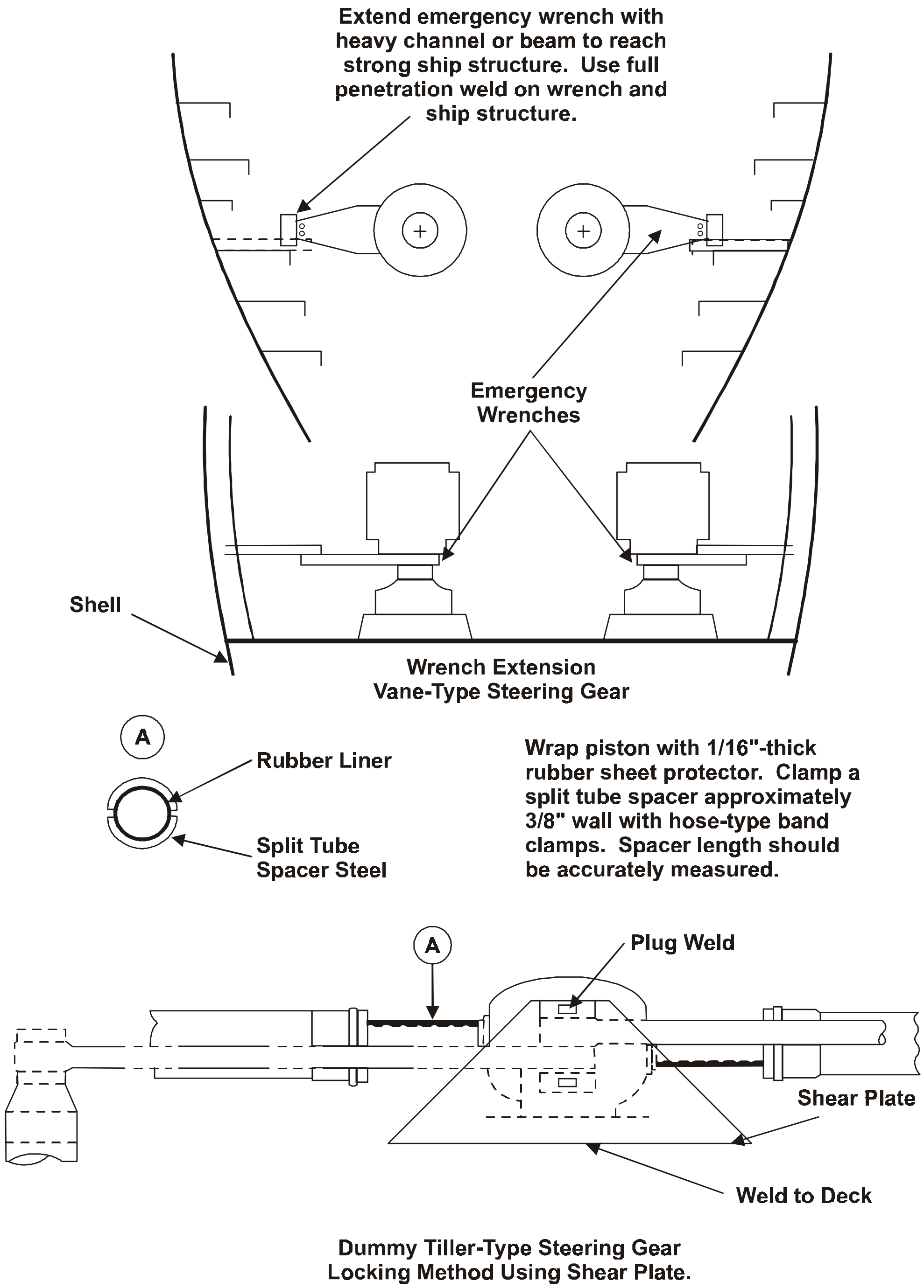


Figure 5-6. Securing the Rudder.

Table 5-4. Battery Capacity Requirements.

Length of Tow (Days)	12 Hr/Day Operation 60 Watt Light (Amp-Hr.)
5	300 Amp-Hr.
10	600 Amp-Hr.
16	960 Amp-Hr.
21	1260 Amp-Hr.
30	1800 Amp-Hr.

- Identify the type of towing rig required for all conditions anticipated during the transit and at either end of the tow.
- Ensure that all rigging is adequate. If in doubt, use a higher safety factor. Pay particular attention to protection from chafing.
- Ensure that multiple tows are configured for optimum seakeeping ability.
- Provide a secondary towing rig on the tow in case the primary system fails.
- Provide for anchoring the tow in case of emergency.
- Provide for all contingencies as outlined in the checklist (see Appendix H).

Before towing a new or unique configuration, ensure design of the rig conforms to appropriate engineering and design criteria. A number of towing configurations and arrangements are shown in Appendix I. Consult NAVSEA 00C to resolve any technical matters regarding towing.

5-7.9 Preparing Tank Vents

Vents to tanks and other closed spaces should be covered with canvas socks to prevent water entry, but not plugged so as to prevent the escape of air or gas. Plugged vents allow pressure to build up within the tank with an increase of atmospheric temperature. Barge sides and decks have been known to bulge severely when vents are plugged. Ensure hatches, scuttles, doors, portholes and other watertight closures are provided with pliable gaskets and that material condition ZEBRA is set throughout the tow.

If vents may be subject to heavy weather flooding (such as vents near the waterline), it may be necessary to weld a blank over the opening to minimize the risk of flooding.

5-8 Emergency Systems

Adequate fire fighting equipment and materials, as well as damage control equipment and associated fuel, should be placed on board prior to starting the tow. For long voyages, tows should have bilge pumping equipment. If permanent bilge pumps on the tow are inoperative portable lightweight pumps or educator systems should be provided, that can be handled by the riding crew or inspection party from the tug. Tests should demonstrate that the pumps have adequate suction lift and discharge head. For larger ships, installation of portable fire-fighting systems should be considered. A portable system could make use of the existing firemain system aboard the towed vessel for distribution of fire fighting water.

5-8.1 Electrical Power

Electrical power is required on the tow for the following systems:

- Fire alarms
- Lights
- Flooding alarms (audible and visual)
- Pumps
- Communications equipment
- Crew accommodations
- Winches and capstans
- Radiological alarms

All electrical and other systems should be inspected and tested periodically to ensure reliable operation. If electrical power on the tow is supplied by an installed or portable generator, a sufficient amount of fuel for the tow should be provided. A simple rule of thumb is to allow two gallons of fuel per day, per generator horsepower, or to allow 2.7 gallons of fuel per day, per kilowatt.

Batteries in a battery powered system should be checked for capacity and condition. Batteries exposed to the weather must be protected in watertight containers that will not permit the batteries to leak to ground. It is essential that all exposed wires and connections be adequately waterproofed. Wires should be secured to prevent chafing and grounding. Provisions must be made to vent hydrogen gas from all batteries.

5-8.2 Fire-fighting

The need for fire fighting equipment must be evaluated by the tow planner and will depend on several factors. The value of the tow, potential sources of ignition, the consequences of fire, and the effectiveness of fire fighting equipment (including personnel), should all be considered when deciding how to approach this requirement. Potential for fire on a planned unmanned tow should be relatively small, but this may not be the case. For instance, ships involved in a rescue and salvage towing scenario will likely have serious potential for fire.

Risk of fire can be greatly reduced by eliminating as much of the combustible material on board as possible. It is virtually impossible to remove all combustible material from a tow as items like insulation and cabling are difficult and expensive to eliminate completely. But paper products, furniture and combustible liquids and paints are relatively easy to remove and greatly reduce risk of a fire. A full walk through of all compartments should be done to identify any areas that may be a potential ignition source. Maintaining watertightness and sealing as many compartments as possible will reduce the chance of a fire spreading.

Fire fighting equipment should be compatible with determined risk. The capacity and portability of installed equipment will determine the effectiveness of any fire fighting effort. Active Navy ships should have three or more portable fire fighting pumps on board. The Navy has replaced gasoline driven P-250s with newer self-priming, diesel-driven P-100s. These pumps produce about 100 gallons per minute at around 85 psi. The 3-inch suction hose (same as the P-250) is used to pull a maximum of about 20 feet of suction. The discharge connection is typically a 2 1/2-inch Y-gate that can be connected to two 1 1/2-inch standard fire hoses. Only one hose should be used at a time due to pressure and flow limitations. It is prudent to connect two, however, to allow quick response in the event of a ruptured line. Pumps and associated gear are generally located on the weather deck near repair lockers.

It may also be possible to connect to the ship's installed firemain. An assessment of the pressure and flow rate needed to meet the fire fighting capability should be made to ensure that adequate pumps are installed. Navy ships will typically use 1 1/2-inch fire hose (50-foot lengths) from a 6 to 8 inch header.

This header should be charged to approximately 150 psi. Access to spaces deemed as potential fire hazards should contain extinguishers and fire hose. These items should be staged in a place to allow the boarding crew to begin fire fighting without endangering their safety.

5-8.3 Dewatering

It is common practice to outfit a tow with flooding alarms. These tell the ship that there is some problem on board and allow the tow ship to assess the severity of flooding to some degree (using high and low level alarms). Dewatering equipment, such as pumps and hoses, is used to control flooding or remove water. If the flooding can be stopped with patches or other repair, water can be removed to restore the vessel to its stable condition. If the flooding cannot be stopped, this equipment can be used to limit the effects of flooding. If the rate of flooding is slow, dewatering pumps may be able to keep the vessel in a stable condition until port is reached or repairs can be made.

5-8.3.1 Deciding to Use Dewatering Equipment

The decision to install or use dewatering equipment should be made by both the tow planner and the tow ship Commanding Officer or Master. Not every tow will need to be rigged with dewatering equipment. It may be desirable to use dewatering equipment on high value tows or tows with little compartmentation. Critical compartments or compartments with damage can be rigged for dewatering while leaving other areas alone. Many tows are decommissioned vessels and have been prepared for long term storage. Often these hulls have a high degree of water-tightness with all hull openings having welded blanks. Flooding is a very unlikely event in these cases. But not every scenario can be foreseen and things break and accidents happen and flooding is still a possibility.

A vessel prepared for tow may have been prepared with extensive compartmentation. Compartmentation will serve to limit the flooding to certain areas of the ship and limit the amount of water taken on. When preparing a tow, level of compartmentation should be a major consideration when determining the need for dewatering equipment.

Operational ships should have a fairly large capacity for dewatering. If one of these ships has been picked up in a distress status, tow ship personnel should become familiar with it’s installed systems. Operational USN ships have flooding effect diagrams as part of their damage control package. These diagrams will tell the effect of flooding of a particular compartment. In the absence of these drawings, a flooding matrix can be developed to show the extent and effect of flooding certain compartments.

Effectiveness of the installed equipment must also be evaluated. Pumps operating on a ship with a very high freeboard will have a difficult time transferring the water from low down in the hold, over the side and into the sea. If large pumps are used, it will likely be impossible for a boarding crew to move them around. Sufficient lengths of hose must be included to reach all areas of the vessel that may require dewatering.

5-8.3.2 Choosing Equipment

When preparing a compartment for dewatering, it is wise to identify potential flooding sources. For example, a damaged ship may have some patching, or a ship may have had a rudder casualty. The size and amount of equipment chosen should be able to overcome any flooding from these sources. Leakage from a large patch may produce a greater amount of flooding than leakage around a rudder post. Pumps should be sized accordingly. P-250s, P-100s or equivalent pumps are often readily available on Navy ships and provide good pumping capability. Submersible pumps may also be used effectively.

Pumps may need to run continuously to overcome flooding until repairs have been made. Sufficient fuel should be carried on board to operate the pumps for at least 24 hours, although more is desirable. Adequate fuel storage should also be included with the capacity to hold this amount of fuel. Provisions can be made to refuel if the operation will last longer. The tow planner should be aware of the capabilities of the tow ship and boarding crew. If refueling is not an option, additional fuel storage will be required.

5-8.3.3 Pre-staging Hoses

Consideration must be given to the capabilities of a boarding crew to rig hoses and operate the pumps. Hoses can be pre-staged to the maximum extent possible, but watertight integrity should not be sacrificed to rig hoses in advance. Locating suctions in the bilge and running hoses throughout a compartment will eliminate a lot of effort by the boarding crew and save valuable time in an emergency. Hoses should be rigged as high up and as near to the compartment access as possible. Final connections can be completed in the event that a decision to open the compartment and run pumps is made.

5-8.4 Marking Access Areas on Tow

A riding crew or boarding party from the tug may find itself in an unfamiliar setting on a large tow. The preparing activity should establish route markings to areas susceptible to either flooding or fire. Painted route markings from a central location and/or from the boarding point would allow personnel to go by the most direct route to the scene of possible emergency. Established route markings to aid a security patrol in making his rounds also would eliminate missed areas, adding to the efficiency of the patrol. Whenever possible a potential boarding party should become familiar with the tow prior to getting underway. Sufficient means for personnel to board a tow at sea should be provided. See Figure 5-7 for examples.

Access markings should be as reflective as possible to allow access in a low light or smoky environment. They should be located in enough areas to ensure that personnel will have no confusion when attempting to locate an exit in an emergency. A line painted down the center of the passage provides a continuous route. Adding reflective arrows will assist in locating the access route.

5-8.5 Preparing for Emergency Anchoring of the Tow

Anchoring the tow in an emergency should be considered. The following provisions should be made when preparing the tow:

- Provide sufficient ground tackle or other anchor-handling equipment. The anchoring system should allow anchoring in a minimum of 60 feet of water with a scope to depth ratio of 3:1. If deeper capacity is required for the proposed route, maintain a 3:1 ratio. The ship’s anchor and chain may be used if in serviceable condition. If other jewelry is brought on board, it should be of similar size to the ship’s normal anchor.
- It may be necessary to seal the chain hawse pipe to prevent water from entering compartments or tanks through this opening. The simplest method of sealing a chain hawse pipe is to pack it with cloth filler and plug with cement.
- Consideration should also be given to power requirements for raising the anchor if the tow will be anchored at the port of delivery.
- The anchoring system should be rigged for quick release, it can be rigged on a specially made billboard (see Figure 5-8). Chain and wire should be able to run over the side without risk of ob-

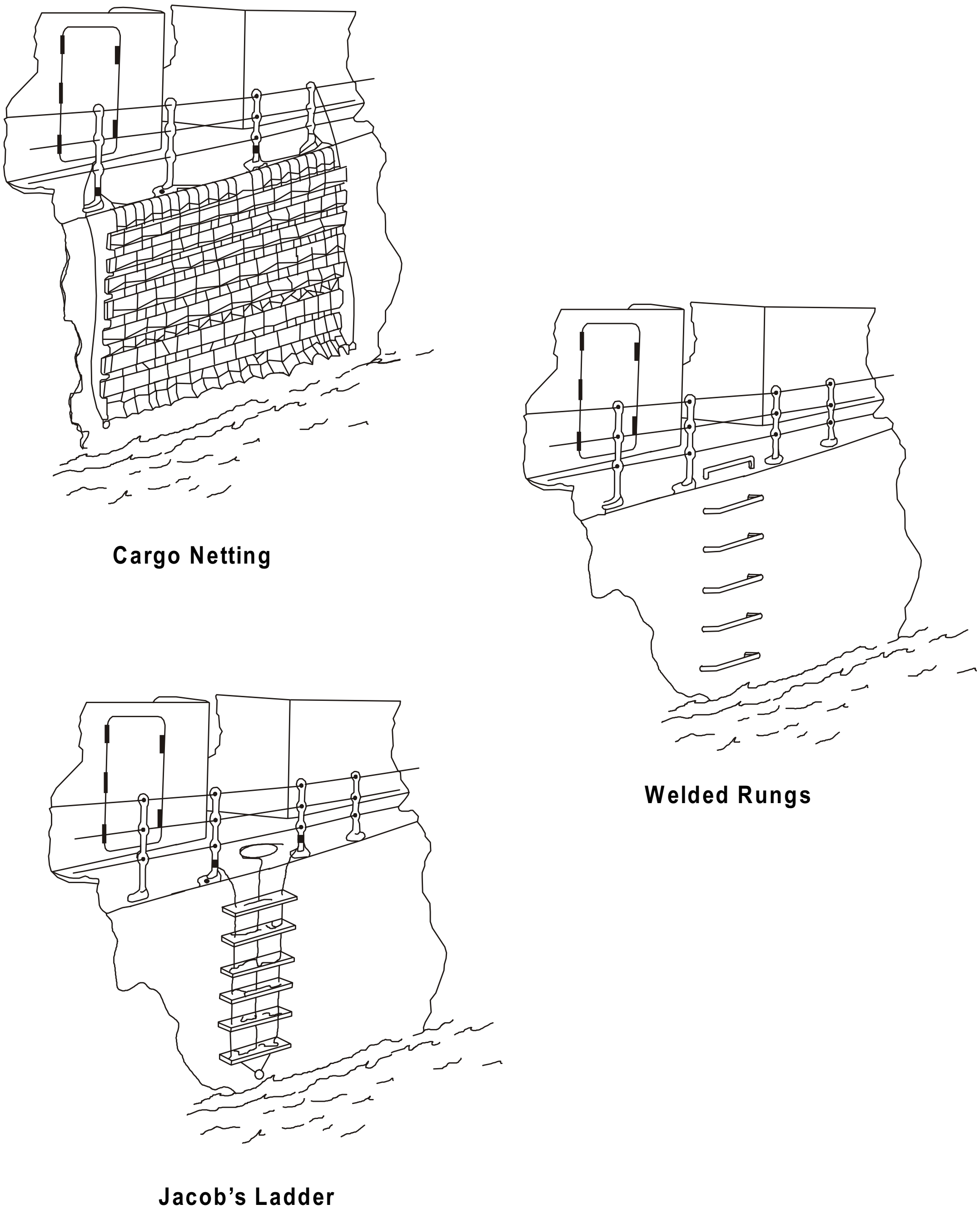


Figure 5-7. Sample Provisions for Emergency Boarding of Tow at Sea.

struction. The bitter end of the ground tackle should be connected to a padeye or other fixture capable of withstanding anchoring loads.

5-9 Completing the Checklist for Ocean Tows

Appendix H provides a simple checklist for preparing a vessel for ocean tow. The checklist is to be used by the preparing activity to aid in preparing a tow for sea and acceptance by the towing unit. It lists general requirements, most of which must be completed before a towing unit will accept it for sea. If the preparing activity has questions concerning this checklist or preparations required to ready the tow, it should communicate via message or phone with the towing unit or its Immediate Superior in Command (ISIC). The preparing activity must fully complete this checklist. Items which are not applicable or cannot be accomplished must be cleared through the towing unit's ISIC or the towing unit.

5-9.1 Determining Seaworthiness

To be considered seaworthy, a towed vessel must have adequate watertight integrity, structural soundness, and intact stability.

A representative of the preparing command shall complete a Certificate of Seaworthiness for ocean tows. The certificate includes general characteristics, type of cargo, towing gear, lights, speed limitation, and similar items. A sample Certificate of Seaworthiness and its endorsements can be found in Appendix H.

5-9.2 Towing Machine/ Towing Winch Certification

The towing machine/towing winch shall be inspected and tested prior to the tow by a NAVSEA designated representative. After all discrepancies are addressed, an annual certificate shall be issued to the Commanding Officer or the Master of the vessel as well as the sponsoring command.

5-9.3 Tow Hawser Certification

The towing vessel shall provide a certification of the tow hawser with respect to its inspection, construction, and type.

5-9.4 Commercial Vessels (U.S. Coast Guard Inspected) Master's Towing Certificate

The towing vessel shall provide a copy of the Master's Towing Certificate that became effective by the USCG TASC of 21 May 2001.

5-9.5 Preparing for a Riding Crew

After receiving approval to use a riding crew, the Commanding Officer or the Officer-in-Charge of the riding crew must ensure that:

- Adequate training and drills are performed. These include fire fighting; flooding and other material condition drills; drills for abandoning ship, boat launching, communications with the tug and securing a secondary towline.
- Security watches of machinery, watertight integrity, the towline, navigational lights, communications, and other watches as necessary shall be stationed.
- There is an adequate method of boarding the tow at sea. When feasible, fixed ladder rungs are preferred. Figure 5-7 depicts several methods for boarding ladders.
- Radios, pumps, hoses, tools, fire-fighting equipment, and handling gear are positioned and ready for use by the riding crew or tug personnel who board the tow. The towing plan also considers requirements for messing and berthing quarters for the riding crew, auxiliary power, fuel, damage-control equipment, and life-saving gear.

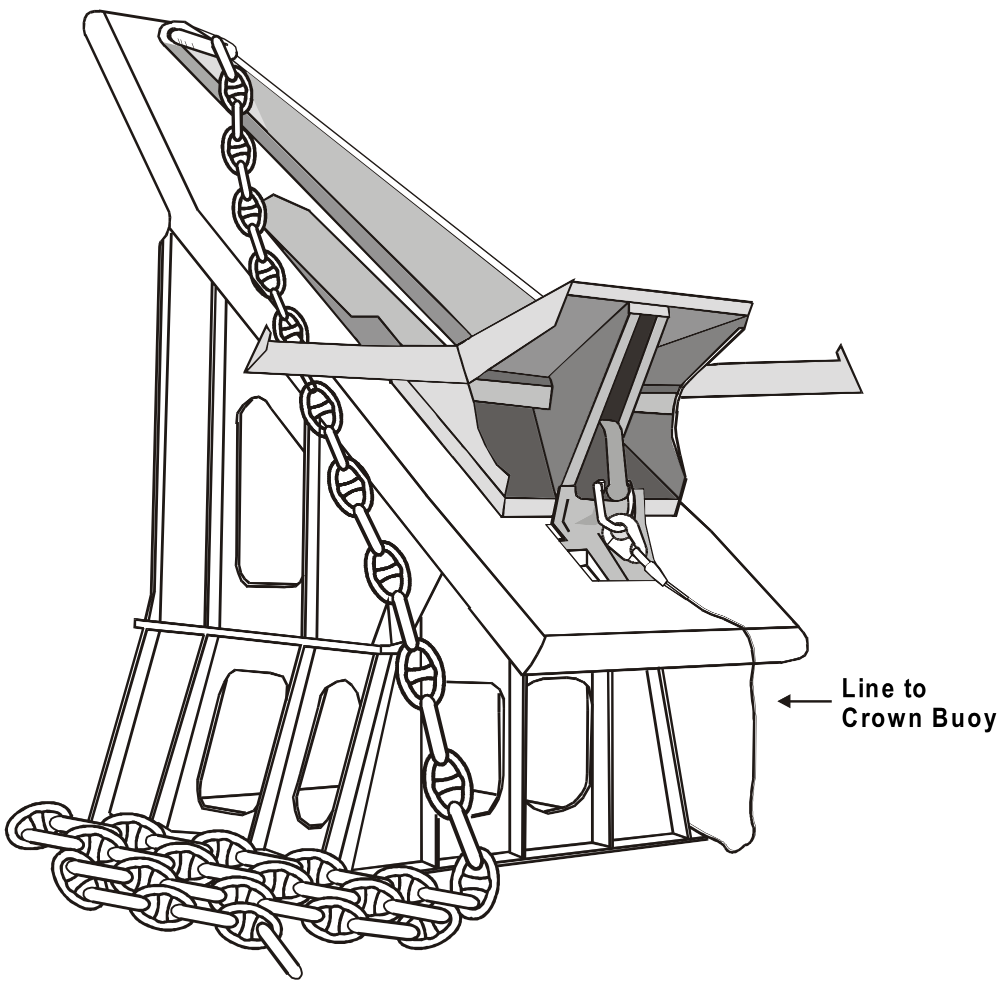


Figure 5-8. Billboard

- Communication between ships is provided as stated in Section 6-2.9.

5-10 Accepting the Tow

5-10.1 Inspecting the Tow

Prior to accepting a tow, the Commanding Officer or Master of the towing ship must inspect the tow to confirm its seaworthiness and readiness for tow. The inspection should include, but not be limited to items listed in Section 5-7 and this section.

- Review the towing inspection checklist, shown in Appendix H, to ensure it is thorough, adequate, and properly completed.
- Inspect tow rig, appendages, and attachment point to ensure that the tow is properly rigged per, applicable instructions, or guidance from the tow sponsor.

WARNING
Substituting materials can be dangerous as well as detrimental to the tow. Substitutions shall not be made unless there is a complete knowledge of the material being substituted. Material substitutes frequently introduce a new and unpredictable weak link. Substituting a stronger material may change the location of the potential failure point in the rig to a position that is hazardous to personnel.

CAUTION
A screw-pin shackle shall not be used as a replacement for a safety shackle in towing. A safety shackle will deform under load and still hold, while a screw-pin shackle's pin can work itself out of the shackle.

- Inspect the towline, bridle, and associated towing gear for wear and to ensure that improper substitutions have not been made in fittings and materials. Typical items to look for include:
  - — Mild steel substituted for forged steel in safety shackle pins.
  - — Stainless steel substituted for other high strength alloys.
  - — Improperly sized components.

  Note whether a retrieving wire is rigged and if proper mooring lines are available.
- Ensure cargo on the tow is properly secured to prevent shifting in heavy weather.
- Ensure liquid cargo tanks are pressed full or left empty.

WARNING
Use the applicable safety precautions for entering voids and unventilated spaces. Failure to do so may result in injury or death to personnel.

- Check all accessible spaces to make sure they are completely dry and watertight.
- Check to ensure that vents to tanks and other closed spaces are properly covered or sealed.
- Ensure hatches, scuttles, doors, portholes, and other watertight closures are provided with pliable gaskets and that material condition ZEBRA is set.
- Ensure that running lights and flooding alarms are operating properly, that batteries are fully charged and battery life is computed to be sufficient for the transit.

- Ensure any required salvage pumps and associated equipment with fuel are safely stowed on board the tow.
- Ensure that any required fire fighting equipment with fuel, hoses, chemicals, and overhaul gear, is safely stowed on board. Require an operational demonstration that fire pumps can take a suction.
- Ensure that all high-value items on the tow are locked up and inventoried on the tow report form.
- Ensure that provisions have been made for quickly releasing the towline in an emergency.
- Ensure a provision has been made for streaming a pickup line for the secondary towline.

5-10.2 Unconditionally Accepting the Tow

Upon satisfactory completion of the tow preparations and inspection, the Commanding Officer or Master of the tug shall accept the tow, notify his operational commander, and proceed with the mission.

5-10.3 Accepting the Tow as a Calculated Risk

If unsatisfactory conditions of seaworthiness or readiness are found and the differences cannot be resolved at a local level, the Commanding Officer or Master of the towing ship should notify his operational commander stating why the tow is unsatisfactory. The report should include recommendations for correcting each deficiency. If conditions or circumstances are such that a calculated risk is involved, the Commanding Officer or Master of the towing ship should state that he will accept the tow only on a calculated risk basis.

5-10.4 Rejecting the Tow

If the tow is in such poor condition that towing would potentially endanger the tow or the tow ship, the towing unit may reject the tow. Every effort should be made to correct any unsatisfactory conditions prior to reaching the decision to reject a tow. But if the Commanding Officer or Master of the towing ship feels that the tow poses a serious risk, he should notify his operational commander stating why the tow is unsatisfactory. The report should include recommendations for correcting the deficiencies.

5-10.5 Preparing for Departure

With all other prerequisites completed, the suggested items to complete prior to departure include:

- Reconfirm the date and time of departure with tasking authorities
- Recheck the weather forecast and suggested track immediately prior to departure.
- Discuss harbor maneuvers with local tug operators. A final tow conference of all parties involved with local charts will provide a forum for clearing any uncertainty about maneuvers. This is particularly useful when accepting a tow in an unfamiliar port.

5-11 Completing the Delivery Letter or Message

Once the tow has been completed, the Commanding Officer of the receiving activity will complete a delivery letter confirming receipt of the tow. A sample delivery letter is included in Appendix H.

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Chapter 6

TOWING PROCEDURES

6-1 Introduction

This chapter will provide some guidelines for operating while underway with a tow, picking-up a tow, and releasing a tow. This information represents the cumulative knowledge of many operators gained during years of towing. Although this will provide guidance for a number of situations, each tow is a unique event with its own unique hazards. Caution and adherence to safety guidelines will help minimize risk to personnel during this dangerous evolution.

6-2 Initiating the Tow

A tow can be picked up at a pier, in the stream, or at anchorage. When rescuing a disabled vessel or recovering a lost tow, it may be necessary to pick up a tow at sea. Ocean-going tugs should not be asked to maneuver unassisted in restricted waters. If possible, the tow should be delivered to the ocean-going tug by harbor tugs. At the very least, harbor tugs should be available to assist the tug and tow to navigable waters.

Positive communication between the tow ship, pilot, and assist tugs is essential and should be established as early as practical.

6-2.1 Accelerating with a Tow

CAUTION
When picking up a tow, increase speed slowly and gradually and maintain an even strain on the towing gear. If a tow hawser tension readout is not available on the bridge, have this information provided by the Towing Watch.

When getting a tow underway, always build up speed slowly. Judicious acceleration and deceleration prevent damage to the towing gear. Sudden speed increases will cause dramatic increases in towline tension and potentially place the tow and crew in danger. An increase in towline scope should accompany speed increases. This will help maintain catenary depth and reduce towline tensions. Good communication between the tow ship and any assist tugs is also necessary for a safe underway.

Frequently the tow begins in restricted waters or a narrow channel. Beam winds or waves may force the tow out of its channel or into the path of other ship traffic. Even if the tow has operable steering machinery, the initial towing speed is often insufficient for control. For these reasons, it is prudent to retain harbor tugs alongside the tow, or at least close by, until the towing ship's Commanding Officer has control of the tow within navigational constraints.

Tow resistance increases with speed, yet water depth may not permit sufficient hawser payout to establish a catenary. A towing machine's automatic features are especially useful in this situation. Also, synthetic springs can provide an excellent means of tension reduction while getting underway (see Section 4-6.5).

6-2.2 Getting Underway from a Pier

Getting underway from a pier with a tow requires that the Conning Officer be particularly aware of tides, currents, and wind. In addition, the Conning Officer should discuss intended procedures with the harbor tug master and pilot before getting underway.

When determining tugs to be used for assistance, consideration must be given to expected sea conditions. The size and number of tugs must be sufficient to control the tow until

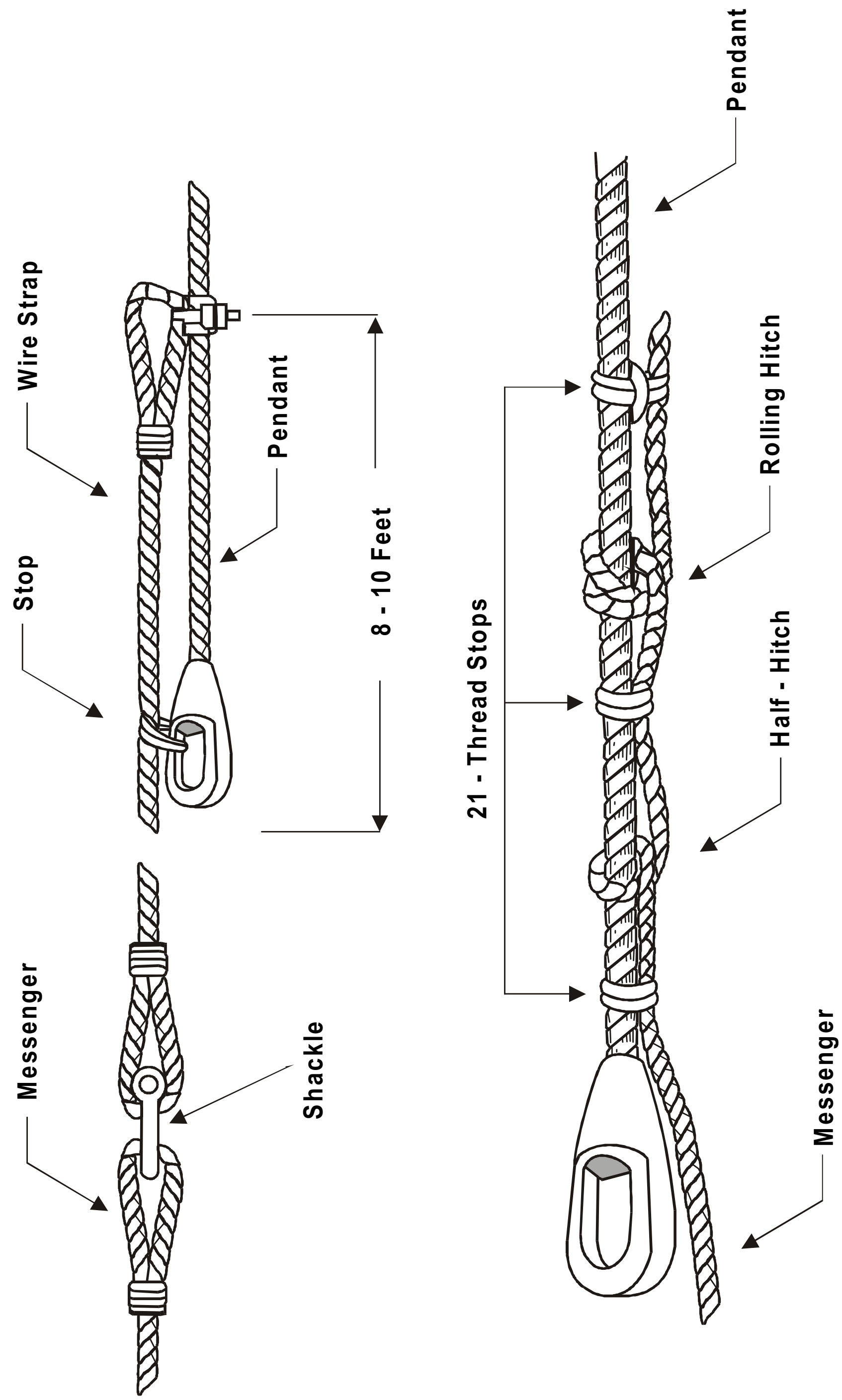


Figure 6-1. Methods for Securing Messenger to Towline.

the tow ship can establish sufficient speed to take control.

CAUTION
Care should be exercised when alongside in a seaway. The motions of the tug and tow may be sufficient to part mooring lines, resulting in damage and causing the tug to lose control of the tow.

Good communication between the tow ship and harbor tugs is critical at this phase. If the tow and tug are not kept in line, at a near constant distance, large strains and damaged tow gear could result. If the tow gear breaks, the harbor tug should be large enough to keep the tow under control to avoid a catastrophe.

Once the towing ship and the tow are in the channel, the towline should be set at short stay in keeping with the depth of confined waters to be crossed. Keep the catenary shallow to avoid snags.

6-2.3 Getting Underway in the Stream

At times it is necessary to accept a tow in the stream. In this case, use the following procedure. The approximate channel course should be taken by the tow ship with bare steerage and assisting tugs should bring the tow to the tug's stern.

Heaving lines are used to send a messenger line to the tow which is then attached to the primary pendant (see Figure 6-1). Depending on the height of the tow's bow or other configuration considerations, it may be desirable to send a heaving line from the tow to the tug. Either way, the tug should always have spare heaving lines on deck in case they are needed. Once a messenger is passed, the pendant is heaved in and the tow connection is made.

CAUTION
The tow should be steadied on the riding lines prior to attempting hookup. Surging can produce high loads on the riding lines very quickly.

If the harbor tugs are limited in their control of the tow or are not available (rescue towing) or if the tug desires to control the tow with its own power, riding lines can be used (see Figure 6-2). When the tow is brought close to a tug's stern, a riding slip line is rigged with its eye on the bitts and then passed to the tow, reeved through a suitable deck chock on the tow, and led back to bitts on the tug. A second riding line may be rigged for increased control. A messenger line is then sent to the tow and attached to the primary pendant. The primary tow pendant is heaved in and the tow connection is made.

Using two riding lines is also a good method for lateral control, especially when towing a small vessel at very short scope in shallow restricted waters prior to final streaming of the tow.

Regardless of attachment method, it is best to have all items to be used in passing the pendant rigged on the tow before leaving the pier. An evaluation of the capabilities of the assets available should be made when deciding the correct method for hook-up.

6-2.4 Getting Underway while at Anchor

At times it is necessary for the tug to make up to a tow with either or both vessels at anchor. This may be due to limited pier space, shallow harbors, or simply the master's preference. Suggested procedures for getting underway in several situations are listed below.

- **Tug underway/tow anchored.** In moderate seas, the tug should come alongside the anchored tow and tie up with her stern as close as possible to the bow of the tow. The tow then passes a line to the tug, which is used to pull a messenger and then a portion of the tow's chain pendant to the tug. As the chain comes down on the tug's faintail, a stopper is passed on it to restrain it while the tug's crew rigs the remaining towline connection. When the connection is made, the chain stopper is released and the tug maneuvers clear. Assistance of a harbor tug is usually required. When headed fair, the tow weighs anchor, once the anchor is housed, the tug can start ahead slowly accelerating. Significant time is required to establish sufficient catenary in the tow hawser and come up to towing speed. If the tow has no power to its anchor windlass, the crew should rig an appropriate retrieval line and buoy so that the anchor can be slipped and recovered later.

If unfavorable conditions for going alongside prevail, passing the hawser can be difficult. Expert seamanship is required to prevent the tug from drifting out of range on a downwind approach. It may be preferable to anchor, as discussed below.

- **Tug anchored/tow anchored.** Rather than passing the towline while underway, it is often advantageous for the tug to anchor upwind or upcurrent from a large ship. While at anchor, the tug can prepare the towline for passing. The tug veers its anchor chain until within a short distance of the tow's bow. When the tug's stern is close aboard the tow's bow, the towline can be passed and the connection made. With the towline connected, the tug can use its engines to come ahead and weigh its anchor, veering towline as necessary. With the tug free to navigate, the tow weighs anchor and the tow commences. If the tow does not have power, it may be necessary to slip the chain and anchor and mark the anchor's position with a buoy for later retrieval.

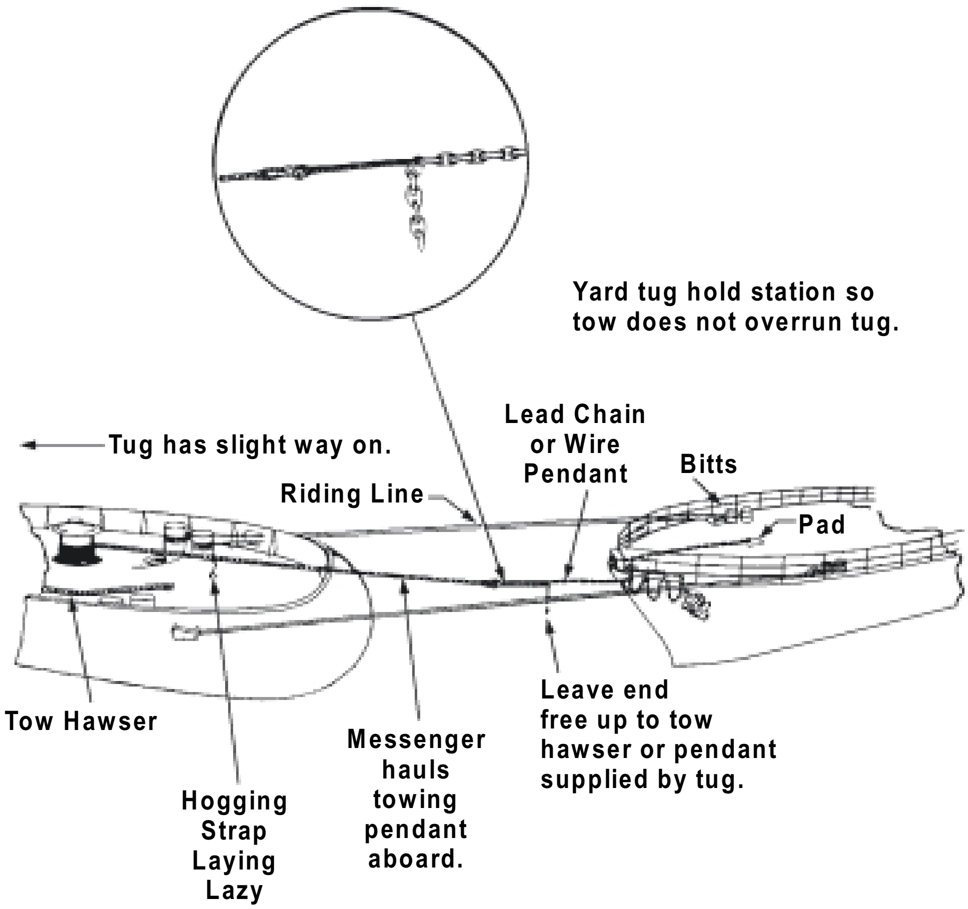
- **Tug anchored/tow underway with steering tugs.** The tug anchors and settles out into the wind and current. A steering tug brings the tow up to the stern into the current or wind. A pendant or lead chain is passed to the stern of the tug. Using the tug's stern capstan, a messenger is heaved on board until a sufficient amount of chain is brought on board to pass a chain stopper. The connection is made, the chain stopper released, and wire paid out as appropriate. The tug weighs anchor and begins accelerating at a very slow rate of speed. This method is safe, simple, and expeditious.

6-2.5 Recovering a Lost Tow

There are occasions when a tug must recover a lost tow at sea. Towline chafing, a mechanical break, or other circumstances may cause the tow to separate from the tug, making it necessary to recover the tow. In other cases, the original tug may become disabled or even abandon a tow. Procedures used to recover the lost tow will be affected by the presence of personnel on the tow, sea and weather conditions, existing contingency plans, and assets available. See Section 6-2.7 for a discussion of approaching a drifting tow.

- If the tow is unmanned and the weather and seas favorable, a boarding party may be put on board the tow, a messenger passed, and the tow reconnected by routine procedures. The risks involved in sending a boarding party and the difficulty of passing a new towline justify rigging a secondary, emergency towline. If the emergency towline has been used, consider rigging another emergency towline.

- If the tow is unmanned and the weather does not permit sending a boarding party, the tow ship should attempt to retrieve the secondary pendant by means of the floating pendant or marker buoy. The tow ship can either recover this using one of its small boats or by grap-



NOTE

Riding lines may not be necessary if there is sufficient tug power available to control the tow.

Figure 6-2. Accepting a Tow in the Stream.

pling the floating pendant directly from the tow ship. The secondary tow pendant is rigged to deploy as the tow ship takes a strain. (See Section 4-4.)

- If the tow is manned, it may still be necessary to send a boarding party on board. If the riding crew is not sufficiently large or able to safely and adequately handle re-rigging of the tow, the tug should provide knowledgeable assistance.

- The tug may use one or more of its small boats to act as a warping tug on a drifting tow, if the tow is not too large. The small boat can keep way on the tow near shoal water, or maintain a tows head into the seas, thereby facilitating recovery. The small boat may also change the heading of the tow as necessary.

6-2.6 Emergency Connection to a Disabled Vessel or Derelict

Devising a means of attachment is a critical concern when rescuing a disabled vessel or derelict. This is particularly important in the case of rescue towing, when time and shoreside support may not be available for installing padeyes and fairleads. Suggested attachment points of sufficient strength to tow in an emergency include:

- Using the ship's anchor chain
- Using installed bitts or padeyes
- Wrapping a chain around a foundation structure such as a gun mount or winch
- Welding a padeye to the deck

The preferred methods are to use the ship's anchor chain or installed padeyes. The other methods are to be used in emergency situations and may be necessary due to damage to the tow or other unusual operating constraints.

For situations where a padeye must be welded to the deck, refer to Section 4-5.4 and Figure 4-7 for acceptable padeye design specifications. These figures provide means for constructing a well-designed padeye. In an emergency situation, however, when detailed calculations cannot be performed, it is recommended that the largest available material be used. These calculations can be performed after installation, when the tow is out of danger, as a check against proposed towing speeds. If the installed padeye is too small, speed should be limited until a more appropriate padeye can be constructed.

All towing bridles, when rigged correctly, must have a backup securing system. This is normally accomplished by using wire rope of appropriate size (able to lace through chain links) and taking sufficient bights of wire from a second securing point (bitts, heavy cleats, etc.) and lacing the wire rope through the after end of links in the chain bridle (no less than four bights). Size and number of bights of wire should equal the strength of the chain used in the bridle. If a towing pad is used to connect the bridle to the tow, the backup wires must be laced forward of the towing pads. The securing point should be aft of the towing pad to prevent snap-loading. If a set of mooring bitts is used as a securing point for the bridle on the tow, the wire should be laced thorough the chain links that remain astern of the bitts after the three or more "figure eights" are secured on the bitts. There must be a sufficient number of wire clips (see Table 4-1) on each bitter end of the backup wire, aligned in the same direction (See Appendix I and Appendix J for tow rig design plans.)

It may not always be possible or practical to rig a backup system (i.e., submarine towing). In these cases, additional analysis of the main towing attachment may provide some reduction in uncertainty. Where possible, the attachment should be designed to a breaking

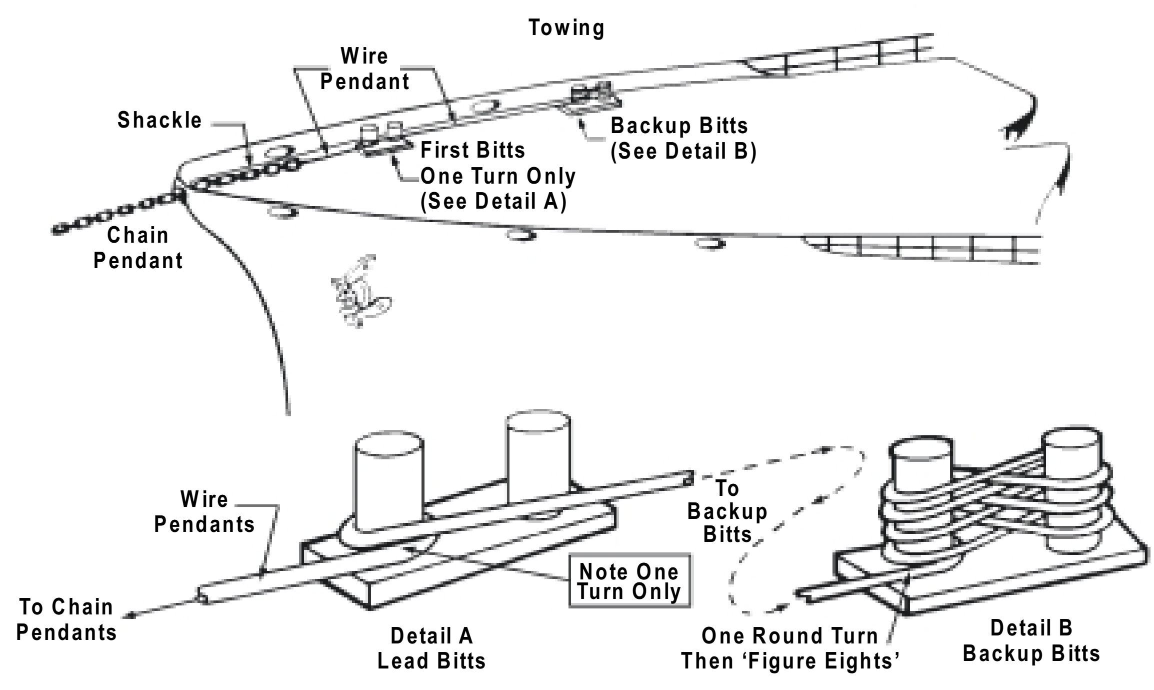


Figure 6-3. Sharing Towing Load Between Bitts.

strength well in excess of the other components.

However the attachment point is affected, it may also be necessary to cut through the bulwark or to remove other fittings from the deck in order to provide a clean sweep for the towing pendant. When rigging a special attachment for towing, twin problems of attachment point and fairlead must be resolved.

6-2.6.1 Using the Anchor Chain

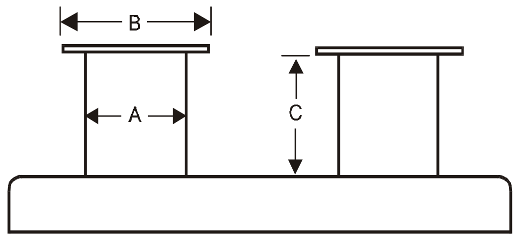
Often the simplest, strongest, and most efficient connection method is to shackle the pendant into the tow's anchor chain with the correct connecting link.

WARNING
In no case should the stud of the common chain link be removed to provide a connecting point to a chain.

The usual method is to stop off the anchor and break the chain. Make sure that the inboard section will not be pulled down into the chain locker due to its own weight after it is cut. This can be accomplished by rigging two stoppers and cutting between them. In an emergency situation, it may be easiest to cut the chain and lose the anchor. However, it is safest and economical to rig stoppers and save the anchor.

Next, connect the bitter end of the chain directly to the towing pendant brought through an appropriate deck edge chock. The anchor chain can then be veered to provide chafing protection and any desired additional catenary to the towline system for improved dynamic load mitigation. In this case, the ship's chain stopper system may not align ideally with the fleet angle of the chain, but in most cases the alignment will be sufficient. If the alignment produces sharp bends or other po-

TABLE 6-1. Information on U.S. Navy Bitts.



Nominal Bitt Size	A Barrel Size (inches)	B Top Plate (inches)	C Barrel Height (inches)	Maximum Moment* (inch-lbs)	Maximum Pull at Upper Edge* (pounds)	Maximum Pull at Mid-Barrel* (pounds)	Maximum Size Synthetic Line
4	4 1/2	6	10	134,000	13,400	26,800	3
8	8 5/8	11 1/2	13	475,000	36,500	73,000	5
10	10 3/4	13 3/4	17	1,046,000	61,500	123,000	6 1/2
12	12 3/4	15 3/4	21	1,901,000	90,500	181,000	8
14	14	17	26	3,601,000	138,500	277,000	10
18	18	21	32	6,672,000	208,500	417,000	12

*These numbers are safe working load with a factor of safety of 3 on Material Ultimate Strength.

tential failure spots, this area should be inspected periodically and appropriate operational steps taken to reduce risk of a failure.

Another method involving a tow's anchor chain is to suspend the anchor from a wire strap, or cut it loose completely, and tow through the hawsepipe. The rigging for this procedure is complex and sometimes hazardous. Furthermore, this method often results in the chain bearing against a sharp forward or upper outer lip of the hawsepipe, which may consist of a much smaller radius than would be ideal for chain.

6-2.6.2 Using Installed Bitts

Mooring bitts are a possible choice for securing a tow hawser. U.S. Navy bitts are designed to withstand the breaking strength of the mooring line for which they are designed, with a factor of safety of 3 on ultimate strength. Since different types of synthetic lines will have different breaking strengths, Table 6-1 lists the capacities of Navy bitts. The chart also contains some typical dimensions that will help to identify existing bitts and shows how each of these dimensions are measured. The maximum pull can be applied to either barrel (not both), in any direction.

The strength criterion for bitts in commercial ships is similar, except older ships and Navy support craft often have been designed for manila mooring lines. Consider this when employing bitts for towing of commercial or older Navy ships. In all cases, the strength of the bitts must be discounted if obvious corrosion or poor maintenance is evident.

Attaching a chain directly to the typical-sized bitts found aboard ships is feasible, but removing slack is difficult. Such a connection is susceptible to shock load from sudden rendering and has a higher possibility of failure.

An improved connection where slack can be minimized can be made using wire that is the same size as the towing pendant. (See Figure 6-3.)

In Figure 6-3, note that the chain provides chafing protection at the deck edge, but wire is used to make the final connection. As stated earlier, when using mooring bitts as an attachment point, a backup securing system should be used. The reason for using backup bitts is to share the load. To accomplish this, the loaded part should make only one turn around one barrel of the first bitts. The first turn will absorb 50 to 75 percent of the total load on the wire, depending on the coefficient of friction, and pass along 25 to 50 percent to the backup bitts. The wire should be secured to the second bitts by making one turn on the first barrel and then making figure-eights with the remaining line. Backing up to a third set of bitts is not necessary.

If two turns are taken around the first set of bitts, only about 6 to 12 percent of the total load is passed on to the second bitts. Thus, effective load sharing is voided.

If the wire required is too large to fit on the bitts, synthetic line may be used. This synthetic line is subject to the same restrictions as synthetic towing hawsers. Minimum bend radius for all components should be checked. The same principles are applicable to synthetic line load sharing.

When using mooring bitts as bridle attachment points, heavy channel iron must be welded across the bitts to prevent the bridle from jumping out.

6-2.6.3 Using a Gun Mount or Foundation

Another way to make an attachment is to pass a chain around a gun mount or foundation of a deck machinery installation or to rig a wire rope strap with a large eye on one end around the bitts (see Figure 4-11).

6-2.6.4 Placing a Crew on Board

WARNING
Boarding a derelict vessel can present many unknown hazards. Safety is paramount during these operations.

In an emergency, the presence of a functioning crew aboard a disabled ship is of considerable help when making the connection. If the ship has auxiliary power and is able to operate its anchor windlass or other winches, passing the towline assembly is a relatively simple task, complicated only by adverse sea and weather conditions.

Connecting to a derelict poses the immediate problem of placing a boarding party on board. A derelict vessel can present many unknown hazards to personnel. The boarding crew should consider personnel safety as paramount. If any potentially dangerous conditions were found during the pre-tow inspection, these should be briefed to the boarding party prior to attempting to board the tow.

If there are no means of boarding, grapnels may be heaved on deck or fabricated pipe boarding ladders may be used to get a man aboard. This person can then lower more conventional means such as a Jacob's ladder. The boarding party may have to carry an assortment of tools and rigging devices to help haul the messenger on board and hook up a tow. These tools may include:

- Welding and cutting equipment
- Various size shackles
- Wire straps
- Rigging lines
- Battle lanterns
- Personal safety gear
- Sheaves for rigging
- Hand-held radios

6-2.7 Approaching a Drifting Tow

There are as many variations of approaching a drifting tow as there are variables in wind and sea. Good seamanship is required to approach and safely take in a drifting tow of any size. Absolute coordination between the Conning Officer and the fantail crew is essential. Direct communication with personnel on the tow and all parties is crucial.

6-2.7.1 Establishing the Relative Drift

The first step in approaching a tow to be picked up at sea is to establish differential drift between the vessels involved. This is critical for positioning the tow properly and avoiding a collision. Despite obvious differences in size and configuration, vessels' rates of drift are also affected by a host of other variables, including displacement, draft, stability, trim, damage, seas, wind, sail area, location of the superstructure, and currents. The above water hull configuration determines the tow's relative heading into the wind. Depending on trim, ships having a greater portion of their superstructure aft tend to head into the wind; ships having a greater portion of superstructure forward tend to lie with the wind from aft of the beam to astern. A midship superstructure will normally cause a ship to lie with the wind abeam. With relative drift between tug and tow determined, and the state of the seas and wind taken into consideration, the tug can make its approach.

6-2.7.2 Similar Drift Rate

Figure 6-4 describes a tug's approach across the wind and seas where similar drift rates exist. The tug begins an approach leading to pass close aboard on the weather bow; the messenger and towline can then be passed. The tug keeps station while passing messengers and making the connection.

6-2.7.3 Dissimilar Drift Rate

Where dissimilar drift rates exist, a downwind approach may be executed, as seen in Figure 6-5. When approaching a ship lying broadside to the wind, tug speed should be slow, but fast enough to offer good steerageway. Because on-station time is short, a messenger must be passed quickly. The towline can be passed in the lee of the ship's bow. This situation requires a special effort to keep all lines clear of the propellers. Once connected, acceleration should be slow and maneuvering sequences gradual.

CAUTION
Approaching at too small an angle in the lee of a larger vessel can be dangerous. When working in the lee of a larger ship, establish an attitude that permits the tug to maintain a safe distance from the more rapidly drifting tow.

6-2.8 Passing the Towline

A towline is passed by messenger to the tow. It is generally preferable to have the tug pass the messenger and towline. The messenger may be passed by a hand-thrown heaving line, rocket, line-throwing gun, small boat, buoyant float, helicopter, or any other expedient means. The hand-thrown heaving line, backed up with a line-throwing gun, is a common and practical way of passing a messenger. An experienced seaman, under favorable circumstances, can accurately throw a heaving line over 100 feet. Backup heaving lines should be coiled and ready on deck to minimize time between attempts, should the first attempt fail. Time considerations and attendant dangers, however, make it prudent to give as much time as possible to pass the messenger. Use of a line-throwing gun, therefore, is the preferable procedure.

- In some cases it may be imprudent to navigate close to a distressed ship. In this event, a boat can be used to pass the messenger. Line, free for running, should be faked down in the boat and

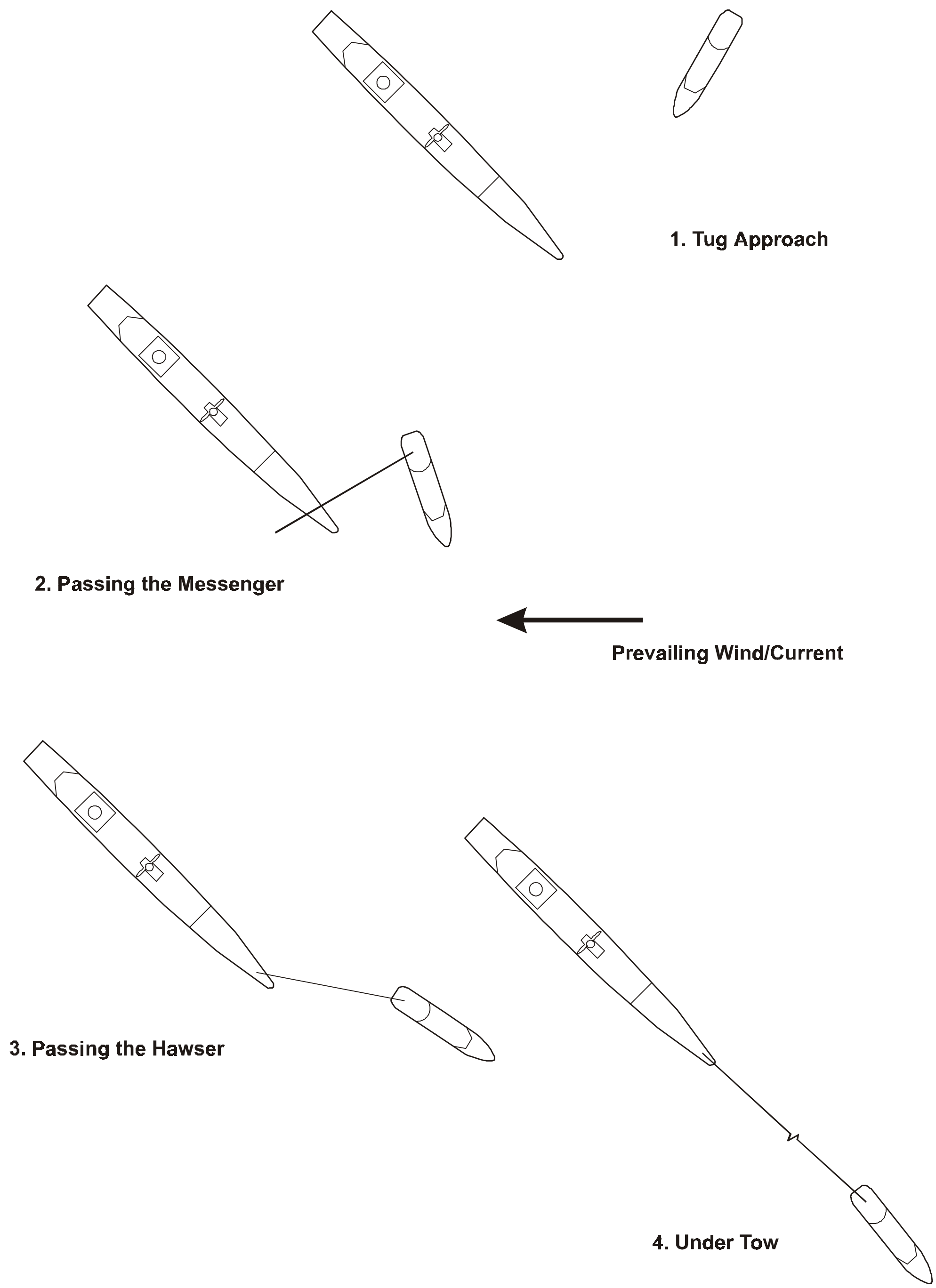


Figure 6-4. Across Sea/Wind Approach - Similar Drift Rate.

on board the tug, with the maximum amount possible in the boat.

- Buoys, life jackets, salvage floats, foam fenders, or drums can be attached to the messenger's bitter end and floated to the distressed ship. This can be expedited by the tug crossing the disabled ship's bow with the messenger streamed.

- Line-throwing guns can carry the bitter end of the messenger; an experienced seaman can safely and accurately fire the gun a distance of over 300 feet. A heaving line can also be used effectively for shorter passing distances.

After a sufficient length of the initial messenger is on board, it may be run through a block and the bitter end passed back to the tug where the tug's machinery can haul the heavy messenger and towing assembly on deck. The tow pendant is then made up to an available strong point on the derelict.

6-2.9 Communications between Ships

In a towing situation, most communication between ships is by radio. Loss of radio, radio silence, weather, or foreign language barriers may require an alternate means of communicating. The most commonly accepted methods for communicating between ships at sea are identified in the International Code of Signals, *Communicating Ship-to-Ship* NWP - 14-1 (Ref. J). These are by no means the only means of communicating. Prearranged signals and codes, as well as standard Navy procedures such as those in NWP 14, are valuable and highly useful tools available for communicating during towing operations.

6-3 Ship Handling and Maneuvering with a Tow

CAUTION
Small increments of rudder angle are recommended when changing course under tow. This will ensure that the tug maintains control of the tow and prevents the tow from ranging up on the tug. Never permit the tow to pass forward of the tug's beam, as the tug or tow hawser may be severely damaged.

When the tow is underway, the tug begins to accelerate slowly to towing speed. Rudder orders should permit slow and orderly course changes. It is important not to subject a tow or towline to excessive dynamic loading. Slow course and speed changes will prevent excessive strain. If an automatic towing machine is installed, a low tension setting can be employed and the tow streamed as speed is increased. Once desired scope is achieved, the setting on the automatic towing machine may be increased to the desired value.

6-3.1 Tug Steering

Maneuvering characteristics of the tug can be dramatically affected when towing another vessel. The ability of the tug to maneuver itself under all conditions is essential.

The position of the tow point (the point where towline tension is applied to the tug) and the tension on the towline can create a moment that opposes the rudder moment and hence restricts the turning motion of the tug. The tug's ability to steer is increasingly hampered as the tow point is located farther aft. The effect is aggravated at low or zero speed. The term

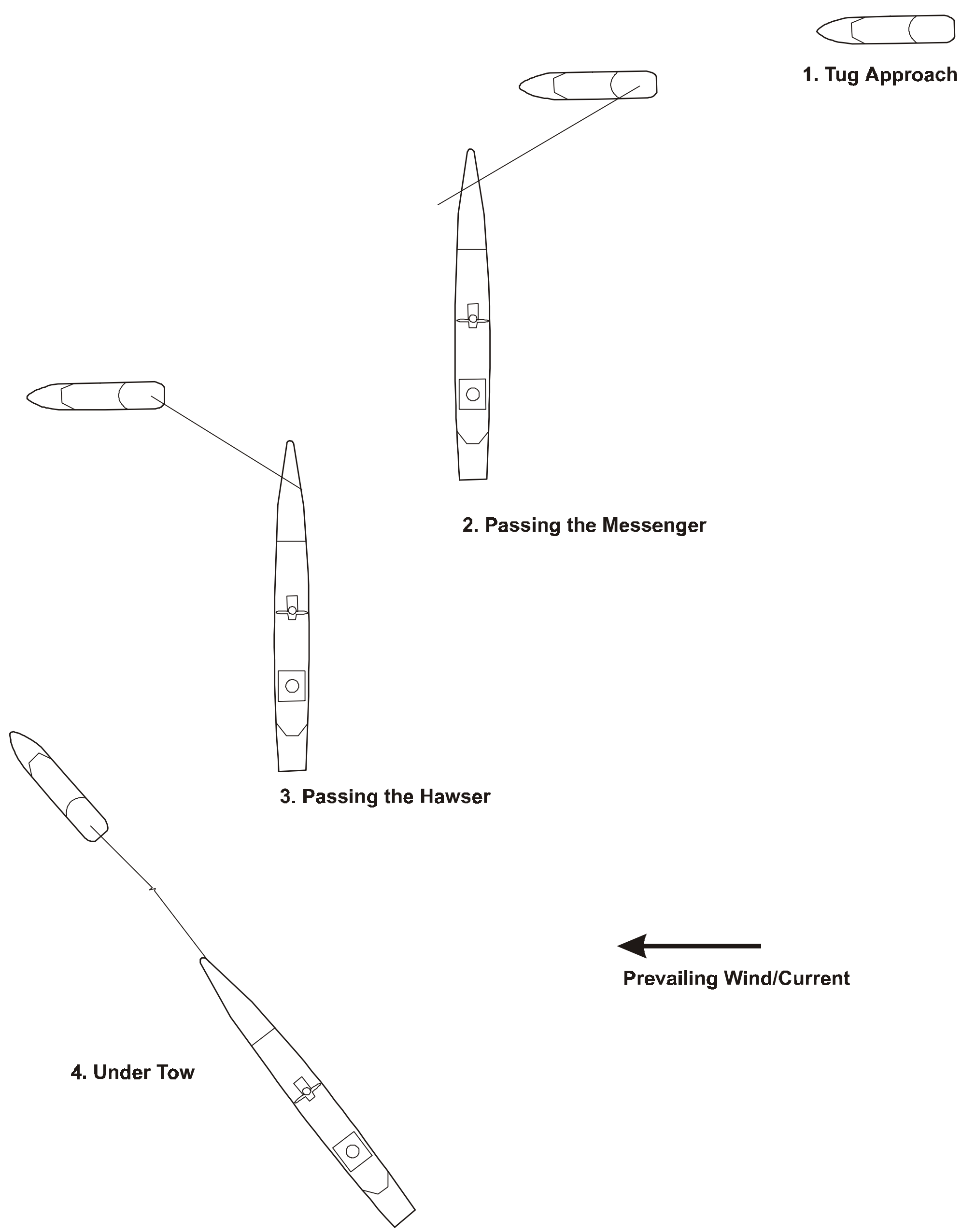


Figure 6-5. Downwind Approach Crossing the "T" to Ship Lying Broadside to Wind/Sea.

"in irons" describes a condition where the opposing moment of the towline is the same as or greater than the turning moment created by rudder and other hydrodynamic forces. The tug is then rendered incapable of steering (see Figure 6-6). Being in irons can be catastrophic for a tug, especially when maneuvering in confined waters or in a poor orientation with respect to the sea. A tug also can be rendered in irons when it cannot make headway under its own power because of the towline making contact with the bottom. In this case, the tug is effectively anchored by the stern. The tow, however, is not anchored and may close rapidly. To avoid being run down, the tug should shorten the wire and regain headway at once.

Ideally, the position of the tow point should be located at the tug's natural pivot point, to allow the tug maximum freedom of rotation in steering. The tug's natural pivot point is dependent on hull and rudder design; it is usually located on the center line at about one-third of the tug's length from the bow. This is why the towing winch is mounted as far forward from the stern as possible, although it is doubtful that any towing winch is located exactly at the pivot point itself. From a practical standpoint, the towing point is designated as the towing winch or towing bitts, if installed.

There are times, however, when the towing point is located farther aft—for example, on a Norman pin, hogging strap, or stern roller. During long ocean tows, these configurations may be preferred since they will restrict line sweep and therefore chafing of the towline. If little maneuvering is needed, moving the tow point aft may be acceptable. In any configuration, it is imperative that the operator be aware of the possible maneuvering restrictions imposed on the tug and take the necessary precautions to avoid being placed in irons.

6-3.2 Keeping a Tug and Tow in Step

When a tug is at sea with a tow, the two vessels move distinctly and separately in surge, sway, heave, roll, pitch, and yaw in response to the surface waves. The degree and timing of motion that either vessel experiences depend on the individual vessel's characteristics. No two vessels will respond to the surface waves in exactly the same pattern. In cases where the surface wave pattern is characterized by a single predominant wavelength, it may be possible to minimize the difference in the timing of the tug and tow motions. This involves adjusting the towline scope to place the tug and the tow on crests of the predominant waves at the same time. By placing both vessels on the crest at the same moment, they will move in response to the waves in the same direction at approximately the same time. Adjusting timing of a vessel motions in this way will reduce dynamic tension in the towline. This practice has been referred to as keeping the tug and tow "in step." In tandem tows, this is rarely possible.

As the tug approaches shallow water, such as a coastline or channel, the wave frequency will change (increase). The length of the tow should be adjusted, in conjunction with a possible change in speed.

Keeping "in step" applies equally to all towing situations, whether towing on the dog, hook, brake, or on an automatic towing machine. The benefit of being in step is lower peak tensions.

6-3.3 Controlling the Tow

6-3.3.1 Active Control of the Tow's Rudder

The tow's rudder can be used to stabilize an unwieldy tow or to maneuver in close quarters. Improper or excessive use of the rudder, however, can cause the tow to become directionally unstable. The decision to use active steering of the tow will depend on the reliability of the tow's steering machinery and qualifications of the riding crew. A decision

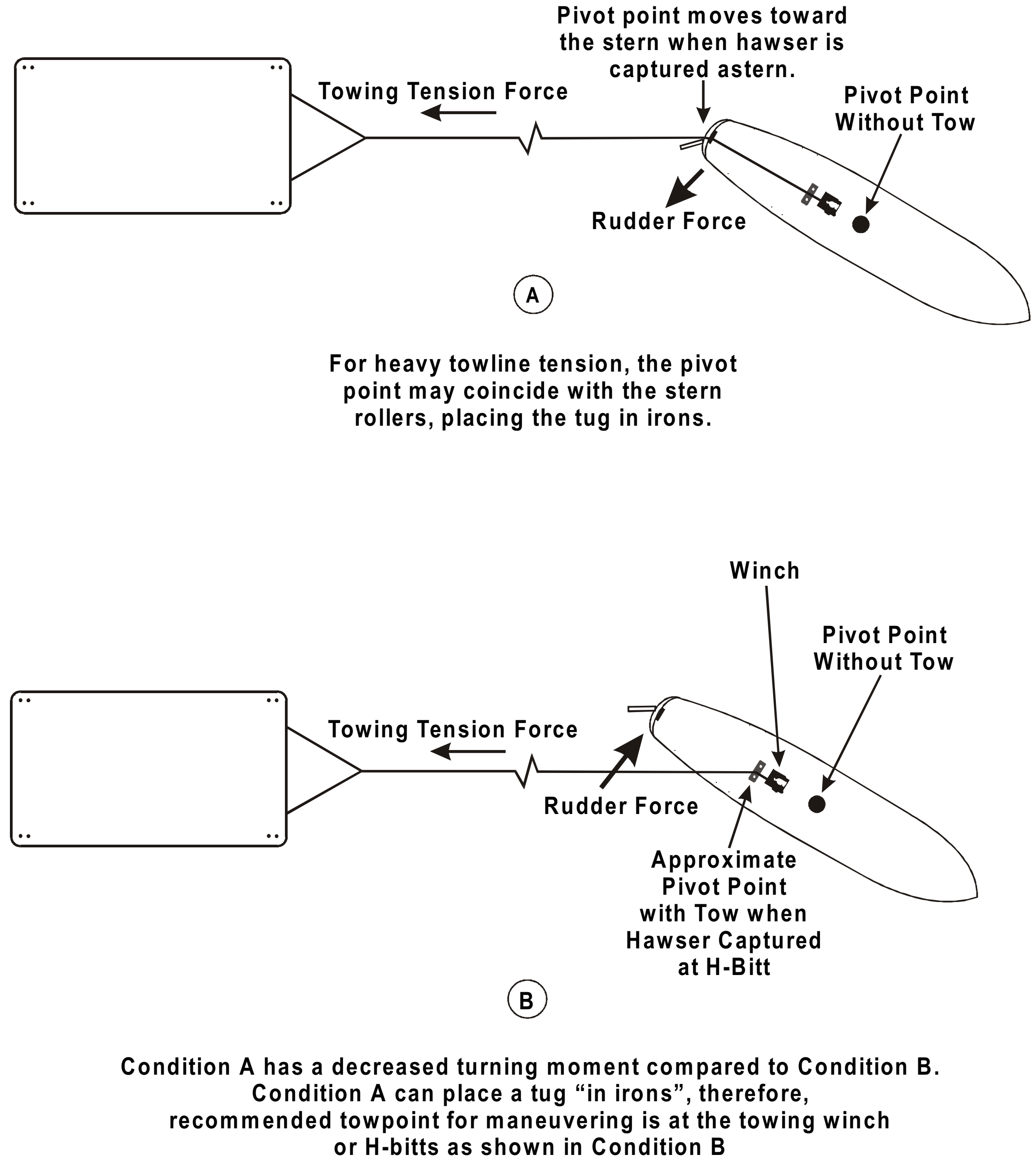


Figure 6-6. Effect of Towpoint on Steering.

whether to use active steering rests with the tug.

6-3.3.2 Yawing and Sheering of the Tow

Most tows will yaw somewhat—that is, oscillate in heading about the base towing course, usually in response to wave action on the tow's bow or stern. This is not a serious problem in itself. Many tows, however, will also sheer off to the side, where the tow's track is offset from the tug's track. This may be especially prevalent in beam winds for ships with large deck houses aft.

The vessel may remain at a nearly constant sheer angle or sheer from side to side, remaining at each side for as much as 10 minutes or more. Excessive sheering will cause excessive chafing of the towing rig, additional strain on the towline, reduction in tow speed, and possible collision or stranding in restricted waters. In extreme cases, the tow can range up to a position abeam or even ahead of the tug.

Sheering may be initiated by an external force or disturbance such as wind or wave action. Tows with bulbous bows tend to sheer more than those with "fine" bows. Improperly rigged bridles can also cause sheering. Legs of unequal length can generate a sheer problem with the tow.

Yaw can also lead to sheering. Depending on the tow's inherent maneuvering characteristics, the amount of yaw and sheer may range from small to substantial. In general, a tow is considered directionally unstable if the sheer angle continues to increase from swing to swing, despite an absence in the force that initially caused the motion. The following paragraphs discuss ways to control the factors that influence yawing and sheering.

6-3.3.3 Trim

Before undertaking the tow, the towed vessel should be trimmed by the stern slightly as described in Section 5-7.2. Trimming by the stern makes the towed vessel less susceptible to yawing.

6-3.3.4 Speed

Yaw of the tow may be increased or decreased with a change in speed; a range of tow speeds may be attempted in an effort to obtain a desired reduction in yaw.

6-3.3.5 Use of Rudder or Skegs

If the tow is tracking poorly but is steerable, the rudder can be used to reduce or eliminate yawing and sheering. Active use of the rudder, however, increases drag and adds the risk of steering machinery failure at a permanent rudder angle. Hull damage may cause the tow to take up a permanent sheer angle. In this case, permanent adjustment of the rudder can significantly improve the tow's behavior.

If excessive yawing occurs on a movable twin-skegged tow, each skeg can be splayed at an outboard angle. Although the drag will increase, the directional stability should improve. Outboard splaying is commonly done on barges and the technique has been successfully applied to twin-ruddered ships and floating dry docks. All such rudder or skeg movements should be made in moderation to achieve optimum towing performance with minimum increase in drag.

6-3.3.6 Location of the Attachment Point

A point of bridle entry into the tow may be selected to offer an optimum angle, and thus eliminate or reduce excessive yaw or sheer. Steps must be taken to prevent towline chafing and to ensure that a fairlead is sufficiently robust. As an example, the LST 1179 Class requires either a bridle or an off-centerline pendant because of the bow doors. Towing is performed through a mooring chock on the side. These ships tow quite steadily with a very slight sheer.

6-3.3.7 Propellers

A locked propeller will create a larger drag than a free-wheeling propeller, thereby resulting in reduced towing speed. The additional drag in the stern due to a locked propeller, however, may decrease the tendency of the vessel to sheer off from the intended track. Refer to Section 5-7.1.7 through 5-7.1.11 for information on preparing the propellers for tow.

6-3.3.8 Steering Tug

The addition of an operational ship astern of the tug can offer effective steering control of a tow. The trailing ship can use its engines and rudder to maintain a light tension on a line to the tow. Following steering orders from the tow ship, it can assist in keeping a tow from sheering off.

6-3.3.9 Sea Anchor or Drogue

An object towed from the stern of a tow will create a drag that acts to resist yawing motions. Nets, anchor chain, line, wire, kite anchors, mine-sweeping gear, and a wide variety of other drogues have been used as stabilizing devices on small tonnage or shallow draft ships, especially those with fine hull forms. Care should be taken to prevent snagging of the drogue in shallow water.

6-3.3.10 Bridle vs. Single Lead Pendant

Certain hull forms are more conducive to being towed by a single lead pendant. Submarines and ships with bulbous bows or forward sonar domes tow better on a single pendant than on a bridle. In general, fine lined ships should be towed with a single leg and broad beamed ships towed with a bridle.

6-3.4 Backing Down with a Tow

CAUTION
Except in an emergency, backing down with a tow is not recommended. It may be attempted if a collision with another ship is imminent.

If backing down is necessary, take great care not to foul the towline in the propeller. Tow position and speed of advance must be considered to avoid collision.

For information on anchoring with a tow, refer to Section 6-7.5.

6-4 Routine Procedures While at Sea

WARNING
Motions of the tug and tow can cause the towline to change positions rapidly and without warning. Personnel must be aware of the potential danger of a sweeping towline and remain clear of all areas that may be within this sweep.

This section deals with procedures that are performed at sea on a routine basis but deal specifically with towing. Each tow is unique, of course, and will present unique problems and challenges, but some general guidelines apply.

6-4.1 Setting Course

When adequate sea room is achieved, maneuver to set course and begin streaming the tow. Do not stream to full scope until sufficient water depth is available to keep the towline from dragging.

6-4.2 Towing Speed

Safe towing speed is determined by many factors, including material condition of the tow, currents, sea states, towing direction relative to the surface waves, wind velocity and direction, hull type of the tow, tug horsepower, capacity of the towline system, and available powering assistance from other tugs or the tow's power plant.

The towing speed should be chosen to minimize the probability of damage to the tow. When towing damaged vessels and flat-bottomed craft, try to avoid excessive seakeeping motions and pounding. When necessary, towing course and speed should be chosen relative to the sea state and wind direction to keep a towed vessel motions within safe limits.

Barges generally should not be towed faster than about 8 knots under mild sea conditions. Small service craft and some dry docks should be limited to about 6 knots. Deterioration of weather conditions requires appropriate speed reduction to ensure continued safe towline loading. When towing larger surface ships, the speed limitation usually is a function of the tug's capabilities. Sometimes, however, the dynamic loads induced by the ship motions of a tug and tow in a seaway will be the controlling factor in determining a safe towing speed (as opposed to the safe towing speed of the towed vessel or the capabilities of the tug). Appendix M contains data about the way ship motion affects dynamic towline loads.

6-4.3 Towline Scope

To estimate the towline scope required, follow these steps:

1. Choose a candidate scope
2. Estimate steady towline tension (see Section 3-4.1.3)
3. Compute catenary (see Section 3-4.2)
4. Estimate maximum and minimum towline tensions
5. Ensure that catenary will not exceed water depth at minimum tension (A maximum scope for the water depths expected should also be calculated.)
6. Adjust the scope as necessary and repeat steps 1 through 5.

The scope should be adjusted to provide an adequate catenary for absorbing changes in towline tension without exceeding water depth. Dragging a towline on the sea floor will damage the hawser through abrasion and could lead to fouling on a sea floor obstruction. Also, once the hawser is in contact with the bottom, the tug no longer has control of the tow and is in danger of being overtaken.

If the surface wave pattern has a predominant wavelength, attempt to adjust the towline scope so that tug and tow ride on crests of the predominant wave components at the same time. Adjusting the towline this way may keep tug and tow "in step," thus reducing changes in towline tension caused by seakeeping motions (see Section 3-4.1.4).

6-4.4 Towing Watch

With the tow streamed, the towing watch must be set to observe the tow, towing loads, towing machine, towline, and the tow's seakeeping performance. The tow watch must routinely advise the Officer of the Deck of conditions observed. On board newer tugs, much of the information is automatically displayed in the pilot house and control stations.

6-4.5 Periodic Inspection of Tow

Elements of the tow's material condition should be visually inspected and continuously monitored, even at night. They include:

- Flooding and fire alarms, navigation lights, draft marks, and trim
- Sheer angle and seakeeping
- Timing of roll period for stability.

To supplement the flooding alarms, tug watch personnel should be alert to signs of flooding such as list, excessive drag (increase in towline tension without a change in conditions), change in roll period, or unexpected trim in the tow. The towline should also be inspected frequently for chafing and damage during a tow.

It is common practice to "freshen the nip" or "nip the tow" to avoid chafing. This is the practice of changing the scope of the towline so no single point is continuously in contact with the caprail.

6-4.5.1 Boarding the Tow for Inspection

When carrying a riding crew, the crew performs most of the inspection functions. Long distance and valuable tows without a riding crew should be periodically boarded and inspected, preferably by the same personnel on each inspection. Because this operation is often difficult and hampered by weather and sea conditions, inspection preparations should be well planned and promptly and efficiently executed. The following suggestions may aid this process:

- When possible, consider seeking the lee of a land mass to make the operation safer, easier, and more controlled.
- Shorten up the tow, this provides an opportunity to inspect the towline and any part of the tow rig that can be brought aboard safely.

6-4.5.2 Inspection Guidelines

WARNING
Carefully adhere to safety requirements when entering closed spaces. See Naval Ship's Technical Manual (NSTM) S9086-CH-STM-030, Chapter 074, *Gas Free Engineering* (Ref. K)**.**

A written account should be kept of each inspection, to be used as a reference for following inspections. The tow inspection party should perform the following:

- Check the tow connections and bridle for integrity and unusual wear.
- Check propeller shaft locking system.
- Check rudder locking system.
- Check navigational lights and batteries.
- Check flooding and fire alarm system.
- Visually check open habitable compartments and topside areas.
- Sound any suspicious or questionable voids, double bottoms, and liquid tanks.
- If indicated, visually check structural framing and hull plating in the bow.
- Operationally check fire fighting and dewatering equipment weekly, or more often if conditions warrant.
- Upon completing the inspection, close and make watertight all hull access openings. Any additional checks appropriate to the peculiarities of the tow should be incorporated as needed into the inspection checklist.

6-4.6 Towing in Heavy Weather

Long ocean passages rarely offer the opportunity to plan for favorable weather during the entire tow. Seasonal storms and sudden, unexpected weather can cause difficulty for both the tug and the tow. Hurricanes and typhoons are the most dangerous and destructive of all storms. Advice on actions to take in the event of such storms is contained in Chapter 18 of *Knight's Modern Seamanship* (Ref. L).

Upon receiving a hurricane warning, take these steps:

- Determine the location and track of the hurricane to plan a course that avoids the dangerous semicircle.

CAUTION
Running before the sea and wind can cause difficulty in steering and in keeping the tow in the desired position. The tow may become awash or start to overtake the tug. If the tow begins to close on the tug, the tension in the towline will be reduced and cause an increase in the catenary, which may also cause the towline to snag on the bottom or bring the tug and tow to collision. The recommended course of action is to head into the weather and maintain steerageway, increase hawser scope and, as long as there is enough sea room, tolerate a negative speed over the ground. There is no reason to slip the tow unless the towing ship is in danger of grounding.

- If necessary, change course to avoid or ride out the storm. It is far better to depart from the projected track, ride out the storm, and accept delays than to endanger the ship and tow by remaining on a dangerous course and speed.

CAUTION
Under more strenuous sea conditions, dynamic hawser tensions can be significantly higher when towing downwind than when heading into wind and seas at the same speed and power. Turning into the wind and seas and slowing to maintain steerageway are appropriate actions under such conditions.

NOTE
If water depth permits, increase the towline scope and use the automatic feature of the towing machine in heavy weather. This enhances shock load reduction for the towline system. Every vessel rides differently in severe storms. Tug captains should use good seamanship to determine how their tugs and tows ride best. They should use the best combination of towline scope, speed, and heading. Generally, heading into the weather allows better control of the tow.

Estimate size and direction of the waves. Review applicable data in Appendix M to establish average hawser tension limits for different wave heights and directions. Determine whether extreme tension predictions can be eased by slight changes in course away from towing directly into the wind.

- Recognize that the tug and tow likely will make negative speed over the ground. Sail for a position that will minimize navigational hazards on a downwind track.
- Rig the fantail for heavy weather. Stern rollers and Norman pins should be down and other obstructions to the towline cleared.
- Increase hawser scope, if possible.
- Set the towing machine on automatic if it has an automatic feature. Otherwise, tow on the brake, rather than on the dog, to ensure rapid reaction to changing circumstances.

- Arrange for quick disconnection of the towline. Methods for slipping the towline are discussed in Section 6-7.3.2.

6-4.7 Replenishment at Sea

Long ocean tows or emergency circumstances may require the tug to replenish at sea. Replenishment at sea is a well-established routine, with procedures documented in Naval Warfare Publication (NWP) *MSC Handbook for Refueling at Sea,* NWP 14-2 (Ref. M). The methods outlined there are suitable for passing fuel, water, and other logistic necessities to a tug with a tow. The method selected is influenced mostly by sea and weather conditions, bearing in mind other factors that affect safe and efficient ship handling. Due to reduced maneuverability of a tug with a tow, consideration should be given to having the supply ship maintain station on the tug, vice the receiving ship maintaining station. It may be advantageous to replenish from astern of the replenishment ship due to speed and maneuvering limitations. It is also possible to replenish from the tow.

6-4.7.1 Transferring Personnel and Freight

Simple light line procedures are used for transferring small freight. During these transfers it may be advantageous, as in fueling, for a transferring ship to keep station on the tug.

Personnel and mail should be transferred by boat or helicopter. In unusual circumstances, personnel can be transferred by rigging a high line, or, if necessary, a Stokes stretcher. Conditions permitting, a rubber raft or boat should be used to avoid the maneuvering restrictions of underway replenishment.

6-4.7.2 Emergency Replenishment

Emergency conditions, wartime operations, or heavy weather may require great ingenuity to replenish the tug or tow. Water and fuel can be received from the tow, if available, by shortening the towline and streaming hoses from the tug. In calm seas, the tug may go alongside the tow to effect necessary replenishment. This requires disconnecting the tow, but in calm seas reconnecting should pose no problem.

6-4.7.3 Rigging and Use of Fueling Rigs

Surging, often experienced in towing, may require that the replenishment ship keep station on the tug. The greater maneuverability of the oiler and the lack of complete control by the tug recommend this procedure. The tug designates the fueling station, receives the hose, and proceeds to take on fuel while employing standard precautions of proper stability, safety on deck, adequate communication, and proper navigation. Astern refueling is also recommended.

6-4.7.4 Astern Refueling from Another Tug

Being refueled astern from another tug while towing has become a common procedure due to the limited number of replenishment ships. This process is somewhat different than that described in NWP 14 and can be accomplished with or without the sending ship taking the receiving tug in tow. Due to the slow pumping rates available, however, taking the receiving tug in tow does simplify station keeping in what is sometimes a 24 to 36 hour operation.

6-4.7.5 Replenishment Near a Port

The towing ship can arrange a temporary transfer of the tow to a local tug or tugs (see Section 6-5.5). Then the ocean tug enters port to replenish, while the tow is maintained offshore by a temporary replacement tug, or offshore mooring. When replenishment is finished, the towing ship returns, the tow is retransferred, and the journey resumes.

If a long replenishment is anticipated, it may be more economical to seek temporary docking for the tow.

6-5 Terminating the Tow

Terminating the tow at its destination requires as much planning as any other phase in towing. If the schedule and the condition of the tow permit, it is generally best to adjust speed to arrive at destination during daylight hours. Darkness can easily magnify a routine evolution into a more difficult and dangerous situation. Based on the nature of the tow, pilot assistance and/or harbor tug assistance might be required.

6-5.1 Requesting Assistance

The Commanding Officer decides when to use a pilot, unless an order from senior authority supersedes. Some pilots, however, may be unfamiliar with towing and with the characteristics of the tug. If a pilot is not familiar with towing, it may be preferable to employ him as an advisor to the Conning Officer rather than giving him the conn. The Commanding Officer should be alert to difficulty and relieve the pilot if he deems it necessary.

Harbor tug assistance may also be necessary. Sea conditions may not permit harbor tugs to make up alongside. In this case, the only significant assistance that can be rendered is for the harbor tug to put a head line to the tow's stern to assist in steering the tow. Once within sheltered waters, harbor tug assistance can be used as required. If an additional tug is available, it and the original tug can be made up, each on a quarter, to effectively keep the tow heading fair to the channel. If the tow is large and unwieldy, additional tugs may provide both steering assistance and propulsion power. When using multiple tugs, it is advisable to have pilots on board both the tug and the tow to coordinate control of the assisting tugs.

6-5.2 Shortening the Towline

When approaching restricted waters, a shorter scope and slower speed will make the tow easier to handle. It may be necessary to bring a tow to short stay to prevent the towline from fouling on the bottom. Bringing a tow to short stay avoids being overtaken and fouling the towline. A delicate balance must be maintained between scope and speed. In this situation, an automatic towing machine is invaluable. Because there will be little or no catenary, automatic control of the towline or the use of a synthetic spring (see Section 4-6.5) are the only means of surge control available. An automatic towing machine can shorten the scope in either automatic or manual modes. Often where there is a long distance from sea buoy to berth, the ocean tug may continue to tow, at short stay, to a convenient and safe location well inside the harbor.

6-5.3 Disconnecting the Tow

Before actually disconnecting the tow, lay out necessary equipment, energize potentially involved machinery, and brief all personnel on procedures. A well-drilled, disciplined team will perform the routine smartly and will also be responsive to any unexpected occurrences.

Disconnecting procedures start by reducing speed to bare steerageway and bringing the tow up short with the towing winch. With assistance from whatever harbor tugs are in attendance, the towline is shortened until the connection fittings are on deck. A stopper is passed onto the pendant, the connection is broken and with all personnel clear, the stopper is released.

CAUTION
Do not permit the disconnected pendant or bridle to drag on the bottom — it can cause considerable additional resistance and seriously disrupt maneuvering.

When a tow bridle is long enough, the pendant can be brought fully aboard the tug and disconnected at the bridle apex. This may keep the pendant from dragging the bottom. The bridle and pendant may also be retrieved on the tow by using a previously rigged retrieving line at the bridles apex. (see Figure 4-18).

When slowing, the towline scope may need to be reduced to prevent dragging the bottom. A decrease in speed will cause a decrease in towline tension when the tow closes on the tug. As the tug and tow separate again, an increase in tension will occur. Deceleration, like acceleration, must also be done in a controlled and judicious manner. (See Section 6-7.5 for information on anchoring with a tow.)

6-5.4 Towing Delivery Receipt and Reports

If a harbor tug master is authorized to receive the tow formally, he should be asked to do so. This allows physical and legal transfer in stream without having to dock or anchor. If the harbor tug master is not authorized, it may be necessary to send personnel ashore to obtain necessary signatures on the letter of acceptance. Sample forms for receipt of tow and towing reports can be found in Appendix H.

6-5.5 Transferring the Tow at Sea

Casualty, operational orders, weather, or other unusual circumstances may require transferring the tow to another tug. Preparing for transfer and understanding the transfer procedure will ensure success and minimize difficulty. If possible, personnel from both vessels should review and agree on a plan prior to any action. Emergency conditions may not allow this.

The following procedure may be used for disconnecting the towline and passing the tow (see Figure 6-7).

a. Set a course into the seas and reduce speed.

b. Heave in until the pendant is on deck.

c. Signal the receiving tug to come close aboard on the designated side on a parallel course.

d. Secure tow bridle or pendant on deck with a chain stopper; allow sufficient length to lay on deck to facilitate disconnection from the hawser.

e. Break the tow hawser from the pendant.

f. Receiving tug passes a messenger connected to the bitter end of its hawser or to a messenger strong enough to control the tow.

g. Bring the receiving tug's hawser or heavy messenger on deck and bend it onto the tow pendant.

h. With all lines and personnel clear, trip the stopper and transfer the tow to the receiving tug.

i. If a messenger was used, the receiving tug makes the final connection to the tow pendant on its own stern.

j. All special equipment and personnel associated with the tow are then transferred and appropriate documentation completed.

6-6 Tow and Be Towed by Naval Vessels

All U.S. Navy ships (except submarines and aircraft carriers) are capable of towing, using their own emergency towing hawsers. When two Navy ships are involved in a "tow and be towed" operation, each provides its own emergency towing hawser to form half of the total towing system (see Figure 6-8).

Some Navy ships may be equipped with old, little-used hawsers. These ships may not be aware of the recently understood problems with deterioration of nylon rope over time. All should be alerted to current directives concerning replacement of emergency towing hawsers. Double-braided polyester hawsers (MIL-R-24677) are preferred.

6-6.1 Towing Systems

Navy combatant surface ships have a towing pad and stern chock aft and a chain stopper pad (towing pad) and bow chock forward. Sometimes, because of equipment interference, the stern chock and towing pad are located on the quarter.

In addition to these deck fittings, Navy surface ships carry a towing hawser, chafing chain, pelican hook, shackles and other appendages needed for emergency towing operations.

Each ship in the Navy is provided with a towing drawing that shows how to rig the ship for being towed or for towing another ship. This drawing also shows such details as towing hawser size, chafing chain, and other appendages. For surface ships and some submarines, the Ship's Information Book (SIB) has details on their towing gear and also contains diagrams that illustrate how to rig for being towed or for towing another ship.

Aircraft carriers are only equipped to be towed. They do not have a padeye or other towing equipment located aft for towing another ship. Carriers are equipped with a 2-1/2 inch diameter 6 x 37 galvanized wire rope, 900-foot towing hawser. The towing hawser is stored in the anchor handling compartment on a horizontal storage reel.

Some submarines carry a towing bridle on board, but in some cases (SSBN 726 Class), the towing gear is stored ashore. In this case, this equipment shall be provided by the towing ship. Submarines are built with the necessary towing pads, cleats and chocks for being towed. When not in use, the cleats and chocks are arranged to retract and are housed inside the faired lines of the hull. See Appendix J for more detail concerning submarine towing.

6-6.2 Towing Procedures

The information presented here is taken from *NSTM CH-582* (Ref. A) which is the governing document for emergency ship-to-ship towing. Where this manual and *NSTM CH-582* differ on this topic, *NSTM CH-582* shall take precedence. Consult this reference for greater detail.

6-6.2.1 Procedure for the Towing Ship

1. Connect the pelican hook to the after-towing pad with a shackle.
2. Connect the chafing chain with an end link to the pelican hook. Lead the chafing chain through the stern chock.
3. Connect the towing hawser end fitting to the chafing chain with a detachable link.
4. Fake down the towing hawser clear for running fore and aft. Stop off each bight of the towing hawser to a jack stay with 21-thread. Place shoring under the stops for ease in cutting.
5. Connect the NATO towing link to the free end of the towing hawser. If a NATO towing link is not available use an appropriate size long link or shackle. This fitting should be capable of being connected to the hawser of the towed ship.
6. Connect a messenger, composed of approximately 100 fathoms (600 feet) of three-inch circumference line and 50 fathoms (300 feet) of 1-1/2 inch circumference line (For a 10-inch circumference or

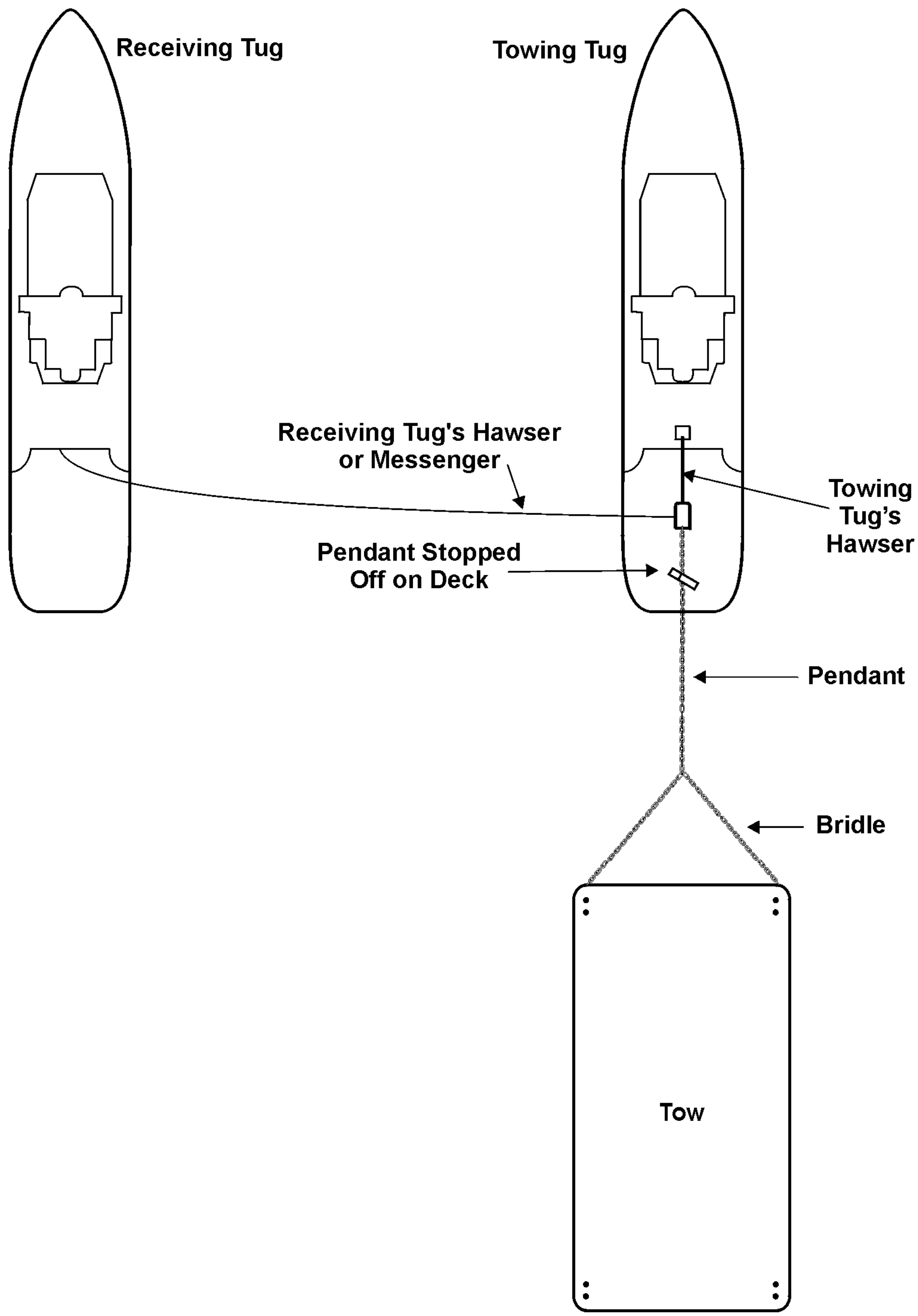


Figure 6-7. Passing a Tow at Sea.

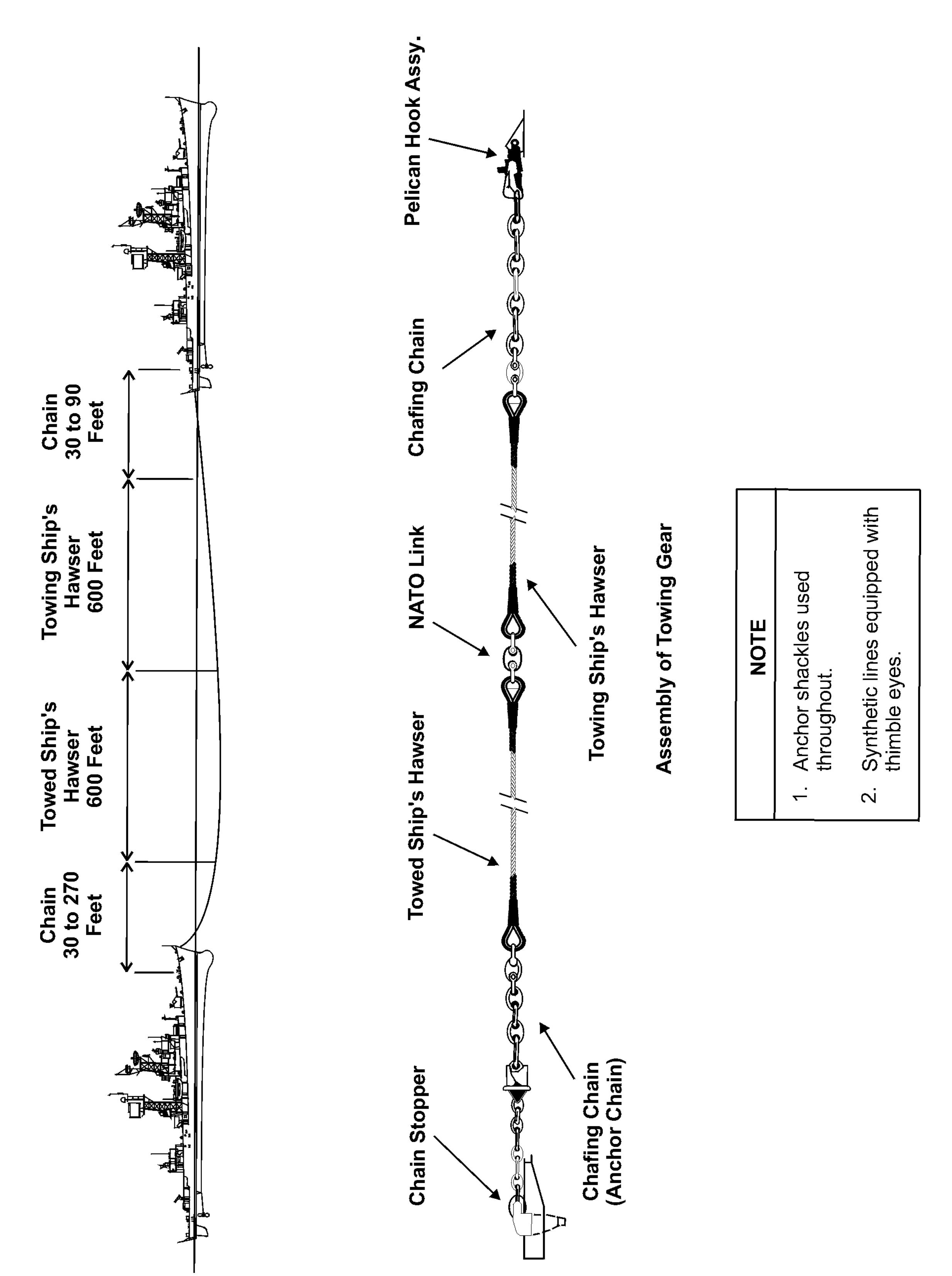


Figure 6-8. Tow-and-Be-Towed.

larger hawser, use four-inch line instead of three-inch), to the outboard end of the towing hawser. Lead the free end of the messenger through the stern chock.

7. Pass the messenger to the towed ship using a heaving line. Preparing extra heaving lines prior to hook up will allow several attempts to complete this pass during maneuvering. Control the pay out of the tow line messenger and hawser by cutting the stops. The tow line messenger and hawser should be payed out gradually to ease handling of the tow line by the towed ship and to avoid fouling the towing ships propellers.

6-6.2.2 Procedure for the Towed Ship

1. Stop off the anchor (port or starboard) of the anchor chain to be used. Set up on the anchor windlass brake. Pass a pinch bar through the chain, letting the bar rest on the lip of the chain pipe, or pass a preventer to prevent the chain from backing down into the chain locker and a preventer on the anchor to back up the stopper. Break the anchor chain at the detachable link inboard of the swivel. If power is available, haul out the desired length of chain using the anchor windlass. If power is not available, the chain will have to be hauled out manually.

2. Shackle the towing chain stopper to the designated (towing) padeye on the forecastle, for stopping off the anchor chain after the tow is properly adjusted.

3. Fake out the towed ship's hawser on deck, fore and aft, on the forecastle for clear running, prior to connecting it to the anchor chain. Use the towing ship's messenger to haul the towing hawser from the towing ship on board through the bullnose. Connect it to the towed ship's hawser secured to the end of the anchor chain. If the towed ship's hawser is not to be used, connect it to the anchor chain.

4. Pay out sufficient anchor chain (5 to 45 fathoms [30 to 270 feet]) to provide a substantial towing catenary when the towing hawser has been payed out. Synthetic line, by itself, will provide very little catenary.

5. Set the brake on the wildcat and pass and equalize the chain stoppers one outboard and one inboard of a detachable link, to take the strain on the towed ship's anchor chain. Disengage the wildcat.

6-6.2.3 Quick Release of Towed Ship

1. Pay out the anchor chain connected to the tow line on board the towed ship so that a detachable link is just forward of the anchor windlass.

2. To prevent the chain from returning to the chain locker when detached, pass chain stoppers on the anchor chain and lash the anchor chain just abaft of the detachable link or apply the chain compressor where fitted.

3. Disconnect the anchor chain between the anchor windlass and the chain stoppers so that only the chain stoppers are holding both the anchor chain and tow line. This arrangement allows quick release of the towing hawser and chain.

CAUTION
In case of emergency, for quick release, tripping the pelican hook on the towing ship is faster than the above procedure.

6-6.3 Getting Underway with Tow

Implement the following steps when the towing hawsers are connected and both ships are ready to start the tow:

1. The towing ship should come ahead as slowly as possible as the hawser begins to take strain. Increase turns slowly until the inertia of the tow is overcome and both

ships are moving with a steady tension in the hawser. Increase speed slowly until the desired speed is reached. At no time should the tow speed be such that the tow hawser lifts completely out of the water. The course of the tow may be changed gradually, as necessary. Getting underway with a tow will likely result in the largest tensions and requires the most care.

2. Pay out or haul in (assuming power is available to the anchor windlass) anchor chain as desired to keep both ships in step (that is, taking wave crests at the same time). When a comfortable distance is found, the chain stoppers are passed on the anchor chain and the strain is equalized between stopper and wildcat. Locking plates are installed and set on both the chain stoppers.

6-7 Emergency Towing Procedures

CAUTION
Riding crews normally consist of a minimum crew and can be expected to perform only limited emergency functions on board.

This section presents general guidelines for handling emergency situations unique to towing. As in all emergencies, prudent seamanship and adherence to safety guidelines are primary assets in bringing a situation safely under control.

6-7.1 Fire

Fire on board is a well-known hazard; fire prevention and methods of fighting fires should be drilled with the riding crew. There should be little danger of fire on board an unmanned tow. One exception is the possibility that a shaft locking device might fail and cause an engine room fire.

When a riding crew is on board, the fire potential should be evaluated. If equipment is being operated for propulsion, auxiliary power, pumps, or allied systems, the danger of fire can be significant. Prudent and adequate placement of pumps, hoses, fire extinguishers, axes, foam, and fire fighting equipment is required to help the riding crew fight fires. If necessary, personnel may be transferred from tug to tow to perform fire fighting and damage control. The tug, if it can be brought alongside, can deliver large quantities of water for use on board the tow; associated power, foam, hoses, and personnel from the tug can be of valuable assistance. A charged 2½-inch fire hose can be streamed aft on salvage balloons if alongside fire fighting is not practical.

6-7.2 Tug and Tow Collision

CAUTION
When towing under unfavorable conditions, inclement weather, or at short stay, danger exists of being overridden. In such a situation, particular care is advised in setting an underway material condition so that watertight doors, hatches, and other openings are secured.

The tug and tow may collide when maneuvering in restricted waters with the tow at short stay, or under other operationally complex circumstances. A collision may also occur when:

- There is a loss of propulsion power or sudden reduction of the tug's speed. With sufficient way on, the tow may override the tug, and in extreme circumstances sink it. The possibility is greater if a tow is at short stay. If propulsion power is lost on the tug, put the rudder hard over to the weather and slack the towline. With sufficient way on, the tug may fall clear of the advancing tow. If power loss is imminent but the tug can still make turns, consider going alongside or otherwise clearing the tow.

- Tug and tow will experience different set and drift from seas, currents, winds, or towline drag. To avoid collision, reduce speed and increase the towline scope. If possible, the tug should turn into the predominant set, if the tow has a larger sail area. This will cause the tow to drift away from the tug. Follow the opposite course if the tow's sail area is smaller than that of the tug, as in the case of a submarine.
- A tug and tow are dead in the water, allowing towline cantenary to draw them together. The same situation can occur between two tandem tows. In an emergency in shallow waters, it may be possible to anchor both tug and tow by letting the towline come into contact with the bottom. (Routine use of this practice is discouraged because of possible towline damage.)

If a collision appears unavoidable, deploying fenders may serve to reduce or eliminate damage to both vessels.

6-7.3 Sinking Tow

Planning to sink a tow also requires special consideration and preparation. Often, special permission must be obtained and adherence to environmental regulation can be difficult. Caution should be used when accepting a tow with the intention of sinking. This may be the case following a salvage operation.

CAUTION
When combatting a sinking tow, conditions can deteriorate rapidly. The boarding party should have sufficient survival gear and should be prepared to abandon at any given moment.

Flooding, structural damage, shifting of ballast or cargo, or other events may degrade the tow's stability. When stability decreases, the tow may be in danger of sinking. Excessive force placed on the tug as the tow sinks can damage and seriously endanger the tug before the towline parts. Prompt action is necessary to save the tow and to ensure the safety of the tug.

It is vital to monitor the condition of the tow during transit. Trim, list, roll period, seakeeping, and draft are monitored from the tug or by a riding crew. Upon noting an irregularity, a boarding party should be dispatched, if possible, to investigate and correct any deficiency on board the tow. If the material condition of the tow is so deteriorated that sinking is likely, the tug should consider the following courses of action.

6-7.3.1 Beaching a Sinking Tow

When towing a casualty or a vessel that is likely to sink, beaching may be the best way to save the tow. The decision to beach the tow is operational and should be based on an assessment of conditions. Weather conditions, rate of deterioration of the tow, damage control equipment available, and distance to safe port should all be considered when deciding whether to beach a tow. Permission to beach should be obtained from the cognizant authority when feasible. Authorization to beach a tow should be made by immediate message or voice communications when feasible. Significant time may be required to steam to a suitable site. It may be impossible to locate a smooth beach in time. If pumps are on board the tow and damage control procedures are employed, the tow may be kept afloat for days before beaching, but indecision has resulted in tows sinking.

When beaching a tow, follow these guidelines:

- When possible, select a beach with a smooth, gradually sloping bottom. Avoid rocky shores with breaking surf.

Potential loss of the tow and danger to the tug exist in shallow, rocky waters.

- Ground the tow with the bow toward the beach. The tug's assistance may be required to put the tow on the beach bow first. If water depth is sufficient, the tug can tie up alongside in the lee of the tow and take the tow in. The alternative practice of allowing a tow to drift onto the beach should be avoided. This can increase the likelihood of broaching and cause increased damage to the tow as well as make recovery more difficult. Assistance from a small, shallow draft harbor tug is very valuable when beaching a tow.

- Disconnect the pendant and bridle before beaching, when possible, to prevent the tow from stopping short of the beach.

- Prevent the tow from broaching and sustaining additional structural damage due to excessive hull loading. Flooding the tow can prevent it from broaching or going further aground. The ship should be set down hard enough so that it will not be too light and, consequently, broach at high tide. It should be assumed that in time the tow will be pulled off; however, this does not eliminate the need for securing it properly and preserving it until it is extracted from the beach. If the tow has a stern anchor, it should be deployed to help prevent broaching.

- Ballast the tow as soon as possible after grounding to hold it securely in position. Even in completely sheltered waters, the range of tides and consequent currents can be powerful enough to alter the position of a beached ship.

6-7.3.2 Slipping the Tow Hawser

CAUTION
Releasing the hawser under tension, or even its own weight, can be hazardous, due to retained energy in the hawser.

In emergencies, wartime conditions, or heavy weather, it may be necessary to slip the tow hawser to remove the tug from a hazardous condition. This condition could be a sinking tow, danger to the tug from weather, or a grounded tow.

Options for slipping the hawser include:

- Paying out the hawser and allowing it to run off the towing machine (free-wheeling).

- Cutting the hawser with a torch or explosive cable cutter. Synthetic hawsers under no tension can be cut with an axe.

- Rigging carpenter stoppers and cutting the cable inboard of the stopper.

- If a ship with power is being towed, it can sometimes cast off the towing pendant on the tow's bow.

If time allows, attach a buoy to the bitter end of the towline before slipping the hawser, otherwise, it will be difficult (if not impossible) to recover. Use a messenger that is at least 200 feet longer than the water depth and strong enough to lift the hawser. One end of the messenger is connected to the hawser and the other to a recovery buoy line. The buoy line must be long enough to reach the bottom and strong enough to lift the messenger, but it need not be strong enough to lift the hawser itself. The buoy should be adequately marked with a bright color, radar reflector, staff, or flag so it can be easily located.

6-7.4 Disabled Towing Machine

The main resource for recovering and storing a towline is the tow machine. If this machine fails, the tow ship should reduce speed and attempt to make repairs. The machine's mechanical brake should be set to prevent an accidental spooling off of the tow wire. If the machine cannot be fixed, it will likely be necessary to disconnect the tow, transfer the tow and recover the towline by a more difficult method. Since Navy tugs employ a 2 1/4-inch wire rope, these evolutions can be very difficult.

6-7.4.1 Disconnecting the Tow

If the tow machine fails while the tow is still connected, it will be necessary to break this connection at some point along the towline. If a retrieving wire has been rigged, this may not be so difficult. If there is power on the tow, it should haul on the retrieving wire until the connection point is on deck. A chain stopper (or other appropriate stopper) should be passed on the towline with sufficient slack to break the connection without tension on the line. It may be necessary to rig a stopper around the tow ship's towline to allow a connection to be broken. It may be sufficient to haul in slightly on the main chain pendant, and break the connection at the main towing padeye. Only stoppers with quick release capability should be used.

WARNING
When stopping the tow line for breaking, only stoppers with quick release capability should be used.

The exact disconnect method and stopper to be used is an operational decision and depends on many factors. If the tow is at its point of destination, and the main tow rig can be destroyed, explosive cutters or torches may be an appropriate method of disconnecting. The use of divers may be possible but, because of the inherent danger, should be used when there is no other solution. Shiphandling and working with heavy gear in a seaway are complicated evolutions that are made more so when there are people in the water.

If a retrieving pendant has not been rigged, the procedure is far more complicated and divers may be the only solution. Sliding a working line down a chain pendant has been done with varied success. The loop may snag on the way down or slide off during retrieval. It may be better to attempt to run a shackle along the tow wire, but this may also meet with varying success. Certainly, divers can make these evolutions more successful by providing assistance to keep the line unfouled. A better solution may be to use divers to rig a retrieval line. Depending on the length of the pendant divers may be able to attach a line at the bitter end of the chain; at the connection point. This is unlikely, though, since there will probably be a pendant longer than 90 feet. If divers are working in SCUBA, bottom times will limit the amount of work that can be done. However, divers may be able to rig a retrieving line of sufficient length to haul the main pendant on deck. By lacing small wire through links of chain 40 or 50 feet below the surface, the chain can be brought on the deck of tow ship (or an assisting vessel), once it has maneuvered alongside. The tow ship's deck machinery can be used to haul the heavy gear on board once dive operations are completed.

Dive Supervisors must be provided with an accurate and detailed sketch of the entire tow rig. This will enable them to develop a safe and efficient plan and ensure that they are prepared with the proper tools to accomplish the mission.

6-7.4.2 Recovering the Towline

Once a tow has been disconnected, it is still necessary to recover the towline without the assistance of the main towing engine. The tow ship is faced with two problems. The first, how to recover the wire and second, is where to put it once its on deck. The weight of a 2 1/4-inch IWRC wire is almost 10 pounds per foot. A typical towline scope is 1500 feet or more. This is a total weight of almost 15,000 pounds. It cannot be handled easily without machinery.

Recovering a towline can be accomplished in several ways. One way is to slip the hawser off the drum and recover it when repairs have been made. A marker buoy and suitable messenger should be rigged to the bitter end so it can be found later. A messenger should be strong enough to be able to lift the hawser on deck for the depth of water. It need not be strong enough to lift the entire hawser, but if it breaks, divers will be required to rig another messenger, and it is very likely that the hawser will not be found without the marker buoy. Moderately deep water will make this alternative impractical. Additionally, it is probably unwise for the tow ship to try to bring the hawser to shallow water. Assuming the hawser is at a scope of 1500 feet or more, the hawser will drag the bottom for some time before sufficiently shallow water is reached. This may damage the hawser or cause maneuvering problems for the tow ship.

Another way to recover towline is to use deck machinery and carpenter stoppers. This method requires a great deal of time and a large amount of manpower. Assistance from shore crews may be advisable. This method does not solve the problem of stowage. A large deck area will be needed to fake out (figure-eight) this amount and size of wire. It may be possible to hang the wire from the side of the tow ship and stop it off in bights, similar to the method used when preparing a main tow pendant on a tow, or a leg of beach gear. This process will also be laborious and time consuming.

A third method that may be used is to turn the towing drum manually. A wire can be secured to a point on the side of the towing drum and looped around the drum in the direction of reeling. A crane can pick up the bitter end and be used to lift this line and consequently turn the drum. Careful coordination between the crane operator and a crewman manning the drum brake is required to prevent accidental un-spooling of the wire. If a crane is unavailable, deck machinery can be used if sufficient blocks can be rigged to reeve the hauling wire in the right direction.

These are by no means the only methods of retrieving a tow wire, but are a few examples. Any of these methods require substantial manpower and large amounts of time. This process, like all towing procedures should be performed with close attention to safety of personnel.

6-7.5 Anchoring with a Tow

In general, anchoring should always be considered less desirable than remaining underway. Steaming with a tow may prevent many difficulties encountered at anchor. Provided that there are no limiting operational factors and there is sufficient sea room, steaming is usually the better choice. When anchoring with a tow is necessary, the following alternatives should be considered.

- Reduce speed to bare steerageway, head into the predominant set, allow the tow to remain well astern, and then reduce speed and allow the tug and tow to come dead in the water at the anchor drop point. Let the tug's anchor go and pay out the necessary scope of chain. The tow will follow as affected by set.

- Reduce speed and approach several hundred yards to port or starboard of the desired anchorage. With the anchorage position broad on the bow and approaching abeam, put the tug's rudder hard over and reduce speed; maneuver to hold at the anchoring point, letting the tow pass by. When the tow clears the tug, drop anchor.

- The tow can be taken alongside in favorable sea and wind conditions. With the tow alongside, the tug can maneuver in restricted waters, back down as necessary, and drop anchor.

CAUTION
The mooring loads of the tug and tow may be greater than the holding power or strength of the tug's ground tackle. A dragging anchor or failure of the ground tackle is possible, resulting in loss of control of the tug and tow.

In some circumstances, such as shallow water, the towline itself may be used for light holding of the tow and tug when the towline comes in contact with the bottom. Routine use of this practice is discouraged because of possible damage to the towline.

If there is little wind or current, the tug must be alert to the probability of the hawser's weight pulling the tow toward the tug, until the hawser rests on the bottom.

6-7.6 Quick Disconnect System

Most routine point-to-point tows are securely rigged with no provision for quick release, other than slipping the tow wire from the towing ship. When towing damaged ships, however, it may be desirable to provide for a quick release of the tow pendant or bridle to facilitate breakup of the tow. Even if the tow hawser has already been disconnected, the weight of the chafing pendant or bridle legs will be significant, and must be considered in selecting the means of disconnecting.

WARNING
The tow wire or bridle will likely be under tension when released, creating an extremely hazardous situation. All nonessential personnel must evacuate the area to prevent serious injury.

CAUTION
The towing ship should reduce the tension on the towing assembly by either slowing down or stopping prior to cutting or otherwise releasing the tow rig.

In the case of a damaged ship, the tow pendant or bridle legs, if chain, should be securely held by multiple chain stoppers, each bearing equal tension. If the pendant or bridle legs are wire, then provision should be made for cutting with an oxyacetylene torch, a cable cutter, or any similar device. As cutting is extremely hazardous, precautions should be taken to prevent whipping, and the wire should be seized on both sides of the intended cut. When an emergency quick disconnect is provided, make sure that all jewelry will fit through all fairleads.

6-7.7 Man Overboard

Standard man overboard maneuvers may not be feasible in towing situations, primarily because of the time involved and the tug's limited maneuverability.

- If maneuvering is limited, the tug should stop, or at least reduce speed to bare steerageway, and recover the man overboard using a boat. If the tug is stopped, take precautions to keep the tow from overriding the tug and to keep the towline clear of the propellers. Communications should be available between the boat and the tug so that the tug can direct the boat to the man.

- If the recovery requires maneuvering the ship back to the man, seamen should be stationed with heaving lines. Swimmers should be outfitted with immersion or wet suits and safety lines ready to swim out to the man.

6-7.8 Using an Orville Hook to Recover a Lost Tow

Using an Orville Hook to recover a lost tow with a chain bridle may be a viable option if a secondary towline is not available or it is not possible to recover the secondary towline.

6-7.8.1 Origin of the Orville Hook

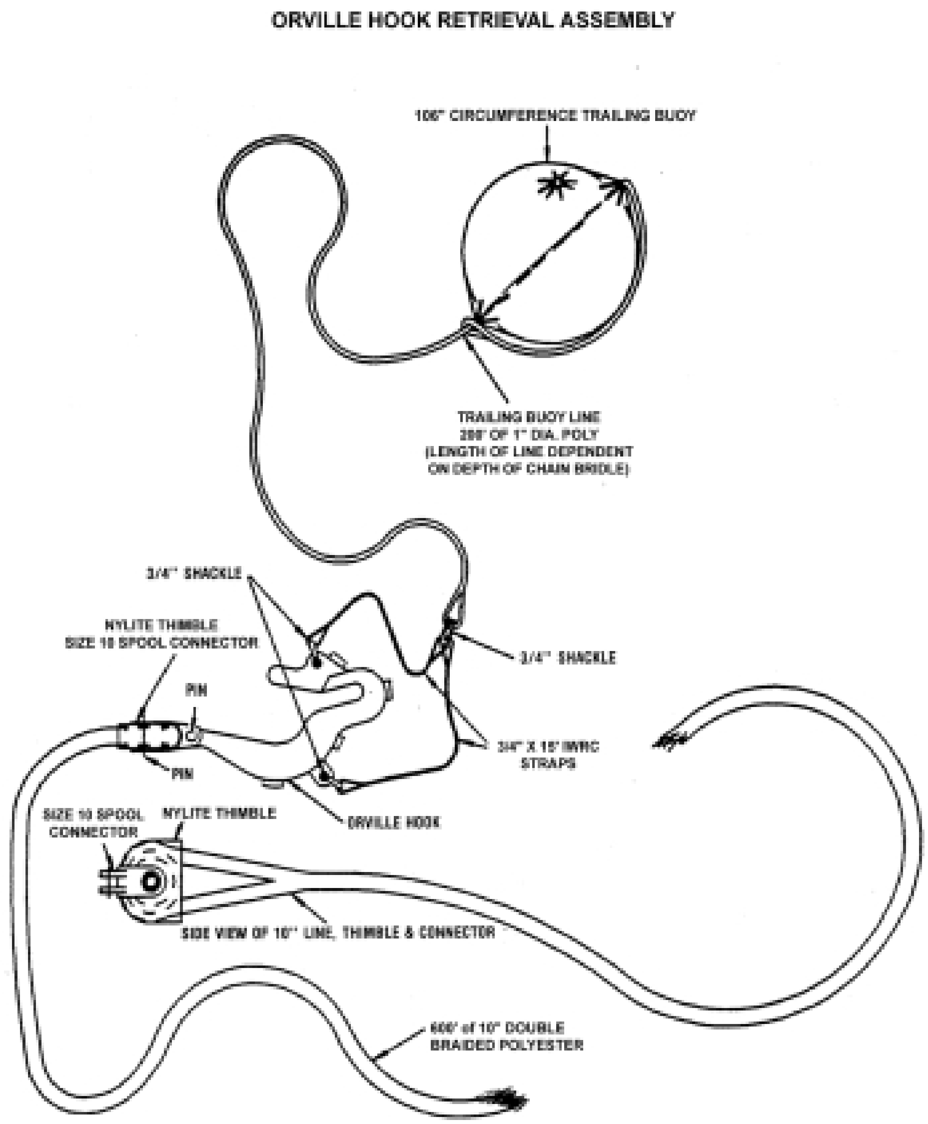
The Orville Hook was initially designed and patented by SAUSE BROS TOWING, Inc to recover lost tows which had a chain bridle. While the patent for this device has expired it still remains a useful tool for emergency recovery of broken or lost tows. This device was successfully used to recover the dry dock SUSTAIN when recovery of the secondary towline was not possible due to fouling.

6-7.8.2 Use of an Orville Hook

Orville hooks are only recommended for recovering tows which have a chain bridle. They are not recommended for recovery of wire or synthetic tow pendants.

Figure 6-9 and 6-10 depict the general configuration of the Orville Hook and its various components. Figure 6-11 depicts deployment of the Orville Hook.

The Orville Hook is suspended in the horizontal plane by a trailing buoy and is towed parallel to the tow by the recovery tug. Once the recovery tug has overtaken the tow by a sufficient distance dictated by the length of the towline, the recovery tug swings across the bow of the tow thereby snagging the mouth of the Orville hook on the chain bridle. The Orville hook is sized to fit between the individual links of the chain. In most cases the Orville hook will remain in place as long as tension is kept on the synthetic pendant. The synthetic pendant can then be retrieved along with the chain bridle so a more permanent connection can be made between the tow wire and the chain bridle.



ORVILLE HOOK (1)
NO. 10 SPOOL CONNECTING LINK (2)
PIN FOR CONNECTING LINK TO HOOK (1)
PIN FOR CONNECTING LINK TO SPOOL (1)

NYLITE SPOOL AND SHIELD ASSEMBLY (2)
42" CROWN BUOY

Figure 6-9. Orville Hook Retrieval Assembly

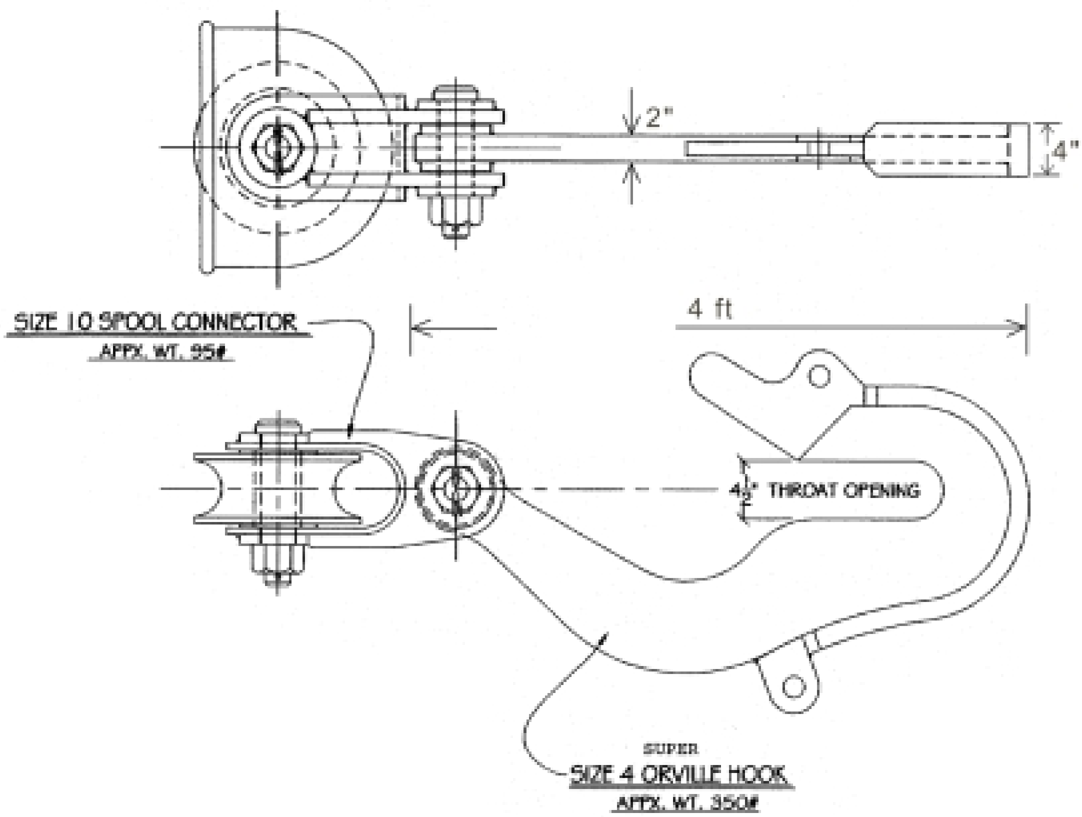


Figure 6-10. Orville Hook Configuration

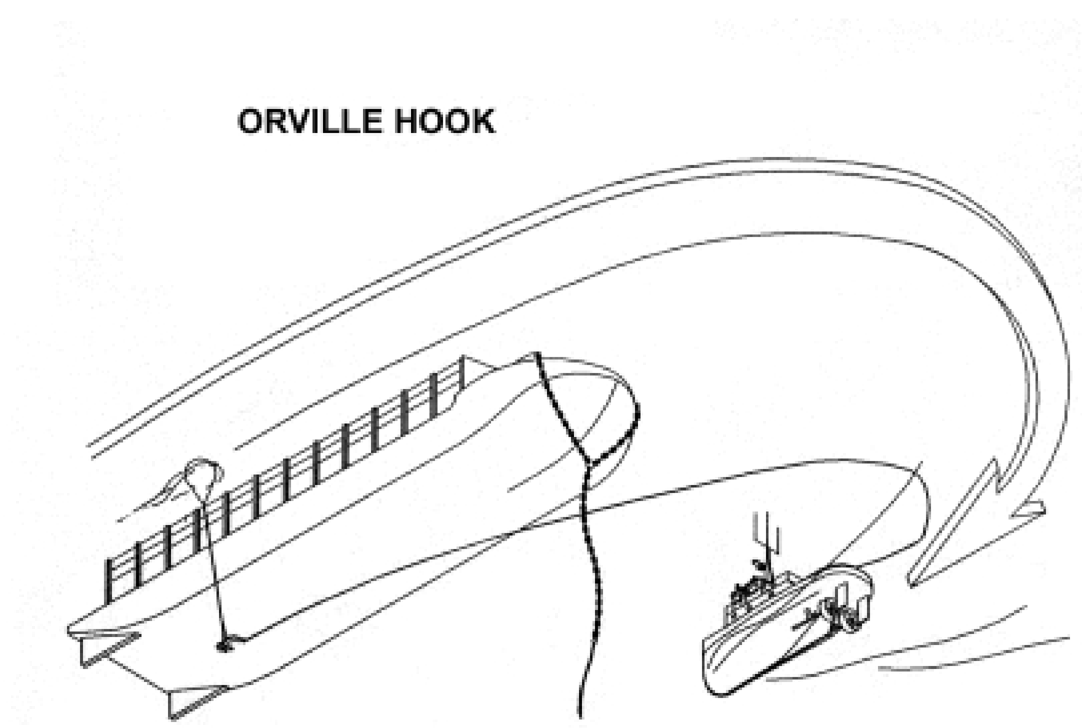


Figure 6-11. Deployment of the Orville Hook

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Chapter 7

SPECIAL TOWS

7-1 Introduction

This chapter addresses tows of unusual configuration that occur infrequently or are of a highly specialized nature. Topics include towing in ice and towing targets, submarines, merchant ships, and NATO ships in peril. Emphasis has been placed on rigging and procedural differences between these types of tows and towing operations previously discussed.

As their recurrence is unpredictable, these types of tows are not treated in depth in this manual. Instead, these topics are presented to make planners and operators aware that such operations have been successfully completed in the past. When faced with a similar situations, they should refer to reports of actual operations.

7-2 Target Towing

The primary functions of ships such as the T-ATF, and ARS classes are salvage and ocean towing; target towing is a secondary function routinely assigned to them. Most combatant ships can tow target sleds with their standard shipboard equipment.

7-2.1 Williams Target Sled

Currently the catamaran-hulled Williams Target Sled is the target used most for gunnery exercises (see Figure 7-1). The Navy also uses sonar buoys, arrays, drones, and remotely operated boats as targets. Targets are towed, escorted, or carried as deck cargo to the operations area.

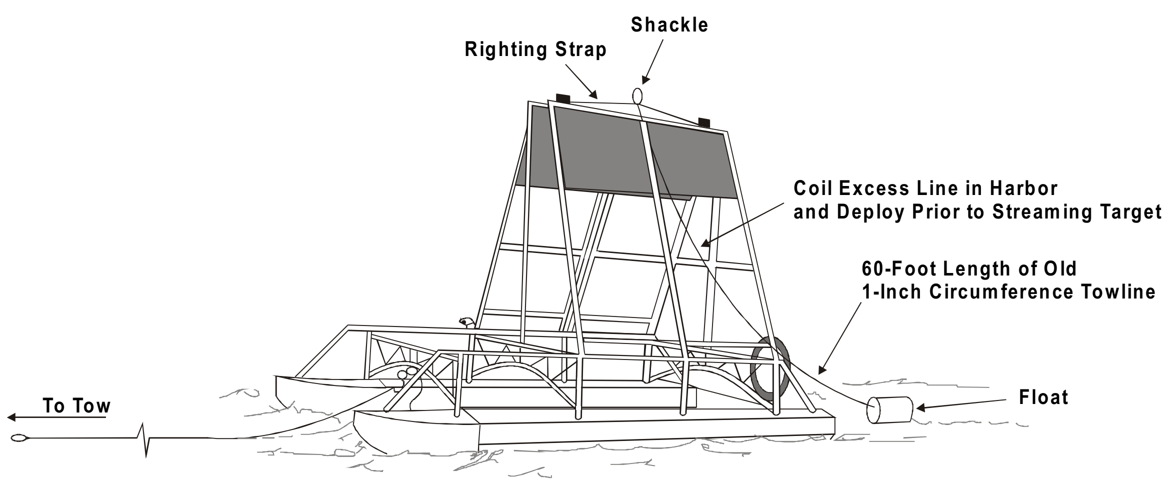

Figure 7-1. Williams Target Sled Rigged for Tow with Righting Line Streamed.

7-2.2 Towing Equipment

The Williams Target Sled is towed from a synthetic line bridle shackled to the inboard sides of the catamaran hulls. The two bridle legs are joined by a triangular flounder plate; a 30-foot pendant of synthetic line is also shackled to the flounder plate. The pendant is shackled to the main synthetic towline.

The towline is generated might cause the target to list or a damaged sled to capsize.

7-2.3 Routine Procedures

7-2.3.1 Transporting the Target to the Exercise

CAUTION
If the target is made up bow-to-stern, it should reverse direction and swing into position when slipped. Too much way on, however, will cause the target to be towed stern first. In a stern-first position, the target has a tendency to stream aft without reversing itself and can end up straddling the towline.

The tug can either pick up the target at its berth or have the target brought out of the harbor by a delivery ship, usually a work boat. If a delivery ship is used to bring the target out of the harbor to the towing ship, slow down and maintain steerageway so that the delivery ship can easily approach the stern.

For tows that begin at the target's berth, the target can be made up to the towing ship bow-to-stern alongside (with the towline shackled to the target's bridle pendant), bow-to-bow alongside, or bow-to-stern aft of the towing ship. The target can also be made up on the fantail of the towing ship. (It may be similarly made up on the fantail during protracted delays between exercises or in the event of impending heavy weather.) If the target is made up on the fantail, use the ship's crane or boom to set the target overboard upon arrival at the operations area.

If the tow is made up in the water, slip the target mooring lines when clear of the pier. Tow target at short stay until clearing congested waters. Steaming at short stay does not affect maneuverability or speed. When clear of the harbor and congested waters, about 600 feet of towline is usually streamed. If the towline is not on the drum of a winch, it may be paid out using a gypsy head or capstan to maintain control. Ships with towing bitts can control the payout of towline by taking turns around the bitts. When enough line has been paid out, the towline is stopped off to the towing bitts with the towline passing over the stern roller. Speed is then built up slowly until the target is towing steadily. If towing at night, make sure that the target's stern and side lights are lit.

7-2.3.2 Streaming the Target

The towing ship times its arrival at the firing range long enough before the exercise begins to allow time to stream the target. Slowing to about 4 knots and paying line out at 150 feet per minute is a safe way to stream.

7-2.3.3 Making Turns with the Target

Depending on the weather, turns can be made in one increment by using a small amount of rudder so as to have about a 1,000-yard diameter turning circle. When making turns, keep the target aft of the towing ship's beam, preferably broad on the quarter.

When proceeding on a circular course, the target's tendency to capsize is determined by the speed of the tow, length and depth of towline, and the sea state and heading relative to the wind. Turns to windward are different from turns to leeward. When turning into the wind, the target screen area acts as a mainsail and holds the target away from the turn, requiring an increased rudder angle and giving a smaller transfer with a slightly greater advance. When turning leeward, the screen acts as a sail effect and propels the target toward the inner part of the turn, requiring less rudder and performing a greater transfer with less advance.

In all turns the target acts as a sea anchor, making a small tactical diameter while the ship turns around the target with a larger tactical diameter. Turns with the current increase transfer; turns against the current reduce transfer. The advance in all turns is small.

To keep the towline tension low and to avoid capsizing the tow, keep the rudder angle as low as is practical. A mean rudder angle of 12 or 13 degrees is satisfactory. A good practice is to make the turn in small increments, steadying up until the target is directly astern before going to each new increment.

7-2.3.4 Recovering the Target

When the exercise is over, the towline is heaved in to a shorter stay for the tow home or brought up short so the target can be lifted aboard. Combatant ships use their capstans to heave the towline, MSOs use one drum of the sweep-wire winch, and salvage ships use their capstans or traction winches. Significant time must be allowed to bring the hawser in at even maximum capstan speed. Hawser recovery typically proceeds at 40 to 60 feet per minute. As soon as the towline is on board, it should be faked on deck or spooled on a reel.

Upon entering port, the tow can either be brought alongside, brought to short stay, or lifted aboard. The use of riding lines that have been stopped off on the tow hawser during streaming contributes to the ease of bringing the sled alongside (see Section 6-2.3). For leaving and entering port, some ships prefer two-blocking the bow of the sled against their stern. When the sled is firmly snugged into position and riding lines are added, this method allows good maneuvering.

7-2.4 Special Procedures

7-2.4.1 Passing the Target to a Combatant Ship

WARNING
When tows are passed, most casualties occur because the ships do not maintain a steady course or speed or because the towing ship releases the tow before the other ship is ready to accept the strain.

It is sometimes necessary to pass a target from one ship to another on the open sea. The towing ship selects the side and speed for passing and signals this information to the receiving ship well in advance of passing the tow. Stop off the hawser along one side of the towing ship. The receiving ship steams into the wind alongside the towing ship.

The receiving ship signals and sends a messenger when it is ready to receive the tow. The towing ship receives the messenger and secures it to the hawser. The receiving ship hauls the messenger through its towing chock. The towing ship frees the hawser and the receiving ship hauls it away (see Figure 6-7).

7-2.4.2 Recovering a Capsized Target

WARNING
Always remain with a target sled until it is recovered or righted and towed to port; it will become a navigational hazard if left to drift.

A capsized target must be righted immediately because it cannot be towed at any speed. Safety precautions must be strictly observed because of the hazards of recovery work.

If the target capsizes, the towing ship should heave in slowly. The ship may be required to back slowly while heaving in, being careful not to foul the towline in the propellers or rudder. Another method is to reverse course and place the ship alongside the target. Weather conditions will determine the best method to use for approaching the target.

Before getting underway, the target should have been prepared for righting. A recovery pendant can be made from 60 feet of line and a float. Attach one end of the line to the middle of the pipe framework at the apex of the target. Coil the remainder of the line and secure it with small stuff to one of the pipe frames near the trailing edge of one of the catamaran floats (see Figure 7-1). Tie the bitter end of the line with a bowline onto the float. Before streaming the target, release the line and float to stream aft of the tow. If the sled capsizes, maneuver the ship alongside the sled and bring the float and recovery line aboard the ship. By leading the recovery line over the caprail to a capstan and heaving in, the sled can be made to rotate to an upright position in a motion that carries the target away from the hull of the ship. Once upright, inspect the target to make sure that it is not damaged and is fit for tow.

7-2.5 Target Towing Precautions

Take the following precautions when towing a target:

- Avoid surges
- Maintain a steady course, avoiding tight turns
- Ensure that the target's stern and side lights are lit at night
- Do not tow the Williams Target Sled at speeds in excess of those authorized by Fleet directives
- Do not tow a capsized Williams Target Sled
- Alter course gradually with a target under tow in order not to capsize the sled
- Approach the target with caution. The shallow draft of the target sled causes considerable pitching and rolling at slow speeds or when drifting.

7-2.6 Other Targets

SEPTARs (Seaborne-Propelled Targets) are remote controlled, high speed surface targets that are transported to the operating area by a tug and then operated from the tug. Similarly, tugs can carry drone-type targets for antiaircraft and antimissile training exercises. They can also carry transducers and arrays for submarine and antisubmarine training exercises. Each of these services is unique and presents special problems not found with standard target sled towing. Some of the information necessary to support specialized target services is classified. Generally, range personnel will provide specific information regarding these special systems.

7-3 Towing Through the Panama Canal

Tows of unmanned vessels through the Panama Canal present some unique concerns and often require additional preparations. A canal tow may be the result of an East Coast decommissioning of a nuclear vessel that needs to go to the West Coast for final disposal. It may be the result of an asset being transferred from a West Coast activity to an East Coast activity. Either way, as more and more vessels are decommissioned, and assets become fewer in number, tows through the canal have become more frequent.

The Panama Canal is unique and has restrictions on size and requirements for special bitts and chocks to accommodate tow wires. While many vessels that are designed for service through the canal have the necessary installed fittings, other ships, particularly warships, may not meet all the specific requirements.

It is essential for a tow planner to fully understand the requirements when towing through the Panama Canal. Code of Federal Regulations (CFR) 35, *Panama Canal* (Ref. N) contains this information and is an invaluable resource when planning a canal tow. It has also proven to be well worth the investment to fly a representative from the Panama Canal Commission to the preparing yard. A walk through of the vessel by knowledgeable personnel can identify any changes that need to be made while the ship is still in the preparing yard. If the tow arrives at the breakwater in Panama, and does not meet the requirements to go through, arrangements must be made to effect repairs and modifications. This can result in both substantial costs and delays. Advance preparation is essential.

7-4 Towing in Ice

Arctic operations may require towing through ice. Towing ships may also be required to recover ships with no steering or propulsion capabilities that have been stranded in ice conditions.

An icebreaker may be required for breaking through heavy ice, but Navy ocean tugs can tow through thin ice or broken ice. The Navy ARS 50 and T-ATF Classes were built to modified ice strengthening rules, but those with Kort nozzles are less suitable for heavy ice operations.

The major considerations when towing in ice are:

- **Protecting the hawser from ice damage**. Long periods of exposure to ice will chafe and wear the hawser. To prevent the hawser from coming into contact with the ice, adjust the catenary so the chain bridle, or chain pendant enters the water at the towed vessel. It may also be desirable to rig additional chain to help make this easier. This is addressed in Allied Tactical Publication (ATP) 15, *Arctic Towing Operations* (Ref. O).

- **Selecting the appropriate towing method**. When towing in ice, a tow should be close to the tug's stern to keep an ice passage open ahead of the tow. The tow may not have an ice-strengthened bow and could sustain impact damage from floating ice. Two approved towing methods for keeping the tow close are the short-scope method and the saddle method. The method used depends upon type of towing ship and the design of the ship being towed. The saddle method will ensure that the tow will not encounter ice, but, if not rigged properly, could cause damage to both the tug and the tow.

7-4.1 Short-Scope Method

Navy ocean tugs should use the short-scope method because they have no saddles. A hawser scope of 150 to 300 feet should be maintained. The tow's rudder can be used, if necessary, to keep the tow in the tug's wake. Occasional kicks from the tow's propeller may also be necessary to augment the rudder's force. The tug's propeller wash should keep the tow from riding up on the stern; if it does not, the propeller of the tow should be backed, if possible. Riding lines may be used for increased lateral stability (See Section

6-2.3). These lines will be very susceptible to chafing.

> **CAUTION**
>
> The tug should follow these recommendations and guidelines when towing at short scope:
>
> - The pull on the towline will be severe if the towed ship suddenly contacts heavy ice.
> - Take special precautions to prevent the chain bridle, chain pendants, and hawser from chafing. An automatic towing machine makes this easier.
> - Avoid towing on the bitts they may be torn out by the sudden increases in tension if ice is encountered when towing at short scope.

7-4.2 Saddle Method

The saddle method can be used by icebreakers and tugs with reinforced sterns and towing machines. The U.S. Coast Guard has operated some icebreakers equipped with towing machines or strengthened saddles. Even when a towing ship has a saddle, the saddle method may not be practical for tows with sharp prows, bulbous bows, or any other protuberances that can interfere with the tug's propellers and rudders. Normally, the tow can be brought up and held firmly in the saddle by the towing machine.

If the tug does not have a saddle and the short scope method of towing in ice is not feasible, a variation of the saddle method formerly used by icebreakers may be possible for tow ships having strong, broad sterns. The tow is brought up snug against the tug's stern, using extensive chafing gear, and heavy fenders. The towline is attached in the normal fashion; the towing machine should be in automatic mode to prevent the towline from parting if the ships pitch or surge. Two mooring lines can also be passed from the tug's quarter-bitts to the tow's forecastle bitts to help keep the tow following fair. The tow's engines can be used. If the tow begins to jackknife or sheer or yaw badly, however, it should slow at once until it is again under control. A fire hose should be kept ready at the saddle or stern because friction may cause fires in the chafing material.

7-4.3 Rigging for Tow

The recommended gear for towing in ice consists of:

- Wire rope towing hawser
- A 2 1/4-inch chain pendant and connection jewelry, or
- A 2 1/4-inch chain bridle with flounder plate and connection jewelry.

This heavy gear will provide protection against the increased potential for chafing and impact damage. Synthetic lines are not recommended as main towing gear.

In a convoy with no icebreaker, any ship may be expected to tow and should be prepared to both tow and be towed. Rigging the tow bridle in advance quickly lowers the chance of being caught in the ice. Gear should be prepared in advance; the crew should know how to complete the rigging quickly and safely.

Before entering the ice, the bridle or anchor chains should be rigged to receive a towline. Even when using a bridle, it is necessary to secure bow anchors to keep them from striking hummocks in the ice. This is especially important on low bowed ships.

7-5 Submarine Towing

This section provides an overview of emergency (unplanned) towing of submarines. Appendix J provides specific data that will be useful in rigging submarines for emergency tow. For planned tows and for tows of deactivated submarines, consult NAVSEAINST 4740.9E *Towing of Unmanned Defueled Nu-*

clear Submarines (Ref. P). This instruction, which takes precedence over this manual, may be useful also in planning and executing an emergency submarine tow.

Submarines are challenging tows. Even though they may be equipped for towing, the towing arrangements are not as strong as on typical surface ships, their configurations present serious topside personnel hazards, and they can be very poor at tracking behind the tow ship.

7-5.1 Towing Arrangements

7-5.1.1 Retractable Deck Fittings

Modern submarines are built with essentially no flat surfaces on the main deck. All submarine deck fittings are either retractable or recessed. They are normally constructed so that they can be retracted to form a flush deck, and rotated into position where they can be used. In most cases, deck fittings can be expected to be safe for working up to the breaking strength of the line with which they are normally used.

Most submarines have small hydraulic capstans, fore and aft, that can be useful in handling lines. They typically have a limited capacity of 3,000 pounds line pull at a maximum 40 fpm and a maximum pull of 4,500 pounds at creep speed. These capstans are severely limited in assisting with the connection of a towing hawser. The tug, accordingly, should plan its connecting procedure to minimize reliance on the submarine's capstans.

The controls for the retractable capstan are usually designed so that the capstan can be operated from topside. The machinery, however, is activated from inside the submarine and is dependent on the submarine's having hydraulic power.

7-5.1.2 Tow Attachment Points

CAUTION
The submarine's designed towing rig was intended for intra-harbor towing and is not generally acceptable for open-ocean towing.

The design of submarines is such that considerable ingenuity may be required to find suitable towing attachment points. See Appendix J of this manual for details on towing arrangements for specific submarines.

CAUTION
Few deck fittings on submarines are designed for loads that are commonly considered in the design of surface ships. Care must be exercised to ensure that the safe load capacity of fittings, such as the bullnose fairlead, cleats, and padeyes, is not exceeded. Particular attention must be paid to the loads that may develop when the submarine yaws.

On several classes of submarines, a tow pad is installed on the forward portion of the sail, where it is faired into the main deck. This is a hard point with an SWL of about 47,000 pounds, depending on submarine class. On some other classes, the tow pad is installed forward of the forward escape trunk and is also rated at 47,000 pounds. The latest submarines are intended to be towed using a bridle-flounder plate arrangement secured to a pair of 70,000-pound (SWL) mooring cleats.

On some submarines, the intended tow point may have been removed. In such cases, an emergency tow may well involve use of some of the installed cleats or other deck fittings such as capstans.

As a last resort, towing by the stern planes, the propeller, or the sail may be the only alternatives. In such an event, all parties must be aware of the damage that will likely result.

7-5.2 Personnel Safety Issues

The main deck of a submarine is frequently inaccessible and dangerous to board in a seaway. There is very little freeboard, and if there is any sea running, the decks will most likely be awash. Great care is required when moving about on the deck; a tether or safety line should be used. A safety track is provided for attachment of personnel-restraining safety lines. The necessary fittings and harnesses are carried on the submarine for use with this track.

7-5.2.1 Protection for Work on the Deck

When connecting to a submarine in the open sea, all personnel working on the deck should wear full wet suits, survival suits, or other such dress that will provide both thermal and physical protection if they are washed overboard. No one should be permitted to work without proper life preservers or other appropriate safety equipment.

7-5.2.2 Boarding the Submarine

An inflatable boat may be the only successful means for boarding a submarine. It is helpful if the submarine is able to rig a Jacob's ladder alongside for boarding purposes.

7-5.2.3 Personnel Experience

Submarine deck hazards are frequently compounded by limited personnel experience. Because submarines normally conduct independent operations, their personnel have few opportunities to become familiar with many of the deck seamanship procedures that are common to personnel on surface ships. At the same time, personnel on the tug may have little or no experience with submarines and may lack familiarity with the particular fittings, equipment, and limitations of the submarine. Good communications between the submarine and tug crews are especially important. Guidance from the submarine crew is particularly valuable in the area of safety. They are far more experienced in the problems of working topside on the submarine than non-submarine personnel. The submarine can also provide additional assistance if required. The submarine, however, should follow the guidance provided by the tug. The tug is responsible after the tow connection is made.

7-5.2.4 Submarine Atmosphere Problems Resulting from Fire

If the submarine has had a fire or has discharged its extinguishing system, the atmosphere inside may not be of breathing quality. If entering the submarine is necessary, proper breathing equipment should be used. The atmosphere in the submarine is difficult to clear unless it is possible to run some of the equipment on the submarine. Running the low-pressure blower or the emergency diesel engine will quickly provide a change of atmosphere.

7-5.3 Tendency to Yaw and Sheer

Some model tests of the towing characteristics of the various classes of submarines have been conducted. These tests confirm the observed tendency for submarines to yaw and sheer far off the towing track. This can be improved if the submarine is trimmed by the stern. This can be done by sealing ballast tanks and deballasting the sonar dome. These actions will also provide more freeboard forward for rigging the tow wire, thus facilitating the tow operation. In deep water, deploying the stern anchor of the submarine may also help (assuming that hydraulic power is available). If rudders and planes are not being used to control the submarine, they should be secured.

7-5.4 Rigging for the Tow

Innovation is often required when rigging a submarine for towing. Creative thinking is needed both when making up a connection and when selecting the hardware to use. In an emergency, it is better to rig something as strong as possible the first time, accepting some possible damage, than to risk loss of the tow at a more inopportune time in the future.

See Appendix J for information on rigging specific submarines.

7-5.4.1 Hardware

There is no assurance that towing hardware will be carried by the submarine. Occasionally the submarine will carry special shackles or other hull fittings to connect the towline to the tow point. In most cases, however, a Navy tug should have sufficient gear to make up a towing connection superior to that included in the submarine design.

The ship conducting a tow must determine what special jewelry is available or required, from either the submarine crew or the appropriate Squadron or Type Commander. If required jewelry is stored ashore, it may be possible for the tug to pick it up before getting underway or to have it delivered to the scene of the casualty. Modifications to submarine's designed towing jewelry may be necessary as circumstances warrant. When jewelry is not available, it may be necessary to manufacture it. The necessity of providing for both adequate strength and chafing capability for whatever jewelry is employed must be kept in mind.

It is advisable to use a length of chain as a chafing pendant where the tow connection passes through the fairlead chock. It may be necessary to include a wire between the connection point and a short length of chain to reduce the length (and weight) of chain used. The chain needs to be just long enough to take the chafing at the fairlead. Assistance may be available from the submarine's hydraulic deck capstan, if it can be rigged and operated. Keep in mind the limited capacity and speed of the capstan. For submarines using a bridle attached to a set of mooring cleats (chiefly SSN 688 and SSBN Classes), no fairlead is used and a wire chafing pendant is sufficient.

7-5.4.2 Underwater Projections

CAUTION
Every retractable item forward of the tow fairlead (or flounder plate, if used) must be retracted by the submarine crew to preclude damage to the submarine and the tow hawser.

The submarine crew can provide information on the location of all underwater projections. These projections must be rigged in to avoid problems. Submarine personnel may not appreciate the deep angle of the tow hawser resulting from an adequate catenary. In addition, most submarines can take wide swings from the direction of the tow, meaning that any projections forward of its tow fairlead, including items on the keel, can damage or be damaged by a tow hawser or pendant. If there is any doubt, a diving survey should be made to assure the hull exterior is clear.

All tugs must also be aware that U.S. submarines have keel anchors, often located aft. If such a submarine is anchored, it will head downstream. See Appendix J for identification of anchor location by submarine class.

7-5.4.3 Towing by the Stern

NOTE
Use of the submarine's anchor chain for towing may be feasible if its windlass is operable.

A submarine that has been damaged by a grounding or collision may require a stern tow. For submarines whose anchor is located aft, the anchor chain is the first choice for a stern tow. Careful coordination is critical. By using divers, the tow ship may be able to connect to the submarine's anchor chain, with or without the anchor removed. It also may be possible to dip a wire around the anchor chain. If the stern planes or the propeller must be used for a tow point, take great care to ensure that the attachment chain, strap, and so forth, are wrapped close to the hull. When using stern planes or rudder, the strong operating shaft extends only a short distance into the control surface. It is important that the attachment point be held against the hull and not at the outboard side of the rudder or plane.

7-5.4.4 Use of the Sail as a Tow Connection

For connection to a sail, consider chain, wire, or a wide heavy strap that is fabricated from plate or from a wide synthetic lifting strap. Chafing gear may be required to distribute the load because the sails after edge may be brought to a relatively sharp edge. Suitable chafing gear can be fabricated from a short section of split pipe and plate. Rigging such a device, however, is not a simple task at sea.

7-5.4.5 Welding to the Hull

CAUTION
Contact NAVSEA to obtain technical advice before any welding is done to a submarine's pressure hull.

If welding is required, make sure that towing pads are fastened to the pressure hull (as opposed to the non-pressure hull) and that the welding is done in accordance with the specifications for the material of the hull.

7-5.4.6 Passing a Messenger

In establishing the initial connection, it is easier for the submarine to pass an initial line to the tug than vice versa. Limited deck space on the submarine makes it difficult to catch a heaving line or the line from a line throwing gun. It may be easier to rig a double messenger around the tow connection and use the tug's power to heave around on the hawser. A sufficiently long messenger should be prepared in this case.

7-5.5 Towing Operations

CAUTION
Due to their severe sheering tendencies, submarines should employ active steering (if available) as directed by the towing vessel.

Once a suitable tow connection is achieved, come up to speed very carefully. A constant watch should be kept on the position and attitude of the submarine. At night, it may be necessary to require the submarine to continually report its relative position until a stable condition is achieved. If they cannot be steered, many submarines will tend to sheer off and hold a position as much as 70 degrees relative to the tow ship's stern. Sometimes the submarine will hold this extreme position for hours, only to veer suddenly to the other side without warning. The tug's Conning Officer must be advised immediately. In such a case, the Conning Officer may have to reduce power to prevent the tug from surging ahead and compounding transient stresses developed when a submarine fetches up on the other side. This sheering characteristic, coupled with a lack of strong fittings, is a major reason for insisting upon relatively modest tensions in towing submarines.

7-5.5.1 Towing on the Automatic Towing Machine

Every effort should be made to tow with an automatic towing machine. Controls should be adjusted for a maximum tension setting not to exceed the safe working loads of the components used for the tow rigging and fittings on board the submarine. Deploying a synthetic spring will also help to reduce peak tensions. More information about the use of springs is contained in Section 4-6.5 and NAVSEAINST 4740.9E (Ref. P).

7-5.5.2 Towline Tension and Towing Speeds

Attainable towing speeds will be dependent upon weather, class of submarine, type of connection, equipment used, and the ability of the submarine to use its rudder. In general, towline tension should be limited to 25,000 pounds for all submarine classes built prior to the SSN 688/SSN21/SSBN 726 Class submarines. This will provide about five knots towing speed under favorable sea conditions. The 688/21/726 Class submarines should be limited to a maximum of 35,000 pounds tension, resulting in about four knots speed under favorable conditions. Normally, increasing tension/speed should not be attempted without first observing the tow's behavior and consulting with appropriate operational and technical authority.

As with all towing operations, it may be necessary to slow down and simply maintain steerage when the weather is severe.

7-5.5.3 Drogue

If the submarine rudder is out of commission, a drogue rigged behind the submarine may assist it to stay on course. In deep water, the stern anchor may be deployed. In narrow waterways or where interference from other traffic is anticipated, docking (harbor) tugs should be used alongside to properly control the submarine's movements.

7-6 Towing Distressed Merchant Ships

Occasionally, during routine operations and national emergencies, the Navy is called upon to engage in towing merchant-type ships in distress. These may be MSC ships, chartered ships, ships engaged in support of operations, or any other merchant ships requiring assistance. In emergencies and in remote areas, these services also may be required to save lives and valuable ships and cargo. If pollution is a concern, towing the ship to sea will likely reduce the impact of any spill. Be sure the distressed vessel is capable of surviving any increased seas.

Information on the events and circumstances surrounding the towing should be collected and documented as soon as practical, if not immediately. The following information may help the Navy in subsequent claims for reimbursement:

a. Note reasonable availability of adequate privately-owned or commercial towing assets at the time that the Navy towed the distressed merchant ship. Examples of such information are:

   - Location of the nearest privately-owned or commercial towing vessels.
   - How the existence of nearby towing companies or vessels was known. Are they locals whose presence was known from past incidents that resulted in the need for towing or salvage? Were they discovered as a result of communications at the time of the casualty that required the tow?

b. Nature and extent of services rendered.

c. Location of the nearest safe haven. If a merchant ship was towed elsewhere, the reason for towing to that farther point should be documented.

d. The citation of funds, cash deposit, "promise to pay", or other agreements arranged by the merchant ship prior to the commencement of any operation.

Supervisory control of the effort will ordinarily remain in the Navy. A situation may arise, however, in which it may be advisable to relinquish supervisory control to an owner or underwriter's designated representative, even though Navy facilities are required. Relinquishment of supervisory control may be effected upon authorization by the cognizant naval commander or higher authority. Prompt notification should be made of such action to CNO; the cognizant Fleet Commander in

Chief; numbered Fleet Commanders; Naval Surface Force Commander; COMNAVSEASYSCOM; and other interested authorities, because this may well affect the status of the Navy's claim. Relinquishment of supervisory control shall in no case be construed to affect the responsibility of commanding officers for the safety of their ships.

NAVSEA 00C should be contacted (703 607 2753; DSN 327 2753; 24 hours: 703 602 7527; DSN 332 7527) to assist in assessing commercially available assets. Information can also be provided regarding towing procedures.

7-6.1 Information Sources

Various companies and trade groups have assembled information intended primarily to provide guidance to merchant tanker operators in contingency planning. This same information can be equally valuable to Navy personnel who may become involved in rescue responses to merchant ships in distress. Some particular publications are cited in International Maritime Organization (IMO) Resolution A.535(13), *Recommendations on Emergency Towing Requirements for Tankers* (Ref. Q) and International Chamber of Shipping Oil Companies International Marine Forum, *Peril at Sea and Salvage: A Guide for Masters* (Ref. R).

7-6.2 Attachment Points

Ideally, a distressed ship would present an easily reached connection to the rescuer. This would be a complete system including the hawser, or at least everything necessary to connect the hawser to the ship. The Oil Companies International Marine Forum (OCIMF) recommendations have been superseded by similar IMO standards, but these have not been formally adopted. Nonetheless, many of the larger tanker operators have complied with the IMO recommendations.

Many ships employ a prearranged attachment point on the tow such as the Smit Towing Bracket (see Figure 4-8). Alternative points for attachment include the bitts, the anchor chain, and the foundations of deck machinery (see Section 4-5).

Many commercial vessels have an emergency tow hawser and connecting jewelry in a packaged arrangement on the bow or stern. These boxes usually require assistance from the crew or a boarding party. Light weight material is usually used and a connection can be made very quickly. This arrangement should be sufficient until a more permanent arrangement can be made.

7-7 Ships with Bow Ramp/Door

LST type tows are required to have hydraulic rams connected with bow ramp operating instructions posted in the hydraulic control room. Ensure that mud flaps at the bottom of the doors are secured and that all dogs, heavy weather shackles, ratchet-type turnbuckles, and strongbacks are tightly and securely in place so that they cannot work free. YFU/LCUs are inherently unseaworthy due to their wide beams and flat bottoms. A lift of opportunity should be used whenever possible. If it is absolutely necessary to tow these crafts, the following must be strictly adhered to:

- The bow ramp must be secured with a minimum of four angle straps on each side, welded on the outside of the ramp. Straps should be at least 4 inches by 3/8 inches and overlap the bow ramp and sides of the craft by a minimum of 10 inches.
- All normal securing devices (such as ramp chains, dogs, and turnbuckles) must be in place and in good mechanical condition.
- All hatches, scuttles, and doors must have good gaskets and all securing devices must be in proper operating condition.

7-8 Towing Distressed NATO Ships

The NATO navies are concerned with emergency towing as part of their military missions as well as normal maritime concerns for safety of life at sea and pollution prevention for all ships.

7-8.1 Standardized Procedures (ATP-43)

Standardized NATO emergency towing procedures are found in the unclassified ATP-43 (Ref. B). It was written for the situation where one combatant tows another. In this type of operation, each ship typically provides its own towing hawser as half of an entire rig of reasonable length. As in the U.S. Navy, this activity is sometimes referred to as "tow and be towed." ATP-43 includes sections on:

- Principles of Operations
- Organization and Command (including Communications)
- General Consideration of Towing Operations
- Preparation, Approaching the Casualty, Passing and Connecting the Towing Rig
- Conduct of the Tow
- Emergency Release or Parting of the Rig
- Transferring the Tow

The Annex to ATP-43 contains data on the emergency towing hawser carried by each class of NATO warship and auxiliary ship, as well as the end fittings on the hawser. It also provides hawser strengths and dimensions and the static tests of the end fittings.

ATP-43 should be available on board every NATO warship and auxiliary vessel. The assigned tow ship might remind the disabled ship's Commanding Officer of the publication's existence, so that the disabled ship can better prepare for the arrival of the tow ship.

The operational data contained in ATP-43, while accurate, are quite elementary compared to the background of the experienced tug crew. Nonetheless, knowledge of the contents of ATP-43 will be useful to the naval tug or salvage ship since it describes what the crew of the casualty should know concerning being towed.

7-8.2 Making the Tow Connection

It may be prudent to use the casualty's own hawser and end fitting to expedite the removal of the casualty from immediate danger. In such a case, the casualty may have already rigged its own hawser ready to pass to the tug. The tug need only heave the casualty's hawser on board the tug to make the final connection to its own hawser, thus being ready to commence towing shortly after arriving at the scene. The towing system can be rerigged with the tug's more robust gear after the casualty is removed from immediate danger.

This is not to suggest that the damaged ship's towing gear is preferred over a tug or salvage ship's gear. On the contrary, the tug's gear will be more robust than that of all but the largest warships, and will almost always be longer than the casualty's hawser. Furthermore, unless the emergency hawser is connected to the ship's anchor chain, there will be insufficient long-term chafing protection for the casualty's own hawser, and possibly insufficient catenary as well. Use of the tug or salvage ship's towing gear is preferred for towing a warship or naval auxiliary. Connecting to the casualty's hawser as an expedient means should be based on a careful balancing of the tactical circumstances, rapidity of commencing the tow, distance to be towed, and existing and forecast wind and sea conditions. If the tactical situation requires initial use of the casualty's hawser, re-rigging to the more conventional connection is recommended at the earliest possible opportunity.

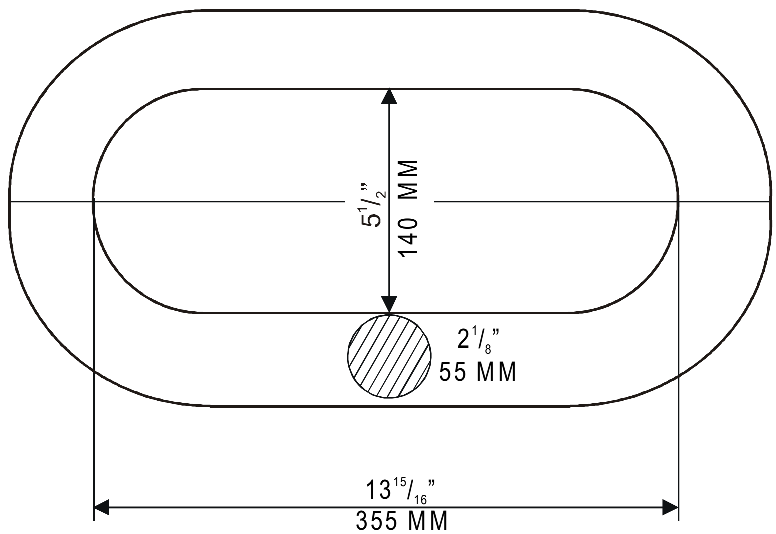

Figure 7-2. NATO Standard Towing Link.

When connecting to the casualty's own emergency towing hawser, the towing ship should consider inserting a shot of chain between the two hawsers to assist in maintaining a healthy catenary, provided that the water is deep enough. This may complicate recovery if the rig is to be changed at sea.

7-8.3 NATO Standard Towing Link

Change 1 to the publication (May 1987) also specifies a NATO Standard Towing Link, which should soon be found on NATO ships of over 1,000 tons displacement (see Figure 7-2).

The ATP-43 comments relevant to the NATO Standard Towing Link are:

a. The NATO Standard Towing link is to be used during ship-to-ship towing operations as an interface between the towing equipment of the towing ship and that of the ship towed, whichever of the two ships provides the equipment, in order to improve interoperability.

b. Ships of less than 1,000 metric tons displacement, other than tugs, are not obliged to have the Standard Towing Link.

c. The interface will be at the presented end of one or both ships' towing hawsers. (One of the ships will have to provide a joining shackle.)

d. The NATO Standard Towing Link shall conform to the dimensions shown.

e. The strength of the link is the responsibility of the providing nation.

The link is quite large, so the largest conceivable tow shackle (4 inches) can be dipped through it. Note that the strength of the link is left to the Providing Nation. In the absence of information to the contrary, assume that the link strength exceeds the breaking strength of the casualty's emergency tow hawser. Assume that the casualty's attachment points also exceed the strength of its hawser.

7-9 Unusual Tows

Conditions may require towing floating structures that are in unusual positions. Many such tows have been successfully completed in the past.

7-9.1 Dry Dock (Careened)

One example of an unusual tow is the towing of an AFDM through the Panama Canal. These dry docks are approximately 124 feet wide. Because the canal is only 109 feet wide, these docks must be careened for transit. This has become an established practice. When the transit operation has been completed, the careening procedure is reversed to restore the dock to its even keel condition for towing to its destination. An attempt should be made to adjust the trim to improve the behavior.

7-9.2 Damaged Ship (Stern First)

If a ship cannot be prepared properly for tow due to bow damage, the feasibility of towing by the stern may be considered. Some ships will tow fairly easily by the stern, but most can be expected to track very poorly.

7-9.3 Inland Barge Towing

Barge towing supports Navy logistic requirements. The basic techniques for inland barge towing are almost identical for harbor tugs and towing ships. The principles of alongside towing and handling become part of the open-ocean tow in making up, streaming, and entering the harbor. Naval Education and Training Command (NAVEDTRA) 10122-E, *The Boatswain's Mate First Class and Chief Rate Training Manual* (Ref. S) provides a thorough discussion of inland barge towing in its most common configuration, alongside. Understanding the basic principles set forth in that manual will enable personnel on board the ocean going tug or salvage ship to approach inland towing in a professional manner.

7-9.4 Other Tows

Contact NAVSEA 00C for information concerning advice on unusual and unique tows including:

- NR-1, submerged tow
- Towing of gravity structures
- Non-self-propelled floating structures
- Minesweeping devices
- Submerged and surface towing of submersibles
- SINKEX
- Test bodies
- Platforms
- Pipe structures
- Cable-layers
- Acoustic arrays
- Semi-submersibles
- Ships of unusual hull forms (SWATHs, PHMs, and so forth).

7-9.5 Towing on the Hip

While it is common practice for harbor tugs to tow on the hip, it is somewhat unusual for an ocean tug to do so. However, if an ocean tug is involved in a salvage it may be necessary to engage in this type of towing. Caution should be taken if there is any sea state. Beam waves, may cause the vessels to roll out of sync and alternately separate and collide.

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Chapter 8

HEAVY LIFT TRANSPORT

8-1 Introduction

This chapter describes the personnel, procedures, preparations, and safety precautions required for float on/float off (FLO/FLO) heavy lift transports of Naval ships and craft. Heavy lift, as used in this chapter, is defined as the transportation of a ship, craft, or other asset aboard a larger semi-submersible ship or barge. FLO/FLO refers to the method of loading and unloading. This alternative to towing was developed for the movement of large drilling rigs and other offshore structures. The United States military has used this method to transport smaller vessels some of which were not suited for ocean transit as well as damaged vessels that could not transit safely under their own power.

Heavy Lift was used to return the bomb damaged destroyer, USS COLE (DDG 67), mine-damaged frigate, SAMUEL B. ROBERTS (FFG 58), from the Persian Gulf and to transport smaller assets such as mine warfare ships, landing craft (LCU) and service craft across the ocean. Two separate lifts brought minesweepers from the United States to the Persian Gulf and three lifts brought others back. Since these were operational ships whose mission required rapid safe transport, heavy lift was used. Tugs, barges, and floating cranes have also been moved using the FLO/FLO process.

The Navy does not currently own any heavy lift FLO/FLO ships and therefore uses contracted vessels to perform these services. This chapter assumes that the heavy lift ship is a contracted vessel.

This chapter does not apply to nuclear powered ships with the core installed.

8-1.1 Repair Work

Conducting a commercially chartered lift is an expensive undertaking therefore, any repair work to the asset should be arranged so it does not interfere with the heavy lift contractor. For example, on the USS COLE heavy lift the Heavy Lift Project Team prepared a design sketch for a hull patch. The patch was not installed prior to departure due to cost and operational considerations. The cost of delaying the operation for repairs is usually far greater than the cost of dry dock lay days and such costs should only be incurred in emergency situations after careful consideration by the Operational Commander. Having the asset completely out of the water does present a unique opportunity for inspection of hull fittings and rudders/propellers and certainly should not go unrealized. For example, on the Desert Storm lift of minesweepers four propellers were found to be damaged and were repaired because the assets were going to war. Because this is a transport operation, the asset has to be ready for sea transit; in particular the water-tight integrity of the hull must be maintained. The operational commander should identify a ship repair officer for the team to coordinate their work.

8-2 Special Considerations

8-2.1 Dry Docking Comparison

A float on/float off procedure may be considered similar to operations involving a drydock. Both involve positioning a floating asset over docking blocks and then reducing the amount of water or distance between the vessel and the blocks. In the case of a graving dock, the water is pumped out of the dock and the asset settles on the blocks. In the case of a floating drydock, the draft of the drydock is decreased by removing water from tanks until the blocks "lift" the asset. Although these procedures are similar, the FLO/FLO portion of a heavy lift transport is much more involved. Take the following considerations into account:

- The transport may be of a single asset, multiple assets from the same squadron, or multiple assets from different operational commanders. Assets of other services may also be transported.
- The asset(s) may be lifted in open water areas.
- Seafastening must be installed to ensure that the asset remains secured on the cargo deck of the heavy lift ship.
- The assets must be secured internally for the sea transit.
- The asset being lifted may be in final days of preparing for extended deployment and therefore may be topped off with provisions, fuel, and water.
- The contract under which a FLO/FLO transport is accomplished is a vessel charter and differs significantly from a dry docking contract.
- Some of the asset's systems may be operational during transit. Therefore all power and support interface requirements must be identified.

8-2.2 Commercial Fleet

Some basic characteristics of the larger, commercial heavy lift ships are presented in Table 8-1. These semi-submersible vessels are self-powered and have large open decks to support cargo. They contain enough internal tankage to allow them to ballast down far enough that their cargo decks are well below the water's surface. This allows assets to be floated over the deck and lifted upon dewatering. This process is almost identical to floating drydocks except that it is often done in open water. Figure 8-1 shows a typical heavy lift ship where the assets can be loaded from port, starboard, or astern. The vessel shown in Figure 8-2 is more similar to a typical drydock. The large wing walls provide some added protection to weather, but assets must be loaded from astern. Figure 8-3 shows a vessel with a deckhouse fore and aft. In this case, assets must be floated on from port or starboard.

Smaller ships of this type also exist but are not used to perform lifts of larger vessels. Commercial submersible and semi-submersible barges may also meet the requirements of some heavy lifts. Barges have the added complexity of a tow arrangement and are also considered less desirable due to stability concerns.

8-2.3 Choosing a Vessel

When deciding on which type of vessel to use, several factors must be considered. These factors are similar to those used to decide on a towing asset and whose significance will vary depending on the mission being supported. For instance, for a coastal or inland lift, a barge may be suitable but for an trans-ocean voyage, the added seaworthiness of a specially designed vessel will likely be worth the extra cost. Some of the factors to be considered are shown in Table 8-2.

8-3 Procedures

This section will discuss planning a FLO/FLO operation. Few FLO/FLO operations are ever duplicates of earlier operations as there will always be differences in season (weather), route, personnel, and configuration of the assets. Each FLO/FLO transport is unique and requires careful planning, preparation, and execution to minimize error and maximize safety. This section presents FLO/FLO transport procedures in general terms.

8-3.1 Designating the Lift

The cost of a heavy lift may make this option seem disadvantageous, but several situations may dictate that this method may be an appropriate way to relocate an asset. Moving

Table 8-1. Commercial Submersible and Semi-Submersible Vessels.

Company Name	Vessel Name	LOA	Beam	Deck Dimensions	Wall Height	Draft Full Load	DWT abt
Netherlands Freight Agencies	DEVELOPING ROAD	134.2 m	34.2 m	115.0 m x 29.2 m	9.2 m	5.15 m	13,230 tons
Netherlands Freight Agencies	SHA HE KOU	134.2 m	34.2 m	115.0 m x 29.2 m	9.2 m	5.15 m	13,230 tons
Smit Maritime	SMIT PIONEER	160 m	29.0 m	2,880 sq. m	7.06 m	4.43 m	6,500 tons
Smit Maritime	SMIT ENTERPRISE	160 m	29.0 m	2,880 sq. m			6,500 tons
Condock	CONDOCK I	92.4 m	20.13 m	74.6 m x 15 m	6.35 m	4.83 m	3,603 tons
Condock	CONDOCK III	106.4 m	20.4 m	87.5 m x 15 m	7.95 m	4.83 m	4,074 tons
Condock	CONDOCK IV	106 m	20.4 m	87.5 m x 15 m	7.95 m	4.95 m	4,500 tons
Condock	CONDOCK V	106 m	20.4 m	87.5 m x 15 m	7.95 m	4.95 m	4,600 tons
Condock	OSTARA	106 m	19.6 m	N/A	N/A	4.85 m	4,400 tons
Dockwise NV	DOCK EXPRESS 10	153.8 m	24.2 m	2,130 sq. m	8 m	8.89 m (max. sailing)	13,209 tons
Dockwise NV	DOCK EXPRESS 11	159.2 m	24.2 m	2,130 sq. m	8 m	8.89 m (max. sailing)	13,209 tons
Dockwise NV	DOCK EXPRESS 12	159.2 m	24.2 m	2,130 sq. m	8 m	8.89 m (max. sailing)	13,209 tons
Dockwise NV	MIGHTY SERVANT 1	160 m	40 m	4,800 sq. m	N/A	22 m (submerged)	21,500 tons
Dockwise NV	MIGHTY SERVANT 2	170 m	40 m	5,200 sq. m	N/A	22 m (submerged)	23,300 tons
Dockwise NV	MIGHTY SERVANT 3	180 m	40 m	5,600 sq. m	N/A	22 m (submerged)	24,800 tons
Dockwise NV	SUPER SERVANT 3	139 m	32 m	3,500 sq. m	N/A	6.26 m (transit) 14.5 m (submerged)	14,112 tons
Dockwise NV	SUPER SERVANT 4	169 m	32 m	4,380 sq. m	N/A	6.02 m (transit) 14.55 m (submerged)	17,600 tons
Dockwise NV	SWAN	180.5 m	32.26 m	4,007 sq. m	N/A	10 m	32,650 tons
Dockwise NV	SWIFT	180.5 m	32.26 m	4,007 sq. m	N/A	10 m	32,101 tons
Dockwise NV	TEAL	180.5 m	32.26 m	4,007 sq. m	N/A	10 m	32,101 tons
Dockwise NV	TERN	180.5 m	32.26 m	4,007 sq. m	N/A	10 m	32,650 tons
Dockwise NV	TRANSSHELF	173.5 m	40 m	5,280 sq. m	N/A	8.8 m (transit)	34,242 tons
Hinode Kisen Co. Ltd.	SEA BARON	150 m	32 m	3,600 sq. m	4.9 m	5.025 m	10,377 tons
	AMERICAN CORMORANT	223.06 m	42.25 m				47,230 tons

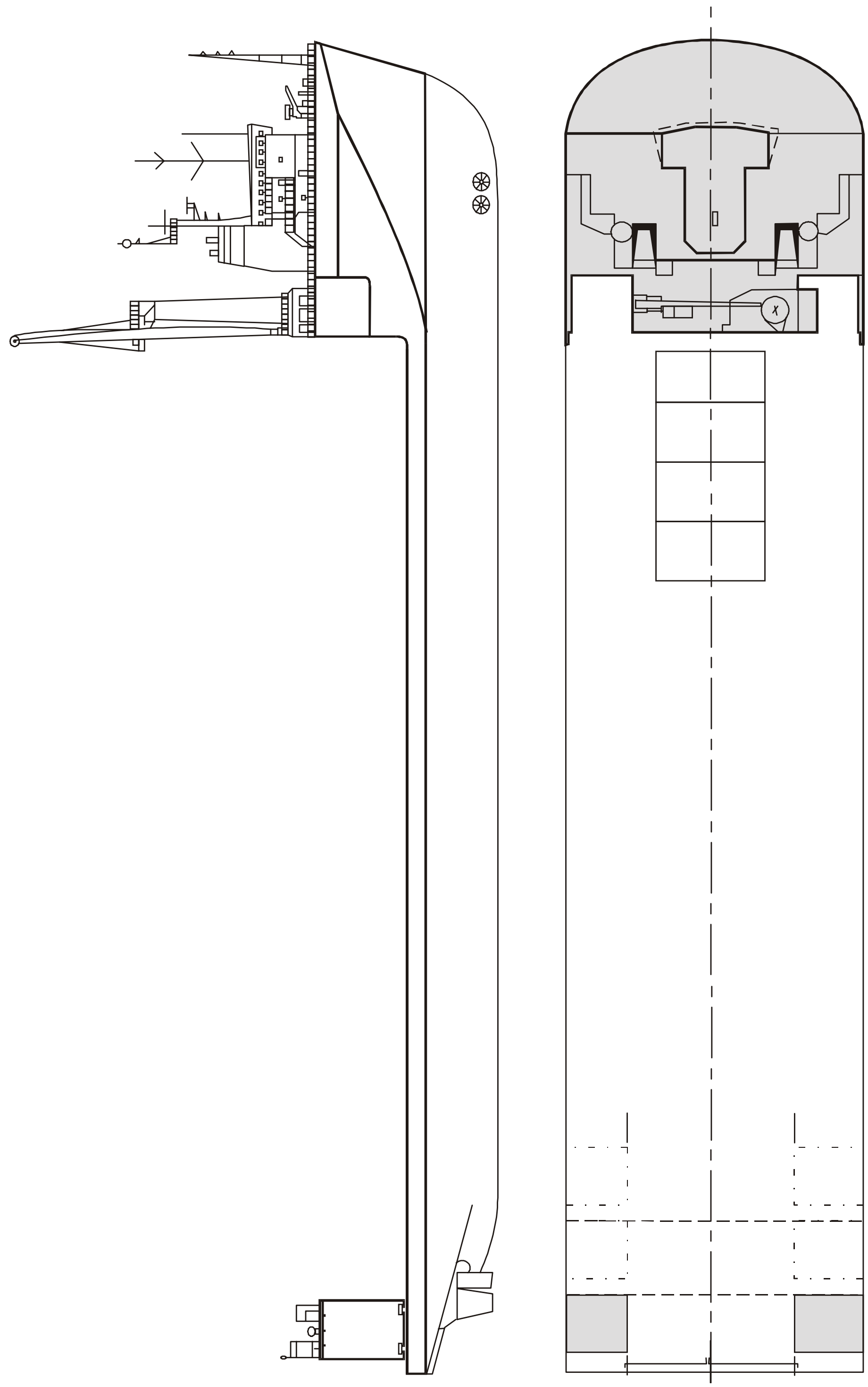


Figure 8-1. Heavy Lift Vessel.

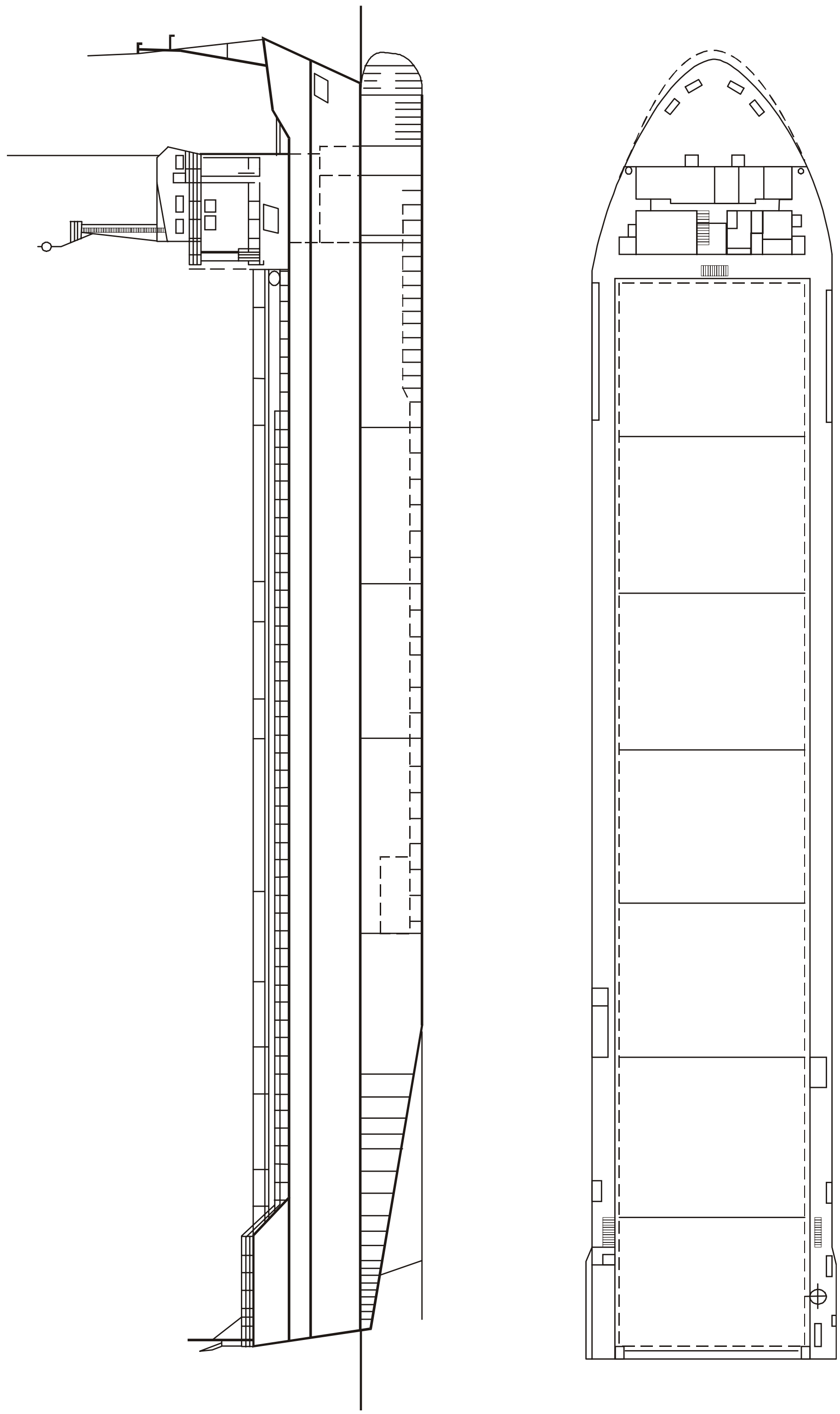


Figure 8-2. Heavy Lift Vessel.

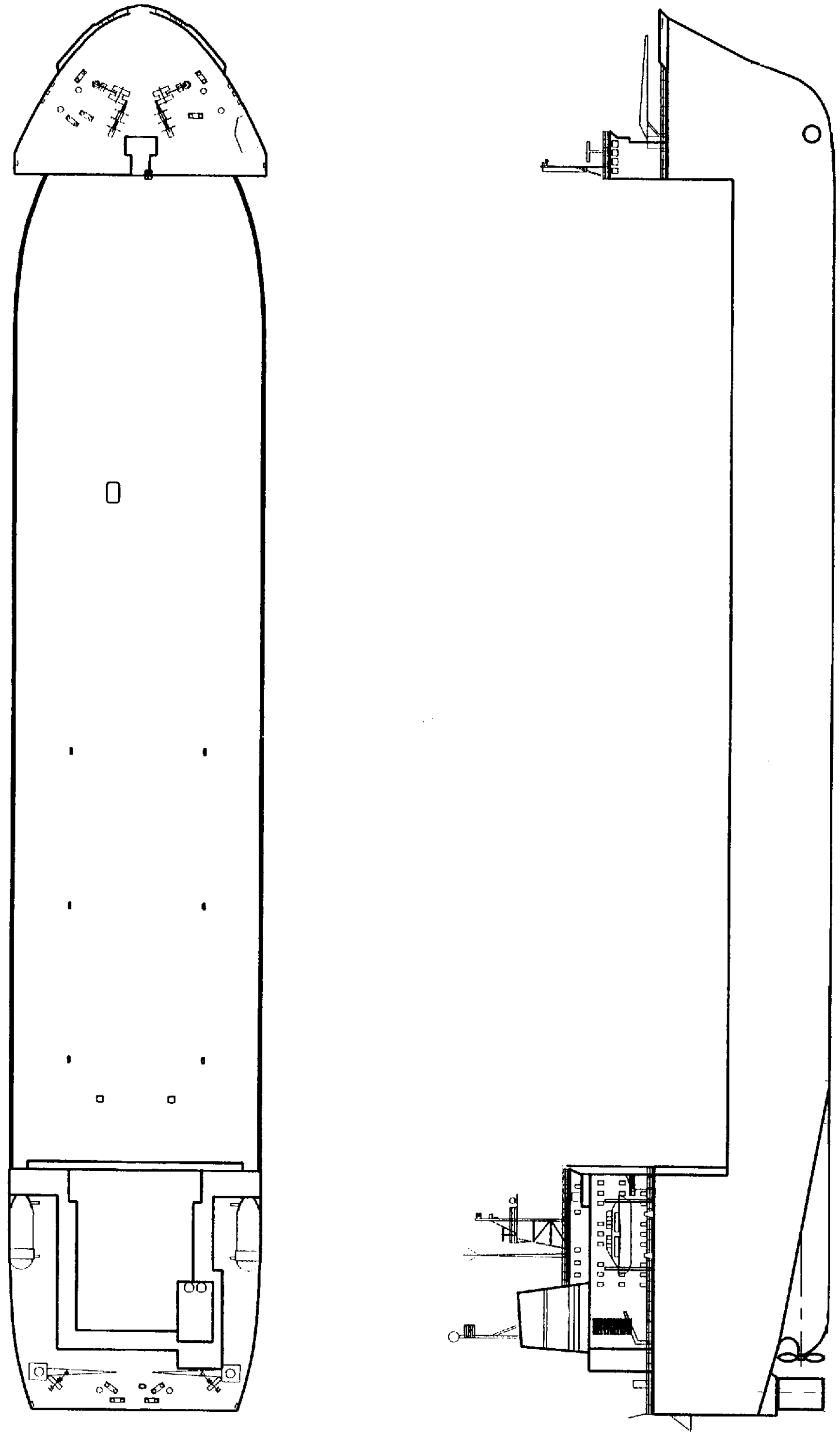


Figure 8-3. Heavy Lift Vessel.

Table 8-2. Heavy Lift Ship vs. Submersible Barge.

	Heavy Lift Ship	Submersible Barge
Stability	Stable in all operational modes, Sheltered in head seas	Relies on bottom contact for stability during lift, limited shelter in head seas
Access to Asset	Asset on deck of vessel, access through brow or ladder	Access limited by weather and small boat capability
Support	Designed to support lift ops, usually good hotel services	Tug may have limited additional hotel services
Cost	Specialized craft, more expensive, but generally shorter transit time	Tug/barge combo may have cheaper day rate, but longer rent time
Insurance/Risk	Generally insurance is less due to larger more controllable platform	Insurance rates can be a substantial cost
Speed	Open ocean design, good speed	Tow will be slower
Risk	One unit, minimal risk with good seafastening plan	With two craft and towline, risk is inherently greater

small coastal vessels across the ocean can be slow, costly and a significant risk to both personnel and the vessel. A vessel designed to operate in sheltered coastal waters is ill-suited to survive the winter storms of the North Atlantic. The asset may not have been designed to have the endurance to make the trip. Towing the assets is an option but a long ocean tow of a small vessel is not without its own risks. In the case of a multiple asset transfer, a heavy lift is far safer than a multiple tow. In the case of a damaged vessel, a heavy lift may be the only option as towing may not be feasible.

Figure 8-4 depicts a notional schedule for preparing a heavy lift. This schedule allows sufficient time to perform all necessary document reviews as well as completion of all block and seafastening builds. Some portions of this schedule are extremely flexible, such as the market search and contract solicitation, but other areas are more rigid. The heavy lift ship will require a certain amount of time to perform the lift and construct the blocking and seafastening. This process can be helped by providing the most up to date documentation.

Once an organization decides that a heavy lift is the preferred method of transfer, they should begin the planning phase by determining some basic details of the operation. Specific information about the what, where, and when of the operation will be needed when developing the request for proposal (see 8-3.2). If the lift is a planned transfer, the Military Sealift Command has been used successfully to administer contracts with commercial firms who are experienced in this field. In the case of an emergency, NAVSEA 00C (Supervisor of Salvage) should be contacted to expedite planning and execution of the lift. The remainder of this chapter as-

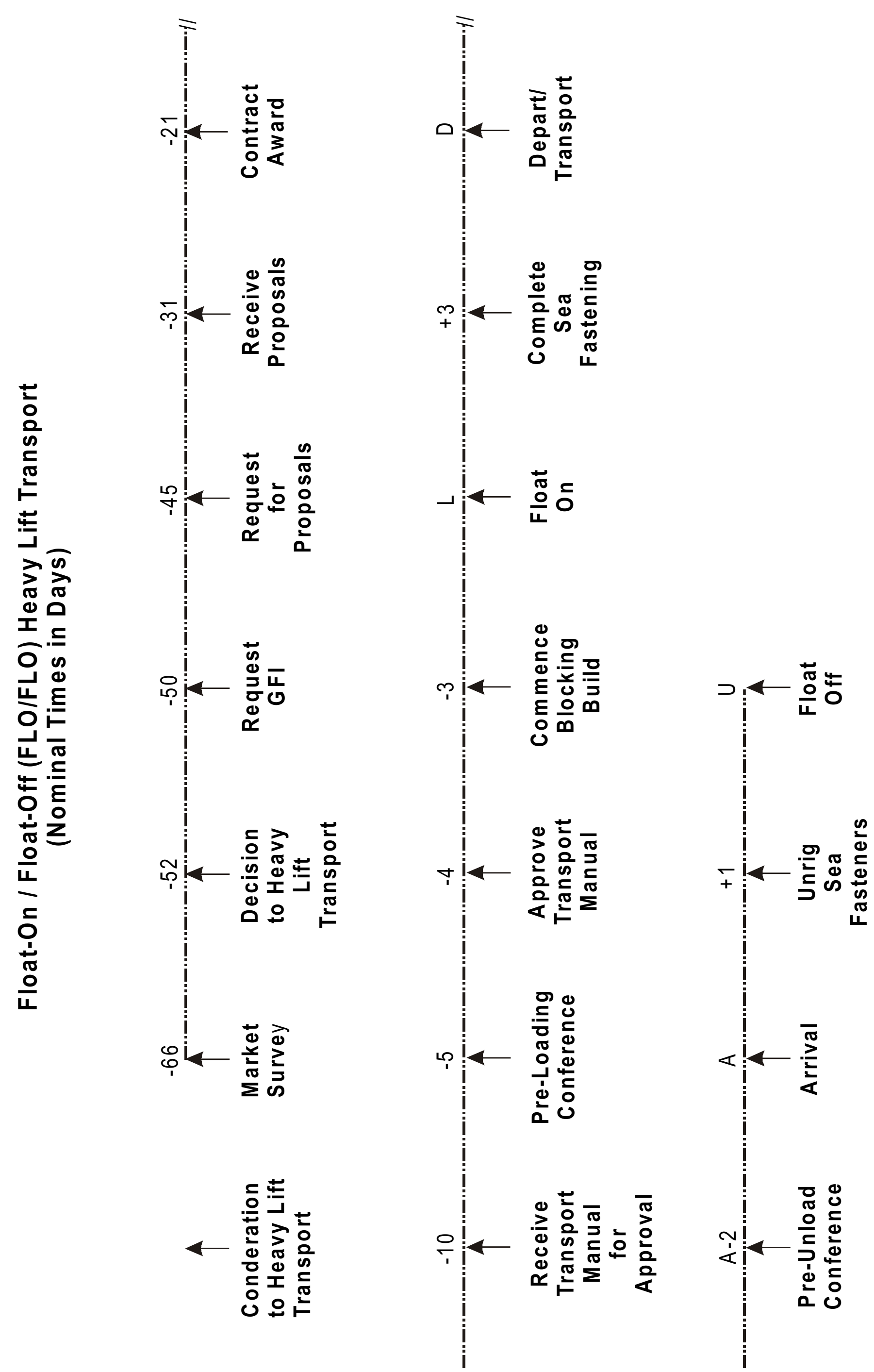


Figure 8-4. Plan of Action and Milestones.

sumes that MSC has issued the charter, but NAVSEA 00C or any office issuing the contract would have the same responsibilities.

8-3.2 Request for Proposal (RFP)

Previous FLO/FLO operations have been accomplished through the Military Sealift Command (MSC) Headquarters Contracting Officer. MSC issues a Request for Proposal (RFP) or modifies an existing time charter to include the details of the particular operation. When the need for a FLO/FLO operation is determined by an operational command, they must specify certain requirements to be included in the RFP or contract modification. Information required may include:

- Assets to be lifted
- Dates and locations of load and discharge points
- Supporting activities
- Asset specifics - class/name, condition of readiness, loading condition, value, date of last dry docking
- Additional cargo
- Asset's plant service requirements - both during the FLO/FLO operations and preparations and during sea transport

Upon receipt of the proposals, MSC (and other technical authorities; the operational command, a dry docking authority, NAVSEA tech codes, SUPSALV, etc.) review the proposals for technical correctness and cost comparison. MSC will then award a contract or contract modification.

8-3.3 Preparations

Once a contract has been awarded, several things need to be done to prepare for the lift. In this preparation phase, communication between the various organizations is critical to a successful and timely execution of the lift. The items listed below should be accomplished in advance of the date that the vessel will arrive at the loading site.

8-3.3.1 Choosing a Heavy Lift Team

The personnel chosen to be the MSC/Navy coordination team functions much like a Supervisor of Shipbuilding monitoring a dry docking availability. They review the contractor's proposals and ensure that he is performing the work in accordance with the contract and the Transport Manual. It is a good idea to choose people that can be present throughout the process (plan development, contract award, loading, off-loading), although it is not necessary. A list of personnel is shown here as an example of what has been used successfully in the past. This list may vary slightly depending on the assets to be lifted, the personnel available, and location of the lift.

Operational Commander

Generally the owner of the asset, the Operational Commander has cognizance of the operation. He designates the need for a FLO/FLO operation, identifies the services required to support the asset during all phases of the lift, and prepares the asset for transport. The Operational Commander is responsible for selecting all the members of the heavy lift team.

Designated Docking Activity (DDA)

The DDA is the technical point of contact during the planning and approval phases. The DDA provides on-site technical personnel and requests technical and coordination assistance from cognizant commands as required. The activity designated as the DDA should have experience in docking and undocking evolutions and is often located in the vicinity of the loading area.

Heavy Lift Project Officer (HLPO)

The HLPO is a senior technical officer, preferably an Engineering Duty Officer. Once designated, he or she will be responsible for coordinating both technical and logistics support for the asset to be lifted and development of lift requirements as well as review of the Transport Manual. The HLPO is the leader of the Navy heavy lift team.

Dry Docking Safety Officer (Docking Observer)

The Docking Observer is responsible for the float on and float off portions of the transport and for seafastening during transport. The Docking Observer reviews and approves all calculations required to conduct the FLO/FLO operation. The Docking Observer must be familiar with the local ship repair and service industry and the environmental conditions in the loading and off-loading sites. He/she is responsible to ensure that the asset is safely positioned, lifted and secured for transport, and discharged.

Blocking Expert

The blocking expert oversees the construction and installation of all necessary blocking and seafastening. He should be familiar with Navy docking drawings and the construction of various types of docking blocks. The blocking expert verifies that all blocks, blocking, seafasteners, and roll bars (spur shores) are installed properly and in accordance with the approved Transport Manual.

Stability Expert

The stability expert should monitor the operation to ensure adequate stability of both the ship and the asset at all stages of the lift process. He/she should be familiar with the operation of a heavy lift ship or floating dry docks and can verify the ballast/deballast sequence is sound and performed in accordance with the Transport Manual. He/she should inspect the ballast/deballast system (including the tank and draft indicator system) to ensure that it operates properly and should monitor this system during loading and off-loading operations.

Services Coordinator

This individual coordinates the installation of asset plant services such as electrical power, fire main, and potable water. He/she also coordinates general vessel support during the FLO/FLO operation such as line handling, security watches, communications, access, scupper overboard discharges, etc. The services coordinator should be familiar with the asset in order to verify all support requirements.

Ship Repair Officer

A Ship Repair Officer is assigned at both the loading and off-loading sites to coordinate any emergent/emergency repair work that may be necessary, using the lift as a docking of opportunity. Because this is a transport operation, the asset must be ready for sea transit; in particular, the watertight integrity of the hulls must be maintained. The Ship Repair Officer should be familiar with local ship repair and other services that may be necessary to complete repair work.

Riding Crew

The riding crew should be familiar with or come from the asset being lifted and include personnel of each of several rates. For multi-asset lifts, the riding crew should include at least one representative from each asset. The size of the riding crew is determined by the asset or assets being lifted and the berthing and messing capabilities of the heavy lift ship. The riding crew is responsible for security, damage control, maintenance, and other duties required for assets in a secured or partly secured status.

Independent Marine Surveyor (IMS)

An Independent Marine Surveyor (IMS), qualified by experience and credentials in the operation of FLO/FLO heavy lift ship operations and transports, should be appointed and be present at all FLO/FLO operations for Navy assets. The IMS will be responsible for independently assessing the following items:

Transport Manual

Material condition of the heavy lift ship

Ship systems

Blocking arrangement

Seafastening

Loading/off-loading procedures

Voyage arrangements

Preparation of the asset

The IMS is an independent third party to act as a mediator between the Navy and the contractor to provide independent analysis of the operation and to assist in settling disagreements. The IMS selected should be agreed to by both the Navy representative and the heavy lift contractor.

Loadmaster

The Loadmaster is the heavy lift contractor's designated coordinator. The Loadmaster directs the heavy lift ship's crew and subcontractors during the blocking build, the positioning of the asset over the submerged heavy lift ship, ballasting/deballasting operations, and the installation of the seafastening. The Loadmaster coordinates the off-loading procedure as well. The Loadmaster also approves the loading and securing of the deck cargo before departure.

Contract Coordinator

The Contract Coordinator works with the members of the different parties represented during a FLO/FLO operation to resolve any contract disputes. He will often be a representative from the Military Sealift Command, the organization that has contracted most Navy lifts in the past. Any modifications or other contractual questions should be coordinated through this individual.

8-3.3.2 Contractor Preparations

Once awarded the contract, the contractor must provide information about the operation. He must choose loading and unloading sites and develop drawings and procedures for the entire transfer including both loading and unloading.

The primary document detailing the preparations and procedures is the Transport or Load Manual. The contractor prepares and provides this document in advance (exact dates will be specified in the contract, but usually no less than four days) of the transport ship's arrival at the load site or the blocking build operations begin, whichever occurs first. It is recommended that the government loading team be in contact with the contractor during the development of the Transport Manual to avoid delays if corrections or adjustments need to be made. The document should be reviewed to:

- Ensure adherence to technical requirements
- Ensure that proper information, including drawings, is provided
- Verify references and their use
- Verify all engineering calculation and assure appropriate technical topics are addressed

Upon approval, this document will serve as the technical guide for all further events.

8-3.3.3 Transport (Load) Manual

The contractor shall provide a Transport (Load) Manual that details the technical requirements of the lift. The manual includes, but is not limited to, the following:

- Description of the heavy lift ship.
- Particulars of cargo from the heavy lift contract used by the contractor in the

development of the Transport (Load) Manual.

- Proposed route and probable sea states to be encountered.
- Motion analysis of the heavy lift ship as loaded with the cargo, for determination of roll and pitch angles and periods and accelerations for use in developing blocking and seafastening arrangements.
- Critical motion curve or table depicting the motions (angle and periods of roll, pitch, heave, and surge) to which the blocking and seafastenings are designed and which must not be exceeded in transport.
- If an asset overhangs the edge of the heavy lift ship's deck (either over the side or over the stern), a slamming study must be prepared to determine the number of occurrences and accelerations to which the asset may be subjected. The study should ensure the asset can be safely transported without sustaining damage.
- Stability analysis of the heavy lift ship as loaded, including calculation of loading conditions and intact stability assessment including righting moment curves and wind heeling moment, as defined in Paragraph 5.3.3.1(b) of MIL-STD-1625 as specified in 8-5.2.3.
- Stability analysis (GM curve) during the ballast/deballast sequence as defined in Paragraph 5.3.3.1(b)(1) of MIL-STD-1625, except that the minimum GM must not be less than specified in 8-5.2.2 unless specifically approved by NAVSEA at the request of the DDA.
- Cargo deck arrangement plan/drawing.
- Structural analysis of longitudinal bending stress imposed on the heavy lift ship by the proposed loading. Include a cargo deck load diagram, plating thickness, and arrangement and size of transverse and longitudinal stiffeners with acceptable cargo deck load capacity or drawing(s).
- Structural data for the heavy lift ship:
  - Maximum allowable bending moment calculation.
  - Transverse strength calculation sustaining the maximum allowable pontoon deck loading in long tons per linear foot.
  - Longitudinal deflection calculation.
  - Maximum keel block, side block, and hauling block loading calculations.
  - Maximum pontoon deck loading at other than keel block and side block locations, if different than that of the blocking area.
  - Structural arrangement and scantlings.
  - Longitudinal and transverse watertight bulkhead design calculations.
  - Maximum allowable differential head between tanks.
  - Maximum allowable differential head between tanks and exterior tank draft.
- Cribbing/blocking plan/drawings, including table of keel and side block offsets as specified in the docking drawings and calculation of loads including analysis of worst-case block loading when the heavy lift ship is at extreme trim angle during ballasting/deballasting.

NOTE
Experience with past heavy lifts demonstrated that locating side blocks in the locations as specified on the Navy docking drawing offers the best chance to have proper offset heights. The Navy standard docking drawing is a Selected Record Drawing (SRD) and takes precedence over all other drawings in determining offsets for height of side blocks.

- Descriptions of the docking blocks showing the physical characteristics of the blocks, including material and dimensions, and calculations to verify that the blocks will be stable and structurally adequate to withstand the loading used in lifting capacity calculations and that side blocks (and shores) are adequate in number to provide sufficient bearing area to resist overturning moments specified herein.
- Seafastening plan/drawings, including design forces.
- Loading/off-loading sequence plan/drawings.
- The amount of damage the heavy lift ship can withstand and survive without dropping the asset off the blocking and seafastening.

8-3.3.4 Choosing A Load Site

While the points of departure and destination for the assets will be specified in the contract, the contractor will select the actual load site, subject to approval. Weather will be the major factor in determining if a choice of load sites is good or bad. The location should be as protected as possible, although open water locations offshore have been used successfully. A poor choice of location for conducting FLO/FLO preparations can lead to major problems. If the operation is to be conducted offshore, take into consideration that the preferred anchoring/mooring method may be to swing on a single anchor.

The site must have enough water depth to accommodate the heavy lift ship's required draft for loading or off-loading, plus at least one meter clearance below the keel. Adequate water depth depends upon the draft of the asset to be loaded and the height of the blocking installed. Semi-submersible barges may require that one end of the barge rest on the bottom (for stability reasons) during loading.

The contractor may choose to do his preparations at a location other than the site of loading. The preparations can be made at any full-service, easily accessible location and then moved to a staging area when ready for sea.

The location should be mutually agreed upon by all parties involved in the loading process including the IMS.

8-3.3.5 Preparing The Deck

It is the contractor's responsibility to prepare the deck of the lift ship in accordance with the approved Transport Manual and he will need to arrange for any necessary subcontractors. To assist in deck preparations, the contractor should be provided with the most up to date docking drawings available for the asset to be lifted. The Planning Yard, or NAVSEA, should ensure that information and drawings provided to MSC for use by the contractor are accurate and current. Any activity reviewing the Transport Manual should also ensure that the docking drawing is the latest markup from the last dry docking, and that blocking locations and heights are correct. The minimum number of keel and sideblocks is discussed in 8-6. These blocks should be installed and inspected a minimum of 24 hours prior to commencement of the lifting operation to accommodate any last minute corrections. The building drawings presented in the Transport Manual should be reviewed and approved prior to the start of the build.

8-3.4 Pre-Load Conference

A conference should be held prior to loading where all parties involved are represented. The pre-load conference covers all aspects of the procedure so that all parties are familiar with their respective roles. Important topics to cover at this meeting are personnel, schedules, procedures, and responsibilities. This is often the first opportunity for some parties to have contact with each other. If possible, the conference should be held near the load site and/or the assets. This will allow site/asset inspection and may identify potential problems early.

This conference should be held far enough in advance to ensure that any changes or adjustments to the plan can be completed without adversely impacting the schedule. It should also be near enough to the date of the loading to allow for as many details as possible to be finalized. Separate meetings should be held as part of that conference to discuss specific operational details with line handlers, divers, block builders, tug masters, pilots, etc. It will likely be beneficial to have each team leader attend the conference. A similar conference should be held prior to discharge.

8-3.5 Load Site

Prior to the start of the float on operation, all assets and support craft must be on scene and all preparations must be completed. The heavy lift ship must complete the blocking build (see 8-6) and any preparatory efforts. These may be completed at the actual load site or at another facility. All work must be inspected to ensure compliance with the Transport Manual.

8-3.5.1 Visual Survey

At the load site (or preparation site), the blocking placement, arrangement, and build on the deck are inspected to ensure compliance with the drawings referenced or included in the Transport Manual. The materials used to build the blocks should be in serviceable condition. Any blocks with rotted wood should be replaced. At a minimum, a visual survey of the heavy lift ship and its systems is conducted, including the ballast/deballast system. This survey must be completed satisfactorily before the heavy lift ship is accepted (described in 8-9.2).

A survey of the assets should also be conducted. The survey should include an inspection of the floating condition of the asset including drafts, trim, and list. An internal survey to document the asset's loading and any on board weights should also be completed.

A complete checklist for both the heavy lift ship and the asset is included in Appendix R.

8-3.5.2 Support Tugs/Divers

To assist in the positioning of the assets over the blocks, support tugs and divers may be used. It is important to keep in mind that the area of loading will likely not be as well sheltered as a dry dock. Therefore, when selecting the number and size of tugs, assume the worst case for the weather. Tugs should be of sufficient size to hold the assets in the greatest expected wind and seas. If wind and seas are too strong, the operation should be postponed or another suitable location found. If multiple tugs are used it is important to keep lines of communication clear. One person, a harbor pilot or the loadmaster, should direct the positioning and operation of all the tugs.

WARNING
All sea suctions for the asset and the heavy lift vessel should be secured during diver operations.

WARNING
All parties must be informed when divers are being used. Extreme caution must be used to ensure the safety of these individuals. No deballasting or other ship movements should occur while divers are working directly under the asset.

Divers should be used to check the final alignment of the assets on the blocks. There is increased risk for divers since the operation is taking place in open water vice in a drydock.

Blocking heights are generally minimized, allowing little clearance between the asset and the cargo deck. Appropriate safety measures must be taken and only divers with experience in checking docking blocks should be used.

Tug masters and divers should be briefed about the operation and should be present at the preload meeting. Divers should be thouroughly briefed on the blocking arrangements, build and marking to include a walk around of the blocking build prior to submerging the cargo deck.

8-3.6 Preparing the Asset

An asset must be specially prepared to be lifted and transported. Many preparations are similar to preparations for a long deployment, docking, tow, or other special event. Appendix P provides a thorough list of all items that should be checked prior to arrival at the load site.

The preparing activity should ensure that the asset has complete watertight integrity. It is not necessary to go through the rigors of preparing a vessel for tow (locking propellers, two-valve protection, etc.) but every effort should be made to make the hull as tight as possible. All of these items should be accomplished as early as practicable, leaving only those that are essential until the loading day.

- Condition Zebra should be set throughout the ship.
- All compartments and bilges should be free from oil and water.
- All sea valves should be secured and tagged out in accordance with normal tag out procedures. This may need to be done while the vessel is being lifted or shortly after float-on. If connections from the heavy lift ship are to be used for items like cooling water, these valves should not be secured until the connection has been made. A list of sea valves should be prepared and made available to watchstanders.
- All sounding tubes should be capped. A list of sounding tubes and there condition should be prepared and made available to watchstanders.
- All between tank sluice valves should be closed.
- All watertight boundaries should be sealed. Where gaskets show signs of wear or deterioration, new gaskets should be installed.
- Rudders should be secured against any vessel motions. This may be accomplished after the asset has landed firmly on the blocks. It may be accomplished prior to this if no steering is required for docking.
- All loose equipment should be secured.

8-3.6.1 Arrival Conditions

When the asset is delivered to the load site, it should be in the condition (loading, drafts, trim, list, etc.) in which it is to be transported. If multiple assets are being transported, they should be in a similar condition of draft, trim and list. The assets should arrive early enough to allow for inspection by the heavy lift team, the IMS, and the Loadmaster.

The trim should be less than one foot and list should be less than 0.25 degrees. The final configuration and details of loading should be completed and made available as early as possible, preferably at the preload conference. This will ensure adequate time to prepare the vessel and plan the lift. It may not be possible to bring the asset into proper trim and list by simply adjusting tank levels. All tanks should be topped off or emptied to minimize free surface effect.

Weights may be added to help achieve the right configuration. If weights are placed on the asset to adjust draft, trim, or list, the structural adequacy of the asset to support the weights during the transport must be considered. It must also be considered that the facilities at the off-load site may preclude removal of the weights. The docking officer should be notified as added weights may effect the blocking build. Assets of the same design that are positioned alongside one another and in the same longitudinal orientation should be at a similar draft and trim.

8-3.6.2 Transport of Damaged Vessels

The transportation of a damaged asset requires careful assessment. Stability must be assured but draft, trim, and list in excess of those indicated above may be accommodated by the heavy lift ship's draft, trim, list, or freeboard. For example, USS COLE was lifted with 4 feet of trim by the bow and 1 $^1/_2$° list to starboard. This condition was the maximum that the heavy lift ship could accommodate by the freeboard on the after starboard caisson.

8-4 Loading Operations

This section will discuss the operations at the load site. It should be understood that many heavy lift vessels require deep water to operate. This may preclude these vessels from performing FLO/FLO functions in protected waters. It is essential that all preparations be completed prior to the day of the lift. Favorable weather windows may be small and unnecessary delays may jeopardize the safety of the operation or cause immense cost increases. Furthermore, poor or incomplete preparation is a leading cause of accidents and hazards.

8-4.1 Positioning of the Asset(s)

When the heavy lift ship is in position and ballasted to the proper draft, the Loadmaster will assume control of the assets for final positioning. The exact point of turnover should be decided and agreed upon by all parties prior to the event. Support tugs, riding crew, and the heavy lift crew should have good communications to ensure that all operations proceed smoothly and all needs are met. Often, alignment columns will be constructed to assist in the athwartships alignment of the asset (See Figure 8-5). Sufficient fendering or other system must be employed on the alignment columns to prevent damage to the asset. This will depend on the number and size of the assets being lifted. Support tugs will position the asset over the blocks and against the alignment columns or other guiding mechanisms. The Loadmaster will verify fore and aft position. Divers may also be used to verify position. (See 8-3.5.2)

Care should also be taken to ensure that there is sufficient clearance for all underwater projections such as sonars, propellers, bilge keels and pit swords. During positioning, a minimum of 1 foot of clearance should be maintained between the blocks and the asset (including all underwater projections). This limit is to allow for ship motions, so, if the ship is expected to pitch more than 1 foot, more clearance should be allowed. No part of the asset should be closer than 1 foot to the blocks. A one foot clearance should also be maintained between the asset and other parts of the heavy lift ship structure, such as wing walls.

Actual placement of the assets on the cargo deck is dependent on adequacy of working area between and around the cargo. This is also affected by installation technique and configuration of blocking and sea fastening. Forklift trucks can be used to move material around the assets on deck. Work space may be limited and spacing may dictate the work flow. A minimum spacing between assets of 2800 mm (9.2 ft) should be adequate for one directional work flow and walking space. However, twice the minimum spacing allows for two directional work flow and forklift truck access between the thrust blocks of the spur shores. A minimum of 2500 mm (8.2 ft)

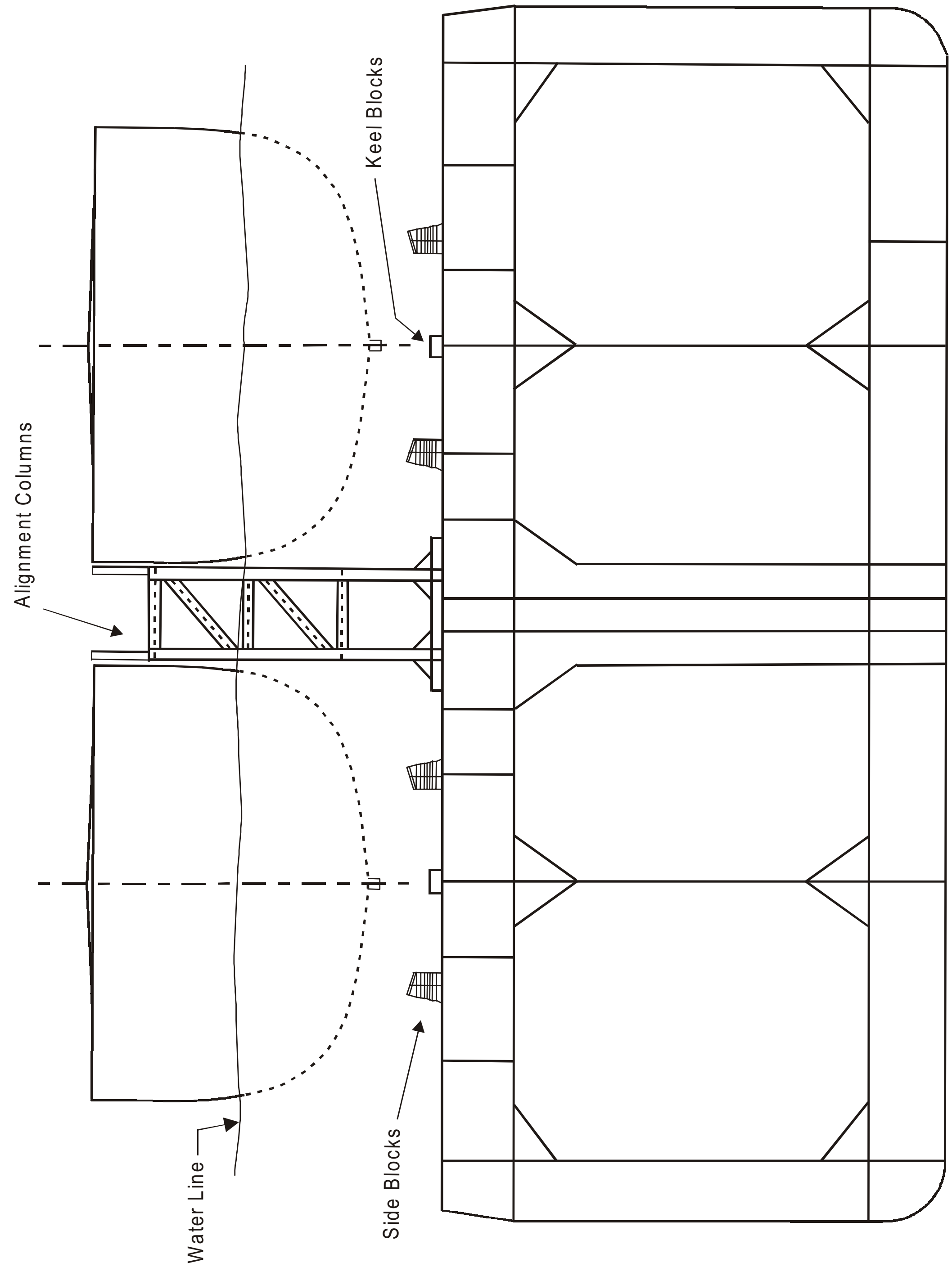


Figure 8-5. Assets Being Loaded.

clearance between the ship and the edge of the cargo deck should be adequate for blocking, working and access requirements. If possible, additional spacing should be allowed so that forklifts can still pass between the ships after the sea fastening spur shores (roll bars) are installed.

8-4.2 Fendering

Support tugs and alignment columns may be used to assist in positioning the asset(s) over the pre-built blocking arrangement. The riding crew should be prepared to provide fendering from the asset in the event that insufficient fendering exists elsewhere. These fenders should be tended during the deballasting operation until the vessel comes to its final resting position. 4’ x 4’ sheets of plywood may prove useful in preventing damage as the asset is moved into its final position.

8-4.3 Riding Crew Accommodations During Loading

The riding crew is required on board each asset for handling lines and tending hand fenders during loading and off-loading. This operation may extend for some time and crew size should be kept to a minimum. Since the asset may be in a reduced operating status and have no power during the loading, sanitary facilities and/or box meals for all personnel aboard the asset during the procedure must be arranged.

8-4.4 Deballasting

CAUTION
Personnel must be restricted from the heavy lift ship deck and on the lifted assets during both ballasting operations and work periods associated with seafastening.

Once the assets are satisfactorily positioned, the heavy lift ship should begin deballasting procedures. The assets should be observed carefully for any abnormal motion or any indications of damage or stress. The riding crew should tend the fenders to ensure that no damage occurs to the asset. See 8-5.2.2 for more information concerning stability during this critical phase.

8-4.5 Connection of Services

CAUTION
Connection of critical services, such as fire-fighting, should be given priority over other events. Firefighting services should be available throughout the process.

CAUTION
Once the asset is lifted, overboard discharge from the asset must be avoided, restricted, or scuppered over the side of the heavy lift ship.

CAUTION
When the asset is on board the heavy lift ship, a security watch should be established at the gangway of the heavy lift ship.

During the transit, the assets may depend on the heavy lift vessel for all necessary services. In planned operations, it is common for the riding crew to live aboard the heavy lift vessel. However, even if no one lives aboard the assets during the transfer, certain services should be made available. Connection of these services should not begin until the asset is in position and the heavy lift ship starts deballasting.

Fire fighting and cooling water services should be connected as soon as possible after the asset is secured in position. These connections should be completed prior to these sea suctions emerging from the water. Careful preparations, including a ship check prior to the event will ensure a quick and trouble free process. Connection of critical services, such as fire fighting, should be given priority over other events. Fire fighting services must be available throughout the process. Power cables and fire fighting hoses, can be pre-staged for ready use when required.

Additional services may be required if the riding crew is to remain aboard the asset during the transit. These extra services should be considered a secondary priority compared to deballasting. If a problem occurs with one of these connections, deballasting should continue without delay. A temporary means of access should be provided as soon as possible after the deck is dry. Primary, all-weather access may be provided later, but must be installed prior to departure.

After deballasting, the asset quarter deck watch should be moved to the cargo deck of the heavy lift ship near the gangway. The asset may be expecting technical representatives or other visitors who must be directed to the safest means of egress. Because these operations are unique and interesting, sightseers may be present; safety considerations should be made for them. Similar coordination is required for loading and fastening of any "Lift-on/Lift-off" deck cargo.

8-4.6 Blocking and Seafastening

CAUTION
Welding and industrial facility safety precautions must be followed closely during blocking and seafastening.

CAUTION
Personnel must be restricted from the heavy lift ship deck and on the lifted assets during both ballasting operations and work periods associated with seafastening.

Once the ship is deballasted, the blocking and seafastening should begin. Depending upon the number and size of assets and the complexity of blocking and seafastening required to accommodate the shape of each hull form, the seafastening may require several days of round-the-clock operation. A qualified Navy representative, normally the Docking Observer or Blocking Expert, should be present to inspect these operations in coordination with contractor personnel at all times. Personnel should traverse the area with caution and avoid the area as much as possible to prevent accidents and/or delays. Because of the extensive amount of welding on the cargo deck, personnel access and overboard discharge from the lifted assets must be restricted. Designated access routes should be created to minimize any interference from traffic. Any overboard discharges from the asset should be secured during the seafastening procedures.

8-5 Seakeeping and Stability

This section discusses some of the concerns associated with the stability of the asset, the heavy lift ship, and the combination of the two. Some calculations are presented here, but a qualified stability expert will be required to ensure the safety of all vessels involved.

During a FLO/FLO operation, several distinct stability considerations must be addressed, namely:

- Stability of the asset
- Stability of the heavy lift ship
- Stability of the asset/heavy lift ship system during the ballast/deballast operation
- Stability of the heavy lift ship with the asset secured aboard during transit

The various phases of stability are depicted in Figure 8-6.

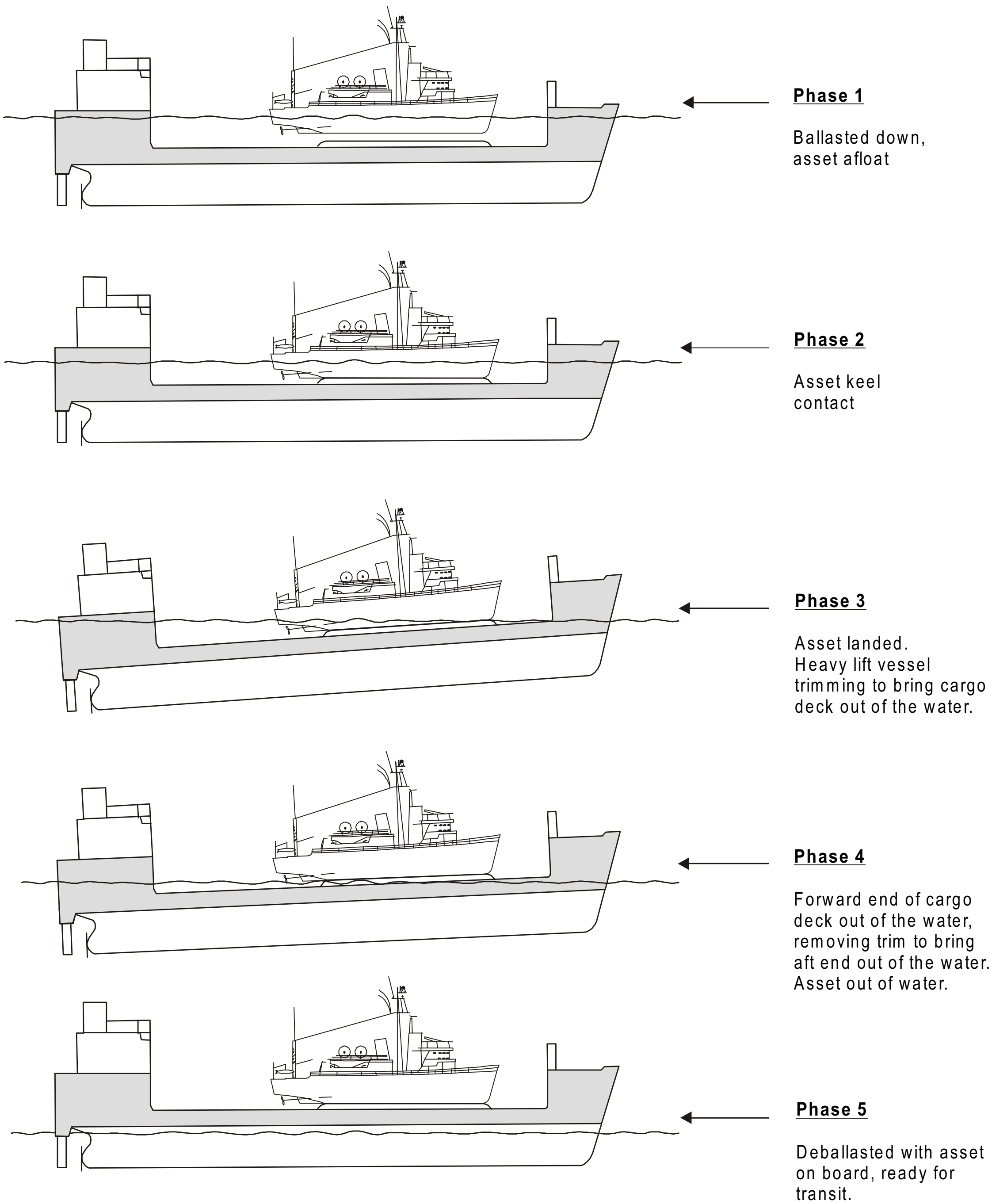


Figure 8-6. Phases of Stability.

8-5.1 Ship Motions

CAUTION
All personnel must strictly adhere to the operational plan and safety guidelines.

A FLO/FLO transport is a very dynamic operation. Each of several assets and the heavy lift ship move independently when the assets are being positioned on the deck of the heavy lift ship. This difficult situation is further complicated if the operation takes place in unprotected waters or even in the open ocean. Once the assets are on the cargo deck of the heavy lift ship, they act as one. This at first would sound similar to the case when the asset is in a floating dry dock. The dry dock, however, is in protected waters and is not normally moved. In a normal dry docking, little else is done to secure the asset, (internally or within the dry dock) with the exception of providing blocking for earthquake or hurricane force winds. With a heavy lift transport, the assets must first be made fit for sea (secured internally) and then secured aboard the cargo deck of the heavy lift ship for transit using blocking and seafastening. The intent is to hold the asset in position on the cargo deck and cradle the asset to keep it from sliding either transversely or longitudinally or rolling over.

As the heavy lift ship proceeds through the waves, it will flex (hog and sag). If the asset is rigidly tied down on the heavy lift ship, this flexing will be imparted to the asset and may cause structural damage. It is therefore necessary to design a structure that will be both strong enough to resist the motions of the ship, yet flexible enough not to cause damage to the asset. An understanding of the dynamics of the heavy lift ship and the asset is necessary to create such a structure. How to analyze the effects of ship motions is covered in Sections 8-6 and 8-7.

8-5.1.1 Wind Heel Criteria

WARNING
Loading and unloading shall not be conducted in winds above 20 knots or in a sea condition of sea state 3 or higher.

FLO/FLO operations are best conducted in sheltered waters, however, currents or channel depths may make this impossible. Wherever the operation is conducted, the dominant weather patterns should be studied. If the loading operation is to be conducted in protected waters a minimum wind of 60 knots with a gust factor of 1.21 should be used to evaluate stability. If the operation is to be conducted in an open ocean area, the historical data for that area should be consulted for expected conditions. A gust factor of 1.21 should be applied to expected winds. In the event that there is no data available, a commercial standard of 100 mph (86.8 knots) shall be used as the expected wind and then multiplied by the gust factor.

Weather routing during transit requires a separate analysis. Information concerning expected sea states and winds should be acquired for planning purposes. Transits include both the transfer from the point of departure to the unloading site as well and the transfer from the loading site to the building site (if they are different). If no data is available the commercial standard of 100 mph (86.8 knots) shall be used. In no case shall a wind of less than 60 knots be used.

8-5.2 Stability of the Asset

Stability of the asset, in the case of an unmodified or undamaged Navy commissioned ship, can be determined by reviewing the data in Chapter II(a) of the ship's Damage Control Book and a recent Inclining Experiment Report. Similar information for commercial ships should be available in the ship's Trim and Stability Booklet and the Deadweight Survey. Ship's from other services (USCG, US Army, etc.) should also have a consolidated source for this information. These documents will provide a good source for information for planning purposes and contain specific measures to improve stability. These books also contain stability characteristics for various loading conditions that meet the Navy's stability criteria.

For small craft and barges that do not have Damage Control Books, follow these general guidelines when attempting to improve stability:

- Completely fill any slack tanks to reduce the free surface effect
- Lower and secure or off-load high weights
- Secure any large hanging weights and add ballast
- Ballast by completely filling low tanks

Completely filling tanks or adding ballast will decrease freeboard but will generally improve stability.

Do not shift, add, or remove any weight from the asset once it is on the heavy lift ship unless specifically authorized by the Loadmaster, including liquids such as fuel or water. When permission is given to shift weights, an accurate record of the amount and location of the weight change must be kept. Always account for weight changes to ensure that the asset lifts from the blocks without losing stability or taking an undue list or trim.

The asset must meet stability requirements for all potential environments of the FLO/FLO evolution. Four different environments should be examined; loading, unloading, transit, and any transitional periods (i.e., from loading site to building site).

8-5.2.1 Stability Afloat

A thorough assessment of the asset's stability should be performed prior to the start of the FLO/FLO process. It is essential to evaluate the stability of the asset in its actual condition. A good weight survey (see 8-6.2.4) should be conducted on the day of the asset's arrival to the loading site to ensure that the actual condition is known. This includes draft readings, tank soundings and determination of displacement (weight) and centers of gravity. However, such a detailed analysis may not be possible if wartime or emergency conditions mandate quick action. Still, some estimate of the asset's stability should be obtained. If documentation of the ship's stability is not available, the stability may be approximated by timing the ship's roll period. This method is reasonably accurate and is used by the U.S. Navy, U.S. Coast Guard, and other regulatory bodies to check the stability calculations to confirm the accuracy of the inclining experiments and other similar determinations. This method is explained in 8-5.2.3 and Table 8-6.

This approximation method is not to be used as a substitute for a thorough stability analysis and weight determination. It only provides a measure of a ship's stability to be used to validate stability estimates in emergent conditions.

Equally important is frequent verification that the ship's roll period has not changed. Even if overall criteria are satisfactory, any significant time increase in the period of roll should be promply investigated, since this suggests flooding or additional free surface.

8-5.2.2 Stability During Loading

A detailed report of the condition of the asset as it arrives at the loading site should be made available to all parties so it can be evaluated and the heavy lift ship can make the final preparations. All assets of the same design that are to be loaded in the same fore and aft

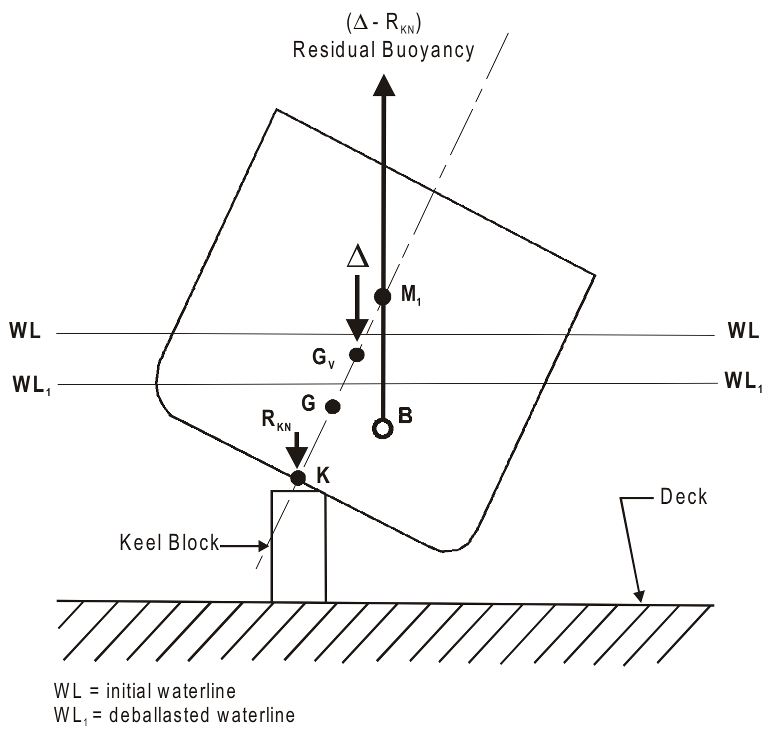


Figure 8-7. Draft at Instability.

orientation should arrive in a similar condition of list (no more than 0.25 degrees), trim (no more than 1 foot) and draft. It may not be possible to meet these limits with damaged assets.

The heavy lift ship can trim and list to match that of the asset. Additional considerations may limit the trim and draft of the vessels.

- Since this operation is performed in a seaway, the trim may be limited by the stability considerations addressed above.
- When deballasting the vessel, consideration must be given to knuckle loading on forward or after most blocks.
- Channel drafts may preclude excessive trim angles by the heavy lift vessel.
- Freeboard requirements and limiting submerged draft may preclude excessive trim angles.
- During the ballast/deballast operations, the trim of the heavy lift ship must be limited so that the asset does not float off or slide on the blocking.

The deballasting operation will put the asset in an unusual stability condition. The reaction of the docking blocks on the asset is equivalent to removing weight from the asset's keel. This weight removal will serve to effectively raise the asset's center of gravity and reduce its metacentric height (GM) and thus reduce its stability (see Figure 8-7). As more and more water is removed from the heavy lift vessel, the asset will be raised more and more out of the water, the reaction on the docking blocks will increase and this effect will be increased. The amount of reaction from the docking blocks is equal to the difference between the asset's floating displacement and the displacement at the waterline under consideration in the landed condition. Eventually, the reaction on the blocks will be large enough to cause the center of gravity to rise to a point where the GM, and thereby the stability, will be zero. This is an extremely dangerous condition, and the asset will almost surely capsize unless side blocks are in place. The asset's draft at this condition is called the "draft-at-instability."

The asset must land firmly on the keel and side blocks before this point is reached. If the asset has trim, it must land fore and aft on the keel blocks before the draft-at-instability is reached, or it will turn over. It is necessary to calculate both the draft-at-instability and the draft-at-landing fore and aft to ensure that the vessel will not capsize during deballasting. A good analysis should be provided by the contractor in the Transport Manual. There shall be a minimum of one foot of difference between the draft-at-instability and the draft-at-landing fore and aft.

If the draft-at-instability is much lower than the draft-at-landing fore and aft, the asset will have acceptable stability and dock safely. For example, if the asset has a draft-at-instability of 13 feet and a draft-at-landing of 15 feet, the asset should remain stable until it lands on the side blocks in calm water. Additional consideration must be given to the local sea state conditions. As an example, if the weather criteria to perform this operation allows for the asset to pitch such that it may lift off the blocks after initial landing, a difference between draft-at-landing and draft-at-instability of 1 foot would not be adequate for the asset to safely dry dock. If these draft values cannot be changed, this difference may dictate the operational weather criteria.

8-5.2.3 Draft-at-Instability

A good measure of a vessel's initial stability is the vessel's metacentric height (GM). It measures the ship's ability to recover from disturbances that cause small angles of heel. If GM is positive, the ship will be stable and return to its original heel angle when the disturbing force (wind, waves, etc.) is removed. If GM is negative, the vessel will be unstable. This means that if the vessel is disturbed, it will not be able to recover and will continue to roll in the direction that it moved at the onset of the disturbing force. In other words it will capsize.

GM can be determined from known or predictable quantities, KM and KG. The height of the metacenter (KM) for a ship is the theoretical point around which a ship rolls and through which buoyancy acts for small angles of heel. This point is based on a ship's geometry and is generally plotted on a ship's draft diagram or curves of form. A ship's vertical center of gravity (KG) is the point that represents the centroid of all the weights of a ship. This value is derived from the asset’s current condition of loading. Both of these quantities are measured from the keel and can be determined with some degree of certainty. GM is simply the distance between these two points or:

$$GM = KM - KG$$

As stated previously, a positive value for GM is required to be stable. By looking at this equation, it is easily seen that KM must be greater than KG to have a stable vessel. As the heavy lift ship deballasts, and the asset lands on the blocks, the draft of the asset will begin to decrease. As this draft goes down, the buoyant force on the asset (or residual buoyancy) will decrease and the height of the metacenter will change. Additionally, the amount of the vessel supported by the keel blocks (or reaction of the keel blocks) will increase.

The reaction of the keel blocks acts as weight removal at the asset's keel. This negative

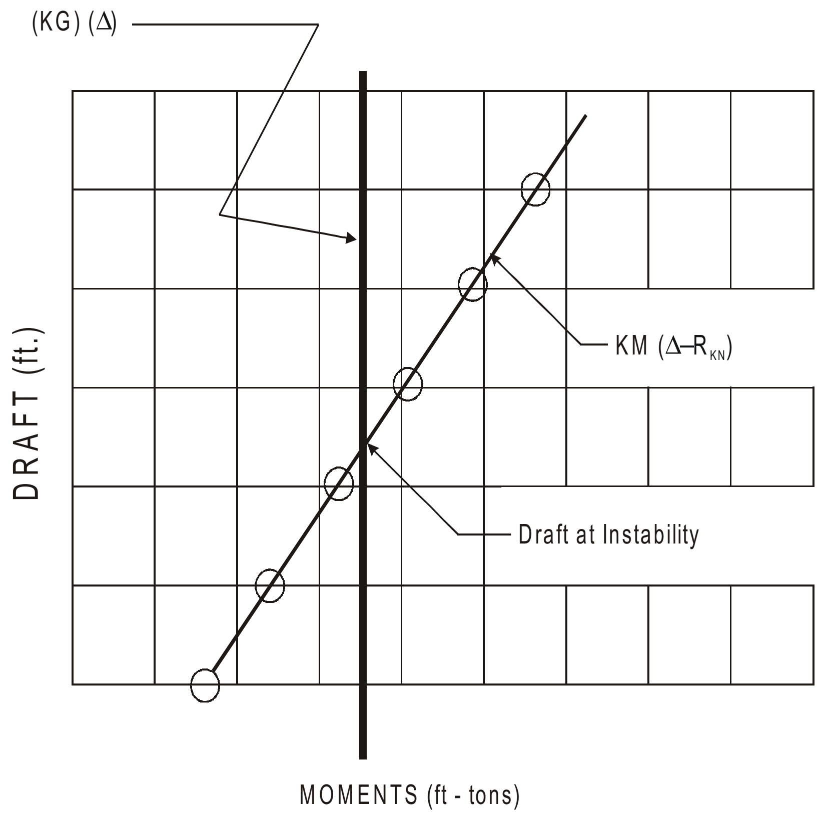


Figure 8-8. Limit of Stablility

weight at the keel causes the same effect as an added weight high in the ship. Both will cause an increase in the height of the center of gravity (KG). Since the asset's weight did not actually change, this rise in KG is called a virtual rise. This virtual increase will effectively cause a reduction in GM and reduce the stability of the asset. As draft continues to decrease, this effect will become more pronounced and the asset will become unstable. This point of instability occurs in every docking. The asset must land on the keel and side blocks before this point is reached or it may capsize.

To determine the draft-at-instability, it is necessary to determine the virtual reduction in metacentric height caused by the virtual rise in KG. The draft at which this virtual metacentric height (GM_v) equals zero, will be the draft where the asset is unstable. The virtual GM can be found by subtracting the virtual center of gravity (KG_v) from the height of the metacenter (KM) at the draft in question.

The virtual center of gravity can be found by summing the weight moments of the asset:

$$(KG_o \cdot \Delta) - (R_{kn} \cdot 0) = KG_v \cdot (\Delta - R_{kn})$$

or:

$$KG_v = \Delta \cdot \frac{KG_o}{(\Delta - R_{kn})}$$

Where:

KG_v = Virtual center of gravity (ft)

Δ = Ship's displacement (tons)

KG_o = Afloat center of gravity (ft)

R_{kn} = Reaction at the keel blocks (tons)

$(\Delta - R_{kn})$ = Residual buoyancy at a reduced draft (tons)

When the asset lands on the blocks and the draft begins to decrease, the asset is supported by two forces, the reaction of the keel blocks (R_{kn}) and buoyancy. The total of these two forces equals the displacement (weight) of the asset. In other words, the difference between the displacement and the reaction of the keel blocks is equal to the buoyancy at the reduced draft. This quantity (Δ - R_{kn}) is also called the residual buoyancy. The residual buoyancy can be determined for a given draft from the asset's curves of form or draft diagram. Knowing these values, the equation for GM_v can be solved.

$$GM_v = KM - KG_v$$

$$GM_v = KM - \Delta \cdot \frac{KG_o}{(\Delta - R_{kn})}$$

Where:

GM_v = Virtual metacentric height (ft)

KM = Height of the metacenter (ft) from ship's curves of afloat draft

KG_v = Height of the virtual center of gravity (ft)

Δ = Ship's displacement (tons) from ship's curves of afloat draft

KG_o = Afloat center of gravity (ft)

R_{kn} = Reaction at the keel blocks (tons)

Note: The term $(\Delta - R_{kn})$ is the displacement at a reduced draft, i.e. the residual buoyancy after keel contact. This equation can be solved for a number of drafts, until a draft is found where GM_v equals zero. A shorter way to determine this value is to set the equation equal to zero and solve graphically. By setting GM_v equal to zero we see that:

$$0 = KM - \frac{(\Delta \cdot KG_o)}{(\Delta - R_{kn})}$$

or:

$$KM \cdot (\Delta - R_{kn}) = \Delta \cdot KG_o$$

Both KM and the residual buoyancy (Δ - R_{kn}) can be found on the asset's curves of form or draft diagram. To solve this graphically:

- Determine a range of drafts, starting at the floating draft and decreasing in increments of one foot.
- For each draft, determine the asset's residual buoyancy and KM
- For each draft, calculate the residual buoyancy moment

  $$(KM \cdot (\Delta - R_{kn}))$$

- Calculate the displacement moment

  $$(\Delta \cdot KG_o)$$

  (Note: This quantity is determined at the assets floating draft and is not affected by the change in draft)
- Plot the residual buoyancy moment and the displacement moment for the range of drafts.
  (Note: The displacement moment should be a vertical line)
- Where these two curves intersect will be the draft-at-instability.

A sample of this graph is presented in Figure 8-8. and in Appendix Q.

If information is not known, such as during an emergency or rescue docking, an estimate of the vessel's condition can be made. By measuring the asset's roll period (see Table 8-6), an estimate of the GM and hence KG can be made. Using the formula:

$$GM = \frac{C_c^{\ 2} \cdot B^2}{T^2}$$

where:

GM = metacentric height (ft)

C_c = a constant (sample values given in Table 8-3)

B = beam of ship (ft)

T = period of roll for complete cycle, from a maximum on one side to a maximum the other and back (sec)

Thus, from the value of GM, KG may be obtained from equation:

$$KG = KM - GM$$

where:

KG = height of center of gravity of ship above keel when waterborne (ft)

KM = height of metacenter above the ship's keel (ft)

GM = metacentric height (ft)

The value of KM is obtainable from the curves of form.

NOTE

It is emphasized that the C_c value is only an approximation and enters the equation as the square of its value. The GM value thus obtained is, therefore, an approximation. This approximation method should not be a substitute for a thorough weight analysis.

Table 8-3. Sample C_c Values.

SHIP TYPES	C_c
Auxiliaries	0.44
Aircraft Carriers	0.58
Cruisers	0.43
DD692 (short hull)	0.42
Destroyers (other)	0.44
Destroyer Escorts	0.45
Landing Ships	0.46
Patrol Craft	0.47
Submarines Body of Revolution hull Other (fleet type)	 0.41 0.36
Tugs	0.40

8-5.2.4 Draft-at-Landing Fore and Aft

A similar method can be used to determine the draft-at-landing fore and aft. Again, it will be a balance of the residual buoyancy moments and the moment created by the displacement and the keel blocks (see Figure 8-9). If the asset lands on the aftermost block (method is similar for bow landings) it will begin to pivot about this point as the draft changes. The ship will land fore and aft when the moment created by the buoyancy equals the displacement moment (each acting about the aftermost keel block). To determine the draft when this occurs, follow this procedure:

- Determine the displacement, LCG, buoyancy, and LCB for the floating asset.

- Determine buoyancy and LCB for selected drafts below the floating waterline.
  (If the asset or heavy lift ship has considerable trim at the time of landing, horizontal waterlines may not provide an accurate estimate. In most cases,

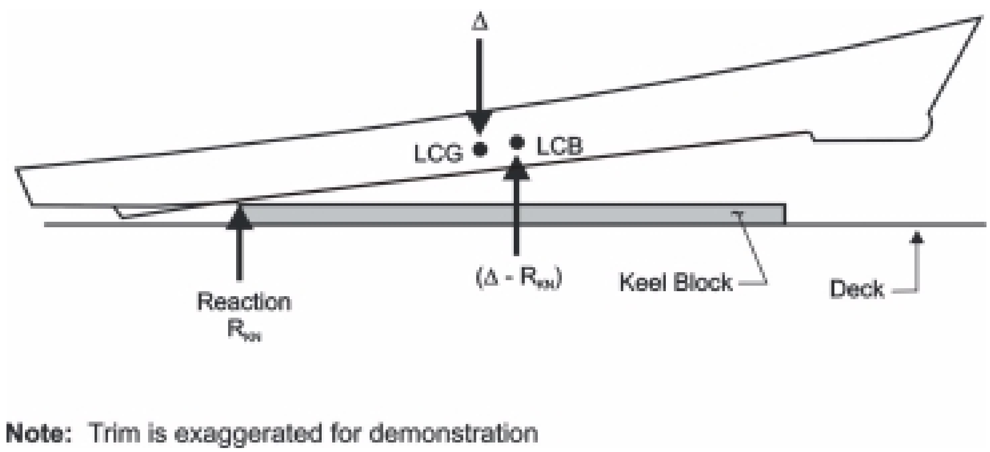


Figure 8-9. Draft at Landing Fore and Aft.

however, differences will be negligible.)

- Determine the distance between the knuckle block and the LCG.
- Determine the distance between the knuckle block and the LCB
- Calculate moments of residual buoyancy and moments of displacement about the aftermost keel block.
(Differences caused by the reaction point moving due to compression of the keel block can be ignored unless the stability is marginal and a more precise calculation is needed.)
- Plot these moments versus draft. The displacement moment will be a vertical line.
- Where the line of buoyancy moment crosses with the line of displacement moment, will be the draft at landing fore and aft.

A sample of this graph and these calculations is provided in Appendix N.

8-5.3 Stability of the Heavy Lift Ship

Any heavy lift ship considered for use as a transport platform for US Navy assets shall be classified by one of the commercial regulatory bodies (ABS, DNV, Lloyd's, etc.). The contractor must provide documentation showing current certification. The regulatory body should be contacted to verify that the vessel has met the latest requirements. When transporting assets, heavy lift ships must be at or below specified load line drafts that are intended to ensure adequate freeboard.

8-5.3.1 Intact Stability Requirements

The calculated stability and buoyancy characteristics of the heavy lift vessel (including displacements and centers of gravity with and without the asset on board) must be provided.

- The intact stability must be determined for all modes of operation, including the five phases shown in Figure 8-6. Longitudinal stability must be included for Phases 3 and 4 of Figure 8-6. Free surface effects must be determined and included in the calculations.

8-5.3.2 Stability During Ballasting/ Deballasting

The ballast/deballast operation presents some unique stability concerns and must be evaluated thoroughly. Stability is largely impacted by the amount of waterplane area of the ship. As the cargo deck of the heavy lift ship goes into or out of the water, the stability of the lift ship changes rapidly and substantially. If the deck is completely submerged, only the waterplane of the raised hull structure, which extends above the cargo deck, will provide stability to the vessel. Additionally, during this phase, the water level in the ballast tanks is changing and may not be in either empty or pressed up condition. This may produce a free surface effect which will also reduce stability. The result is that the heavy lift ship passes through a phase of minimum stability (minimum GM) while the cargo deck is under water. To control the amount of this change, heavy lift ships generally go through this phase with some list and trim.

CAUTION
Submersible barges that are used for FLO/FLO lifts rely on bottom contact of one end of the barge to ensure sufficient stability until the cargo has landed on the blocks and stability can be increased through added waterplane. Problems with exact positioning and high knuckle block loading add to an already difficult procedure. When one end of the cargo has landed, the barge must rely on the cargo staying in position and contributing to the stability of the barge/cargo system until more of the barge's cargo deck comes out of the water.

A thorough study of the changing conditions of the heavy lift vessel must be completed for the entire loading and unloading process. The point of minimum stability should be known to compare to the minimum stability conditions already calculated for the asset. Review the stability of the heavy lift ship to ensure that it is not at the point of minimum stability at the same time that the asset assumes its draft-at-instability. If this happens, the asset and the heavy lift ship may roll out of phase, causing landing problems, or, even worse, causing the asset or the lift ship to become unstable, assume a large list or capsize.

During operations involving lifting of U.S. Navy assets, the heavy lift ship shall maintain a GM (including free surface correction) of no less than 3.28 feet (1 meter). Trim of the heavy lift ship of up to 3° may be included to meet the minimum GM. More trim than this may cause the asset to float off the blocks on one end or slide on the blocks. The effect of this trim should be investigated to be sure it is satisfactory. Normally, if this trim on the heavy lift ship's cargo deck does not cause the assets draft at one end to be zero while the draft on the other end is less than 2 - 5 feet of the afloat draft, the asset should not slide or float off. See Figure 8-6, phase 3. To waive the 1 meter minimum GM, the asset must be hard on the blocking before the phase of minimum stability and the minimum GM (not accounting for the list) must meet or exceed regulatory body requirements of 0.5 feet (0.15m) in all phases of the operation, including the free surface effect. This is the minimum GM required by regulatory agencies. A detailed stability analysis for all operations must be included with the waiver request. In no case should a GM below 0.5 feet be accepted. Efforts should be made to meet the Navy requirements.

8-5.4 Stability of the Heavy Lift Ship with the Asset Secured Aboard during Transit

The heavy lift ship with the asset aboard, must be able to withstand beam winds as described in paragraph 8-5.1.1. The contractor must present a stability analysis (righting arm curve) meeting these criteria in the Transport Manual.

The dynamic stability under the righting arm curve at a given angle of heel is a measure of the amount of energy that has to be put into the ship to give it that angle of heel. This heeling or overturning energy can be supplied by wind, waves, or a combination of these and other forces. This quantity can be measured by making a plot of the righting arm (GZ). See Figure 8-10. The area under this GZ curve from zero degrees (or where the curve first crosses the x-axis) to the angle in question, multiplied by the displacement, is equal to the amount of energy that is available to return the vessel to the original static heel angle (most likely zero degrees).

The righting arm curve should also display the wind lever curve (see Figure 8-10). This curve represents the heeling energy developed by the wind acting on the sail area of the vessel (with the asset aboard). The area will change as the vessel heels which gives this curve a downward arc. This curve is dependent on wind velocity and represents only one particular speed. For the purposes of analysis, the maximum wind including gusts expected during transit should be used.

The American Bureau of Shipping (ABS) uses this GZ curve to establish their requirements for dynamic stability. The area under these two curves are then compared to determine adequate dynamic stability. The area for the GZ curve is computed from the first intercept (where it first crosses the x-axis) to the second intercept or the downflooding angle whichever is less (see ship's stability book for downflooding angle). If both the downflooding angle and the second intercept are greater than 50 degrees, then 50 degrees is used. The area under the wind lever curve is taken from 0 degrees to the same limiting angle. The range of dynamic stability, from the intersection of the wind lever and righting arm curves to the point of zero righting moment must not be less than 36 degrees (see Figure 8-10). Additionally, the second intercept point must be greater than 36 degrees.

ABS requires that the area under the righting arm curve at or before the second intercept or downflooding angle (whichever is less) is not less than 40 percent in excess of the area under the wind lever curve to the same limiting angle. Figure 8-10 demonstrates this graphically.

The angle of heel at which the cargo deck edge is submerged must also be indicated.

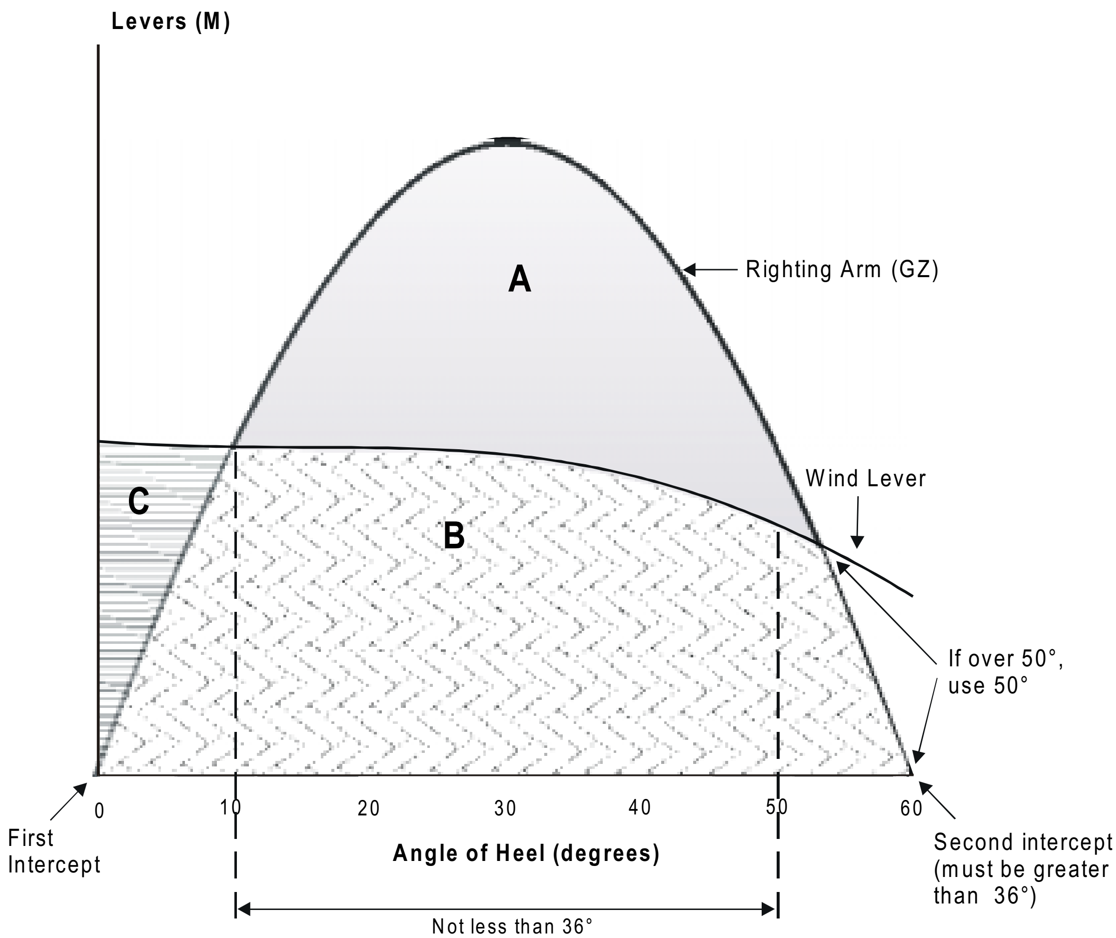
8-5.4.1 Damage Stability

The damage stability requirements of MIL-STD-1625C *Safety Certification Program for Drydocking Facilities and Ship building Ways for U.S. Navy Ships,* (Ref. T) were developed to ensure the safety of a vessel in a dry dock. If a floating drydock is subjected to damage to two main watertight subdivision groups, adherence to these guidelines ensures the safety of the docked vessel. These requirements may not be stringent enough to ensure survival and safety of an asset on the heavy lift ship if it is damaged in a seaway.

NOTE
The current commercial fleet of heavy lift ships and barges does not meet these requirements. The vessels should meet the damaged stability requirements of their classification society. These requirements should be studied to understand the limits and risks involved in regard to damaged stability.

8-6 Blocking

Unlike normal dry-docking operations, heavy lifted assets are subjected to significant motions caused by exposure to an ocean environment. This section will discuss the design of the blocking which will be the support system for the asset. This structure will carry the entire weight of the asset as well as protect the asset from potential damage from the motions of the heavy lift ship. The proper design of this system will ensure a safe transit for the asset.



For Adequate Dynamic Stability:
AREA (A+B) ≥ 1.4 · AREA (B+C)

NOTE
Downflooding Angle not shown. See ship's stability book for appropriate downflooding angle.

Figure 8-10. GZ Curve

8-6.1 Preparing the Docking Plan

NOTE
Check with the planning yard to be sure that the latest revision of the docking plan is being used.

Most vessels, and certainly all active Navy vessels, have a dry-docking plan. This plan contains information that shows the correct placement of docking blocks to provide a proper fit to the hull and to eliminate damage of underwater projections as well as distribute the docking loads. This serves as a first estimate in preparing a docking plan for a FLO/FLO operation, but preparation of the docking and seafastening plan requires consideration of factors other than what is normally considered in a dry docking.

A FLO/FLO is not an ordinary dry docking in terms of operations and loading. For a FLO/FLO operation, the keel block height must be minimized. The keel block height will affect the stability of the lift ship by dictating the required depth of water and depth of submergence of the heavy lift ship. This will probably determine acceptable loading sites. Additionally, tall keel blocks will require even taller side blocks. These blocks may be subject to loads caused by currents, waves or motions of the asset. Precaution must be taken to be sure that these blocks do not tip over during loading. Transporting across the ocean subjects the docking blocks to higher dynamic loading and, at the same time, requires the docking blocks to absorb the flexing of the heavy lift ship under the asset.

A docking plan should be prepared for every operation. Previous plans can be used as a guide, but each FLO/FLO presents unique concerns. The asset's loading condition, weather, and expected sea conditions will likely be different and must be accounted for in the plan. Careful preparation is essential for a successful operation. As a start, the assets dry-docking plan should be used as a preliminary plan. This will be sufficient to support the weight of the vessel with minimal dynamic loadings. The loading due to dynamic motions, the gravity component at the maximum angle of inclination, and the effects of wind loading must all be included in the analysis.

Check with the planning yard to be sure that the latest revision of the docking plan is being used. This plan, along with any previous FLO/FLO docking plans for the asset, should be provided to the lift contractor early in the process and, if possible, in the RFP.

8-6.2 Docking Blocks

The contractor should provide a proposed docking plan in the Transport Manual. It should contain descriptions of all the docking blocks. It should provide the physical characteristics of the blocks, including material and dimensions. Keel block height should be kept to a minimum to reduce the required depth for float on and float off. As such, the use of concrete base blocks, common in dry docking, should be avoided.

The Transport Manual also provides calculations to verify that the blocks are stable and structurally adequate to withstand the loading used in lifting capacity calculations and that the number of side blocks (and shores) is adequate to provide sufficient bearing area to resist overturning. Due to the dynamic nature of the operation, all blocks and shores should be secured to the cargo deck of the heavy lift ship. Prior to loading, these blocks should be inspected to be sure that they are the same dimensions, in proper location and in the same material condition as that reported by the Transport Manual.

The keel blocks are subject to both the static weight of the asset and the dynamic loads in the vertical direction imposed by the action of the sea. The side blocks and sea fasteners will bear some of the assets weight and also be subject to dynamic loading in both the vertical and transverse directions. To find the total force on the blocks it is necessary to calculate the effects of dynamic motion.

8-6.2.1 Dynamic Loading

The commercial industry designs sea fasteners using load forces based on equations from the *Principles of Naval Architecture (PNA) The Society of Naval Architects and Marine Engineers* (Ref. U) for roll and pitch. The US Navy developed their own series of equations for determining these dynamic forces. An explanation of these equations is contained in DOD-STD-1399-301A, *Interface Standard for Shipboard Systems Section* (Ref. V). The two equations produce very similar results for a similar set of conditions. The equations from PNA are used to calculate the forces due to dynamic motions separately from the static force due to weight then they are combined. The Navy equations combine these effects into a load factor. Both sets of equations use assumed values for maximum roll and pitch. Either approach can be used but only the Navy approach is demonstrated here. See *Principles of Naval Architecture (PNA) The Society of Naval Architects and Marine Engineers* (Ref. U) more information about the commercial approach.

The keel blocks will bear most of the weight of the asset with the side blocks and seafasteners taking only a partial load. To be conservative, the keel blocks will be designed to support the entire weight. The weight of the asset is equal to its displacement at the time of loading. As discussed earlier, an account of the dynamic loading must also be included for accelerations in the vertical direction.

To determine the design loads (forces) that must be resisted to hold the asset on the cargo deck of the heavy lift ship, multiply the weight of the asset (w) by an acceleration factor (a) determined from the motions of the heavy lift ship, taking into account the location of the asset.

The formulas for computing the acceleration (a) in the vertical direction (z direction) are as follows:

$$a_z = 1 + h + \frac{0.0214Px}{T_p^{\ 2}} + \frac{0.0214Ry}{T_r^{\ 2}}$$

where:

a_z = vertical acceleration factor (g)

h = heave acceleration (g) (Table 8-4)

P = Maximum angle of pitch (degrees) (Table 8-5)

x = distance of center of gravity of asset forward or aft from center gravity of heavy lift ship (ft)

R = Maximum angle of roll (degrees) (Table 8-6)

y = distance of asset off centerline of heavy lift ship (ft)

T_p = Period of pitch (sec) (Table 8-5)

T_r = Period of roll in (sec) (Table 8-6)

The first term in this formula accounts for the static force due to the weight, gravity component. This factor represents the portion of the asset's weight to be borne by the blocking. A value of 1.0 is used for keel blocking to be conservative.

Values for pitch and roll amplitudes and periods are given in Table 8-5 and 8-6. The commercial industry typically uses the following values as a first estimate to develop their load factors:

R = 20 degrees of roll, one direction

P = 15 degrees of pitch, one direction

T_r = roll period of 10 seconds, port to starboard back to port

T_p = pitch period of 10 seconds, bow to stern back to bow

The load factors which have proved effective on past lifts, are approximately equal when compared to those developed in *DOD-STD-1399 Section 301A*, provided that the loading is similar to those in the past. Namely, GM and roll/pitch periods must be in the same range. The ship motions observed during actual operations indicate that both approaches are comparable for a sea state 7 analysis.

Using these commercial standards or the US Navy approach is acceptable, however, they should not take the place of a detailed motion study. This commercial industry approach does not include an additional heave acceleration. If the results from the motion analysis indicate that the heavy lift ship with assets aboard will roll or pitch at periods greater than this rule of thumb, further evaluation by NAVSEA is required. These values should be compared with the expected values from route planning. If larger angles of heel or pitch are expected, those values should be used.

Information concerning acceleration factors along with the angles or roll, pitch, heave, and surge should be presented in the Transport Manual.

8-6.2.2 Loading of Keel Blocks

To find the total force on the blocks, multiply this acceleration factor by the weight of the asset.

$$DL_k = wa_z$$

where:

DL_k = total dead load on the keel blocks (tons)

w = weight of the asset (tons)

a_z = vertical acceleration factor (g)

NOTE

The vertical acceleration factor, a_z, represents an increase in the downward force. It is essentially a multiplier to increase the effect of gravitational acceleration and the units used, g, reflect this.

8-6.2.3 Keel Block Loading Distribution

Using the Navy docking drawing as a guide in placement of keel and side blocks will assure alignment with ship's structure, omissions for hull penetrations and appendages and a proper fit to the curvature of the hull. Specifics of the blocking must be provided for the proposed blocking arrangement to make sure that the asset's hull is properly supported. To ascertain that structural requirements are not violated, the loading distribution of the asset on the blocking must be calculated. The distribution of the asset's weight, as shown on the longitudinal strength drawing (20 station weight breakdown), indicates how the asset's weight is distributed on the asset's hull structure and thereby onto the blocking as shown on the Navy docking drawing.

The weight of the asset and the location of the asset's centers of gravity (vertical, transverse, and longitudinal) must be accurately predicted in order to avoid overloading the blocks. Keel bearing should be uniform and continuous. If keel bearing is non-uniform, as in the case of a asset with a partial bar keel, long overhangs, highly concentrated weights or excessive hull projections, special considerations must be given to further spread the load over individual keel blocks. For loadings that are not continuous and uniform, a more rigorous method may be required to determine the load distribution. As an example, MSOs and MCMs require additional shores to be placed under the stern due to long overhangs.

8-6.2.4 Distribution of Asset's Weight

Once the total force on the keel blocks is known (DL_k from 8-6.2.2), an assessment of the loading distribution should be conducted to ensure that the blocking is not overloaded. This loading distribution should be compared to the docking drawing that was used as a first estimate of required blocking. To conduct a loading distribution:

Examine ship data for the latest information. Sources include docking drawings, curves of form, and full load weight distribution.

Survey the asset to find information on all variable weight and abnormalities (trim weights added, hull damage, cargo, etc.)

- Record vessels drafts
- Calculate the asset's expected drafts at the time of docking
- Calculate the asset's displacement and centers of gravity

Compare the expected values with the recorded values and resolve any discrepancies.

Table 8-4. Heave and Surge Motion Parameters for Calculation of Loading Factors for Conventional Surface Ships.

Sea State	LBP meters (feet)	Heave acceleration (g)	Surge acceleration (g)
4	Less than 46 (150)	0.10	0.06
	46-76 (150-250)	0.10	0.05
	76-107 (250-350)	0.10	0.05
	107-152 (350-500)	0.06	0.04
	152-213 (500-700)	0.06	0.04
	Greater than 213 (700)	0.04	0.02
5	Less than 46 (150)	0.17	0.10
	46-76 (150-250)	0.17	0.10
	76-107 (250-350)	0.17	0.10
	107-152 (350-500)	0.14	0.05
	152-213 (500-700)	0.10	0.05
	Greater than 213 (700)	0.07	0.05
6	Less than 46 (150)	0.27	0.15
	46-76 (150-250)	0.27	0.15
	76-107 (250-350)	0.27	0.15
	107-152 (350-500)	0.21	0.10
	152-213 (500-700)	0.16	0.10
	Greater than 213 (700)	0.11	0.05
7	Less than 46 (150)	0.4	0.25
	46-76 (150-250)	0.4	0.20
	76-107 (250-350)	0.4	0.20
	107-152 (350-500)	0.3	0.15
	152-213 (500-700)	0.2	0.15
	Greater than 213 (700)	0.2	0.10

Table 8-4. Heave and Surge Motion Parameters for Calculation of Loading Factors for Conventional Surface Ships.

Sea State	LBP meters (feet)	Heave acceleration (g)	Surge acceleration (g)
8	Less than 46 (150)	0.6	0.35
	46-76 (150-250)	0.6	0.30
	76-107 (250-350)	0.6	0.30
	107-152 (350-500)	0.5	0.25
	152-213 (500-700)	0.4	0.25
	Greater than 213 (700)	0.2	0.10

NOTE

In the event of lifting a damaged asset the displacement at the time of lift may differ from the displacement to be transported. This is due to the entrained water in the damaged area that will run out during and after the lifting operation.

8-6.2.5 Calculation of the Asset's Loading on the Docking Blocks by the Trapezoidal Method

It is important to get an estimate of the load on the blocks to ensure that they are not overstressed. To do this, start by examining the required blocking of the docking drawing. This will provide the first estimate of the longitudinal location of the asset with respect to the blocking and its center of gravity with respect to the center of blocking (see Figure 8-11).

Table 8-5. Pitch Motion Parameters for Calculation of Loading Factors for Conventional Surface Ships.

Sea State	Length between perpendiculars (LBP) meters (feet)	Pitch angle* degrees	Pitch period seconds
4	Less than 46 (150)	2.0	3.5
	46-76 (150-250)	2.0	4.0
	76-107 (250-350)	1.0	5.0
	107-152 (350-500)	1.0	6.0
	152-213 (500-700)	1.0	7.0
	Greater than 213 (700)	1.0	8.0

Table 8-5. Pitch Motion Parameters for Calculation of Loading Factors for Conventional Surface Ships.

Sea State	Length between perpendiculars (LBP) meters (feet)	Pitch angle* degrees	Pitch period seconds
5	Less than 46 (150) 46-76 (150-250) 76-107 (250-350) 107-152 (350-500) 152-213 (500-700) Greater than 213 (700)	3.0 3.0 2.0 2.0 2.0 1.0	3.5 4.0 5.0 6.0 7.0 8.0
6	Less than 46 (150) 46-76 (150-250) 76-107 (250-350) 107-152 (350-500) 152-213 (500-700) Greater than 213 (700)	5.0 4.0 4.0 3.0 3.0 2.0	3.5 4.0 5.0 6.0 7.0 8.0
7	Less than 46 (150) 46-76 (150-250) 76-107 (250-350) 107-152 (350-500) 152-213 (500-700) Greater than 213 (700)	7.0 6.0 6.0 5.0 4.0 3.0	3.5 4.0 5.0 6.0 7.0 8.0
8	Less than 46 (150) 46-76 (150-250) 76-107 (250-350) 107-152 (350-500) 152-213 (500-700) Greater than 213 (700)	11.0 10.0 9.0 7.0 6.0 5.0	3.5 4.0 5.0 6.0 7.0 8.0

*Note: Pitch angle is measured from horizontal to bow up or down.

It is important to use the weight distribution of the asset at the time of its loading onto the heavy lift ship. For the current condition of loading, the displacement and centers of gravity are calculated using the current draft readings and the weight distribution as described above. In the case where the blocking can be assumed to be continuous and uniform (see Figure 8-12), the loading distribution may be approximated by using a trapezoidal approximation.

If the asset's longitudinal center of gravity (LCG) aligns vertically with the center of blocking (C_b), the forward and after blocks will share the load fairly equally. In practice, this is rarely the case. When the asset's LCG

Table 8-6. Roll Motion Parameters for Calculation of Loading Factors for Conventional Surface Ships.[1]

Sea State	Beam meters (feet)	Roll angle [2] degrees	Roll period
4	Less than 15 (50) 15-23 (50-75) 23-32 (75-105) Greater than 32 (105)	7 6 6 5	See note[3] for determination of roll period
5	Less than 15 (50) 15-23 (50-75) 23-32 (75-105) Greater than 32 (105)	12 10 10 9	See note[3] for determination of roll period
6	Less than 15 (50) 15-23 (50-75) 23-32 (75-105) Greater than 32 (105)	19 16 15 13	See note[3] for determination of roll period
7	Less than 15 (50) 15-23 (50-75) 23-32 (75-105) Greater than 32 (105)	28 24 22 20	See note[3] for determination of roll period
8	Less than 15 (50) 15-23 (50-75) 23-32 (75-105) Greater than 32 (105)	42 37 34 31	See note[3] for determination of roll period

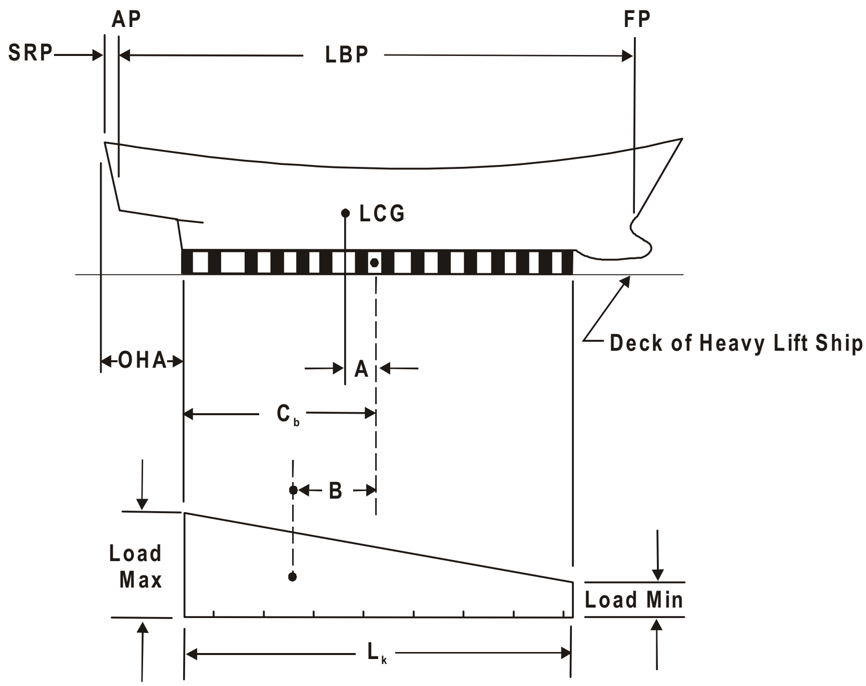
[1] Excludes multi-hulls, surface effect ships, and all craft supported principally by hydrodynamic lift.
[2] Roll angle is measured from vertical to starboard or port
[3] Full roll period is to be calculated from:

$$T_r = (C_c \times B)/(\overline{GM})^{1/2}$$

Where:
T_r - is the full roll period (seconds)
C_c - is a roll constant based upon experimental results from similar ships - usual rate 0.38 to 0.49 (sec/√ft) (0.69 to 0.89 (sec/√m)). For Heavy lift ships use C_c-0.40 unless a better estimate is provided. It may be as high as 0.44. See Table 8-3 for examples of other surface ships.
B - is the maximum beam at or below the water line (m or ft).
$\overline{GM}$ - is the maximum metacentric height (m or ft).

is forward or aft of the C_b, we can assume the load distribution is roughly trapezoidal. Again, this is assuming that there is no significant anomalies in either the ship's load distribution or in the blocking build. If the LCG is aft of C_b, the after blocking will carry more of the load.

The amount of load supported by the after blocks will depend on the distance that LCG



FP = Forward Perpendicular

AP = After Perpendicular

LBP = Length between perpendiculars of asset

SRP = Distance from AP to point from which distance to keel blocks is measured

LCG = Asset's longitudinal center of gravity

OHA = Distance from SRP to keel block

L_k = Length of keel blocking

$C_b = \frac{L_k}{2}$ = Center of blocking

$B = \frac{L_k}{6}$ = Approximate Center of Trapezoid

A = Distance from asset's LCG (center of Gravity) to C_b (center of Blocking)
= C_B-[LBP+SRP-LCG-OHA] (Note that if A is a negative number the trapezoid is reversed in the above diagram so the Load max is greatest at the forward end of the asset

Figure 8-11. Load Distribution.

is from C_b. The further away from LCG that C_b is, the more uneven will be the distribution of loading. In fact, if the LCG is outside of the center third of the blocking arrangement, the load distribution will be triangular and the difference between maximum load and minimum load may be significant. See Figure 8-11 for an illustration of the relationship between LCG and the center of the assumed trapezoid, B. For a trapezoidal load distribution, B will be approximately 1/3 of the length of the keel blocking (L_k) from the after end or 1/6 of L_k from the center of blocking (based purely on geometry). This is a good initial estimate to determine the maximum and minimum load.

To determine the maximum and minimum loads, use the following equations:

If A < B, load distribution is trapezoidal:

$$\text{Load Max} = \frac{DL_k}{L_k}\left(1 + \frac{A}{B}\right)$$

$$\text{Load Min} = \frac{DL_k}{L_k}\left(1 - \frac{A}{B}\right)$$

If A > B, load distribution is triangular:

$$\text{Load Max} = \frac{4DL_k}{3(L_k - 2A)}$$

$$\text{Load Min} = \frac{\text{Load Max}}{L_e}$$

where:

Load Max = Maximum expected blocking load (tons)

Load Min = Minimum expected blocking load (tons)

DL_k = Loading due to weight and dynamic effects (see) (tons)

A = Distance from center of gravity of asset to center of blocking (ft)

B = Distance from center of trapezoid to center of blocking (L_k/6) (ft)

L_k = Length of keel blocking (ft)

L_e = Length of effective keel blocking (ft) = 1.5 L_k - 3 A

The load distribution, as defined by Load Max and Load Min, is used to determine if the blocking (and in some cases the cargo deck) is adequate to support the asset. Check the maximum loading against the loading assumed for the ship's docking drawing. The keel blocks should be checked to ensure that they are not overstressed. Assume that the last block in the line will see Load Max. To find the stress on this block use:

$$S = \frac{\text{Load Max}}{A_e} \times \left(\frac{2240 \text{ lb}}{1 \text{ ton}}\right)$$

where:

S = Stress on block (psi)

Load Max = Maximum expected blocking load (tons)

A_e = Effective area of keel block (in^2)

CAUTION
These calculations assume a continuous row of keel blocks. If this is not the case, increases in loading should be made accordingly.

This stress should be lower than the proportional limit for the material used. See Table 8-7 and paragraph 8-6.2.7 for the allowable stress on blocks. If it is not, consider using more keel blocks, keel blocks with better contact area, or redistributing the asset's load more evenly.

8-6.2.6 Knuckle Loading

Special consideration must be given to the end of the blocking arrangement as an asset

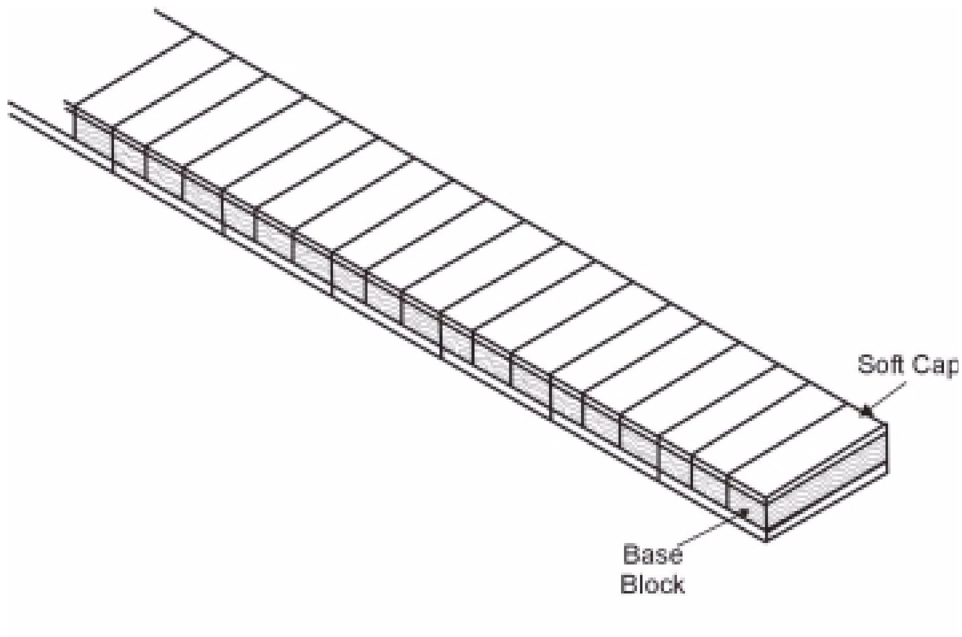


Figure 8-12. Keel Blocks.

Table 8-7. Allowable Block Stress (Assuming Douglas Fir).

Keel Width, ft	Allowable Unit Stress for Blocking (S), lb/in^2
≥3.00	370
2.50	323
2.00	277
1.75	254
1.50	230
1.25	207
1.00	184

makes initial contact with the blocking. The individual block at each end of the keel block row is referred to as the knuckle block and may be subject to high compressive stress as the asset first lands. Initial contact will be highly localized and may cause high stresses and deformation of the block. For an asset with trim by the stern, the reactions at the aftermost block should be analyzed. Even when an asset is at an even keel condition, the heavy lift ship will likely deballast in a way to expose deck area as quickly as possible. This trimmed condition may also cause localized loading on the knuckle block.

As the heavy lift ship continues to rise, the knuckle block will deform and the asset will reduce trim. Additional support will be provided by blocks forward of the knuckle block and contact with the asset will increase. At the same time, more and more of the asset's weight will be supported by the blocking. The stress seen at the knuckle block will likely rise at first and then decrease, reaching a maximum somewhere between initial and full contact. This maximum stress should be analyzed to ensure the strength limits of the material is not exceeded. Naval Ship's Technical Manual (NSTM) S9086-7F-STM-010, Chapter 997, Docking Instructions and Routine Work in Drydock (Ref. W) provides a sound methodology for computing the knuckle block stress and much of the material presented here is borrowed from that source.

8-6.2.7 Safe Allowable Compressive Stress of Blocking

The allowable timber compressive stress for distributed loading on keel blocks, taken as the fiber stress at the proportional limit for Douglas fir, is 370 psi. This assumes a uniform pressure on a 42 by 48 inch docking block resulting in a total load of approximately 330 tons. When computing the stress for the actual condition, the weight of the asset and the area in contact with the blocks should be used to determine loading. Note that this limit applies only to keel blocks. Side block criteria are discussed in 8-7.1.

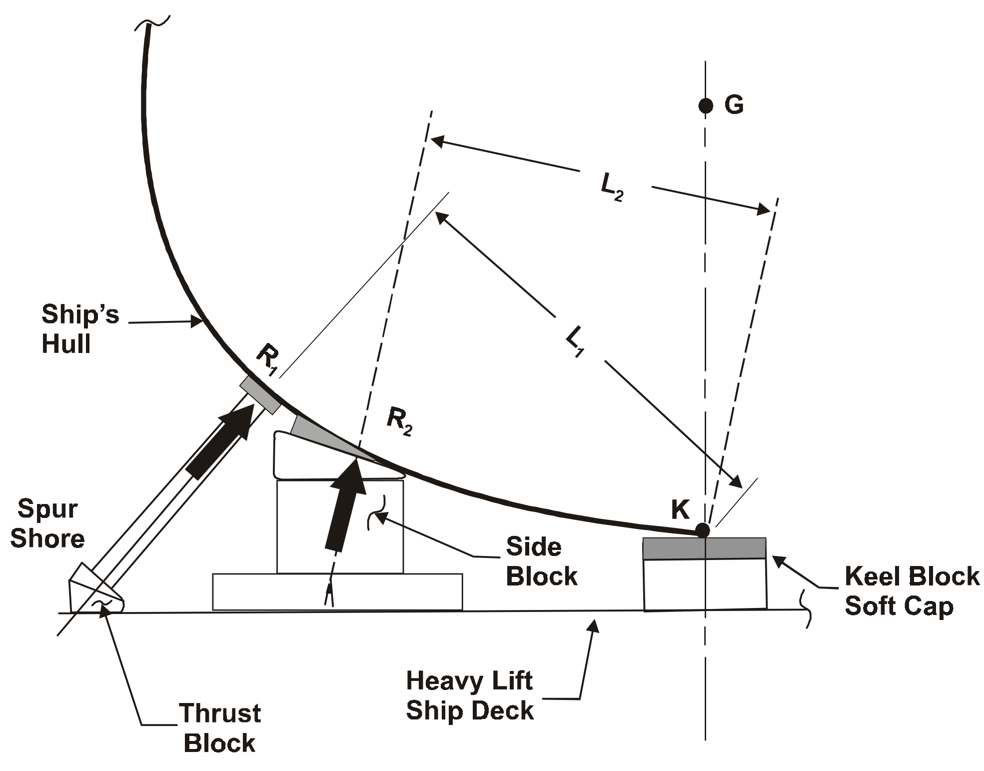


Figure 8-13. Heavy Lift Blocks.

Table 8-7 lists allowable timber compressive stresses for the blocking based on the proportional limit for Douglas fir. The computed stress is dependent upon the area of the keel in contact with the knuckle. For vessels with keels that are narrower than 3 feet, the allowable stress has been reduced. This is necessary because of the compression of the block during loading. For narrower keels, there will be less area in contact with the blocks concentrating the load so that less load can be supported. Appendix D of NSTM, CH-997 (Ref. W) presents a detailed explanation of total load as a function of compressive stress.

When docking ships with keels that are narrow, it is advisable to use hard wood capping at the knuckle block. The hard wood capping will be able to carry stress concentrations that would cause severe crushing of soft capping. Hard caps should be used in conjunction with a soft wood stratum below to give the same overall compressive characteristics to the block. For certain vessels with bar keels (e.g., tugs), using caps bound with steel angles will prevent the keel from cutting into the cap.

8-7 Seafastening Plan

The seafastening plan is a composite arrangement of side blocks, spur shores and seafasteners (Figure 8-13). Side blocks will supply some of the necessary support associated with the vertical loading for the initial docking phase. They provide resistance of any overturning moment resulting from ship's motions and heel angles. Spur shores, or roll bars, are installed to provide further resistance to the dynamic overturning moments in a seaway. Seafasteners (stopper blocks) are installed to prevent fore and aft and athwartships sliding action as the heavy lift ship pitches and rolls. Each of these will be addressed separately in this section.

Normal dry-docking plans contain calculations to analyze the block's resistance to the dynamic forces associated with both hurricane and seismic (earthquake) loading. In the case of FLO/FLO, the dynamic loading must be based on ship motions and wind forces. This will result in greater angles of inclination and significant overturning moments.

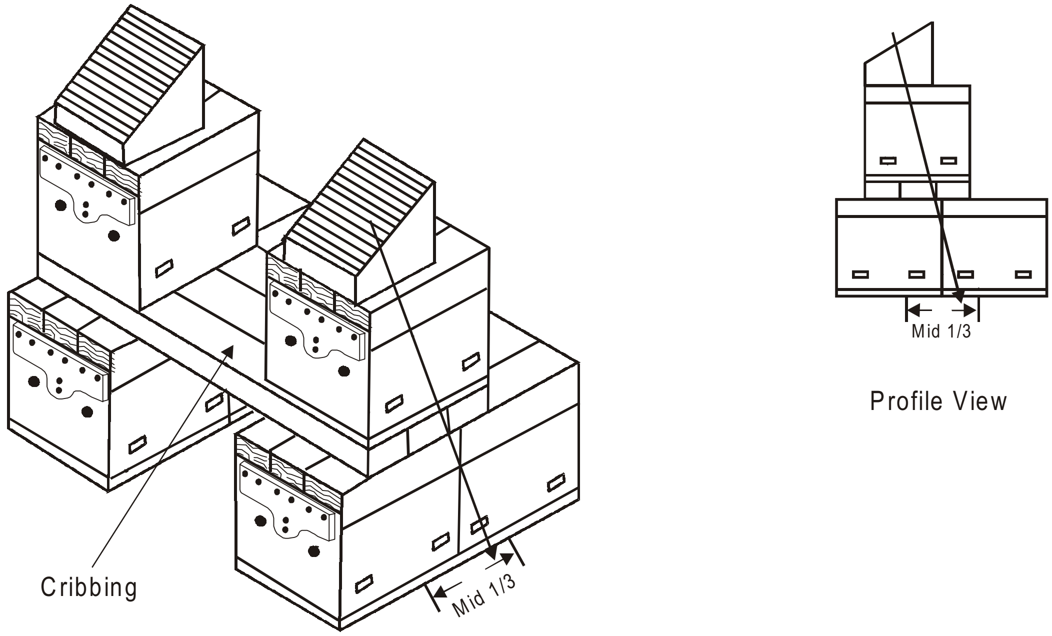
8-7.1 Side Blocking

Side blocking must be able to withstand some portion of the asset's deadweight as well as dynamic loading. As the heavy lift ship rolls or pitches, the contribution of the side blocking in supporting the deadweight will increase. There is also an increase in dynamic loading due to the effect of rolling and pitching. The static and dynamic effects will be examined separately.

Side blocks are used for handling the loading up to the angle to which the heavy lift ship will heel over or a heel of 15°, whichever is greater. Roll bars or spur shores (see Figure 8-13) should be used for angles from 15° - 45°.

To be effective, side blocks should have relatively planar surfaces (minimum curvature). Blocks will form to the shape of the hull under significant compressive loading. Attempting to shape the blocks to exactly fit the surface of the hull will add considerable effort and may not significantly improve their contact area or overall performance. It will be difficult to land the ship precisely in the intended location and small variations may prove to make the shaping of the blocks a wasted effort. Contact can be improved by using wedging material. This will likely be easier to accomplish if the block surfaces are planar.

The blocks should be placed under the asset's major structural members such as main transverse bulkheads and secondary frames. They should also have enough effective surface



NOTE

Cribbed blocks should be arranged such that the force at loading acts through the middle one-third of all tiers.

Figure 8-14. Cribbed Blocks.

area (width) to span two frames. The asset's docking drawing will provide recommended locations.

The transverse stability of individual side blocks is essential and depends on overall block height and hull shape. These side blocks must be of a construction and located such that the resultant force (normal to the shell at point of tangency) falls within the middle one-third of all horizontal layers of blocking. Using a two-tiered block with a double wide base will help ensure this stability in both the transverse and longitudinal direction (see Figure 8-14). The side block caps should be of a soft material such as Douglas Fir or Southern Yellow Pine. The discussion concerning the use of hard woods as capping material for keel blocks does not apply to side blocking. Side blocks will compress and form to the curvature of the hull and are not subject to the high knuckle loading associated with initial landings. Side blocks must be securely fastened to the deck of the heavy lift ship to resist overturning and sliding.

Figure 8-15. Spur Shores

8-7.1.1 Stability of High Blocks

Heavy lifting Navy ships with large sonar domes or other underwater projection may require the use of excessively tall blocks. In these cases, the stability of the blocks are a concern and special precautions must be taken. These blocks may require additional cribbing to ensure that they do not tip over. Use the following guidelines when considering the stability of the blocks.

- All keel blocks over 8.5 feet in height require cribbing
- Keel blocks over 6 feet but less than 8.5 feet should be cribbed when located in the after one-third or forward one-third of the block line
- Side blocks over 6 feet in height (measured from the deck to the highest corner of the soft cap) shall be tied together longitudinally (steel tie rods, cribbing, etc.)
- Loading force should act in the middle one-third of all tiers of blocks (see Figure 8-14)

8-7.2 Loading on Side Blocking

The side blocking will support both static and dynamic loads. The side blocking supports some of the weight of the asset in the zero heel condition. This support increases as the vessel heels. Side blocking is also needed to resist dynamic loads that may be caused by ship motions and wind which are dependent on environmental conditions during loading and transit.

8-7.2.1 Assessing the Loading on Side Blocking

There are several conditions that need to be examined in determining when to install and the amount of side blocking required for a transport. The most strenuous condition is when the asset is loaded on the heavy lift vessel and the vessel is in an open seaway. In this condition, the most extreme wind and motions will be experienced. A reduced condition of loading exists during Float On. The condition of the loading associated with the float on operation should be evaluated. It may be advantageous to not complete the contruction of the side blocking until after the asset is loaded. This is normally to reduce the height of the side blocking so that less submergence of the cargo deck is required during the loading operation. If it is proposed to use fewer side blocks for the float-on operation, this condition must be analyzed separately (see Section 8-7.3). As this is conducted in a relatively sheltered place, the expected loads are less. A third potential condition arises when the load site and the build site are not the same. That is to say that there is some transit after the loading but prior to the completion of the seafastening plan. If the location of the build site requires moving the vessel with the asset loaded, the environmental conditions associated with the transit should also be analyzed as a separate evolution. This may occur if an asset is in extremis or the port of loading does not have deepwater and adequate industrial services located in the same area. Therefore calculating the side loading of the blocking is a multi-step process.

The approach outlined here breaks down the loading into static (deadweight) and dynamic (rolling and wind). Each of these components can be considered separately and then combined to determine a suitable blocking arrangement. As a minimum, an analysis of the open ocean seafastening plan should be conducted. Winds and ship motions associated with this transit should be evaluated to determine the total number of side blocks and spur shores.

8-7.2.2 Loading on Side Blocks

The side blocks will support a portion of the deadweight of the asset, both in a heeled condition as well as an upright condition. For the zero heel condition, assume that side blocks will take 15 percent of the assets displacement (w) and that this load is evenly distributed between port and starboard. Therefore, the load on the side blocking for port or starboard is calculated by:

$$DL_s = \frac{(0.15)w}{2} = 0.075w$$

where:

DL_s = Vertical load on side blocks for one side (tons)

w = Displacement of asset at time of loading (tons)

The number of side blocks required on one side for supporting displacement (N_d) without considering dynamic and wind effects can be calculated by:

$$N_d = \frac{DL_s}{S_pA_e}$$

$$= \frac{0.075w}{S_pA_e\left(\frac{1\text{ ton}}{2240\text{ lbs}}\right)}$$

$$= \frac{1086.4w}{S_pA_e}$$

where:

N_d = Minimum number of side blocks on one side to support displacement

DL_s = Vertical load on side blocks for one side (tons)

S_p = Strength at the proportional limit of the block material (lb/in^2)

= 800 psi for Douglas fir

A_e = Effective surface area of side block in contact with asset (in^2)

w = Displacement of asset at time of loading (tons)

8-7.2.3 Dynamic Loads During Transport

Side blocks and spur shores are also needed to resist dynamic loading due to wind and ship motions. The method for calculating the moments associated with these forces are presented. In performing an analysis, it is important to examine all likely conditions the vessel will experience. The predicted sea state during transit may be as high as sea state 7 while the conditions during loading may be limited to sea state 4. Each of these scenarios should be evaluated to ensure that the blocking arrangement is sufficient. These dynamic loads will be dependent on the environmental conditions encountered during the transport.

8-7.2.4 Dynamic Loads from Ship Motions

Calculating overturning moments caused by sea state dynamic forces is similar to calculating seismic overturning moments for a normal dry-docking operation (see *NSTM 997*). These calculations are modified to include the acceleration loads associated with rolling and pitching of the heavy lift ship. The maximum ship motion and roll angle is found by examining the expected weather during transit. For example, if the routing indicates that the maximum condition is sea state 7, use roll and pitch angles from Tables 8-5 and 8-6. This is the limit to which the heavy lift ship is assumed to heel during the transit. Note that this load is supported by only one side of blocks.

For example, typical ship motions for ocean transport are:

R = 20 degrees of roll, one direction

P = 4 degrees of pitch, one direction

Tr = roll period of 10 seconds, port to stbd back to port

Tp = pitch period of 7 seconds, bow to stern back to bow

NOTE
These values should be compared with the expected values from route planning. If larger angles of heel or pitch are expected, those values should be used.

This estimate should not be used as a substitute for an actual route analysis.

The acceleration factor is calculated by:

$$a_y = \sin R + \frac{0.0107Px}{T_p^2} + \frac{.0002R^2y}{T_r^2} + \frac{0.0214Rz}{T_r^2}$$

where:

a_y = athwartships acceleration factor in (g)

R = Maximum angle of roll (deg)

P = Maximum angle of pitch (deg)

x = Distance of center of gravity of asset forward or aft from center of gravity of heavy lift ship (ft)

y = distance of asset's centerline off centerline of heavy lift ship (ft)

z = distance of center of gravity of asset above center of gravity of heavy lift ship (ft)

T_p = Period of pitch (sec)

T_r = Period of roll in (sec)

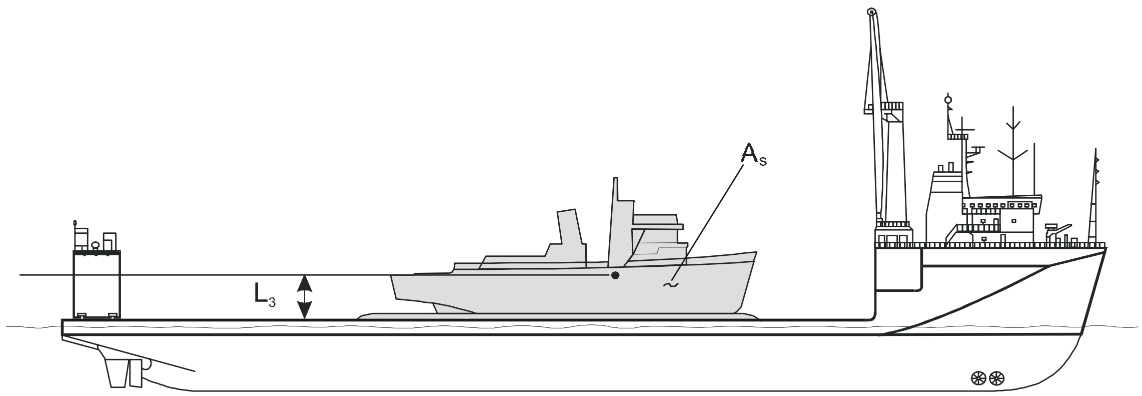


Figure 8-16. Overturning Moment Due to Wind Forces.

To calculate the overturning moment (M_r) associated with athwartships motion, the weight of the asset is multiplied by the height of the center of gravity above the asset's keel. This is then multiplied by an acceleration factor similar to that calculated for keel blocks.

$$M_r = (w \cdot a_y)(KG)(2240 \text{ lbs/ton})$$

where:

M_r = Overturning moment due to rolling (ft-lbs)

w = displacement of vessel at time of loading (tons)

a_y = acceleration factor for athwartships motion (g)

KG = The center of gravity of the asset above its keel (ft)

The effort to resist this overturning moment can be provided by the side blocks, but the number of side blocks needed is dependent on the size of the blocks and their distance from the centerline (see Figure 8-13) and available space on the cargo deck around the asset. Therefore, the number of additional side blocks on one side required to resist the dynamic loads due to rolling is:

$$N_r = \frac{M_r}{A_e S_p L_2}$$

where:

N_r = Number of additional blocks for rolling

M_r = Overturning moment due to rolling (ft-lbs)

A_e = Effective surface area of side block in contact with asset (in^2)

S_p = Strength at the proportional limit of the block material (lb/in^2)

= (800 psi for Douglas fir)

L_2 = Average moment arm of side block reaction force (ft)

But a better solution is to resist this moment with a combination of side blocks and spur shores.

8-7.2.5 Dynamic Loads from Winds

Additional side blocking is necessary to resist the overturning moment associated with the wind forces that will be encountered during transport. Calculating overturning moments caused by wind is similar to calculating hurricane loading in a normal dry docking situation. This is also a 2 step process, once for the wind force during loading (< 25 Knots) and once for the wind loading during the transit. To determine the expected wind during transit, use the guidelines listed in paragraph 8-5.1.1.

The overturning moment associated with the wind forces can be estimated by the following equations:

$$M_w = 0.004\ A_s\ L_3 V^2$$

where:

M_w = Overturning moment due to wind forces (ft-lbs)

A_s = Projected sail area of the asset (ft^2) (See Figure 8-16)

L_3 = Lever arm from the cargo deck to the center of the sail area of the asset (ft) (See Figure 8-16)

V = wind speed (knots)

Note: The factor in this equation provides for unit conversion.

The number of additional side blocks required on one side to resist the forces due to wind is:

$$N_w = \frac{M_w}{A_e S_p L_2}$$

where :

N_w = Number of additional blocks for wind

M_w = Overturning moment due to wind forces (ft-lbs)

A_e = Effective surface area of side block in contact with asset (in^2)

S_p = Strength at the proportional limit of the block material (lb/in^2)

= 800 psi for Douglas fir

L_2 = Average moment arm of side block reaction force (ft)

8-7.2.6 Determining the total amount of side blocking required

The total amount of side blocking required is a combination of the amount calculated in paragraph 8-7.2.3 for dead weight loading in paragraph 8-7.2.4 for dynamic loading and in paragraph 8-7.2.5 for wind loading. That is

$$N_T = N_d + N_r + N_w$$

But a better solution may be a combination of side blocks and spur shores. Side blocks provide better support to static type loading because of their higher compressive strength. Spur shores may be better placed farther out and higher against the hull of the asset to resist dynamic loading.

8-7.3 Additional Side Block Considerations

In some cases, the heavy lift contractor may desire to install a minimum number of blocks during float on and build the remainder of the blocks after the asset is loaded. This is normally done to reduce the required depth of submergence during loading. This is acceptable given that the environmental conditions during loading and transit to the build site are evaluated. The above calculations should therefore be repeated using the maximum expected weather conditions during loading and building. Generally, using a sea state 4 condition is acceptable. In no case should the minimum number of side blocks be less than the number necessary to support the static load and the expected roll angle. A minimum of five degrees of roll should be used. If the asset has an initial list, e.g., USS COLE had a 2.5° list on loading, that value should be added to the 5 degrees to determine the number of initial side blocks for loading. The static load is calculated using the equations in paragraph 8-7.2 and adjusting the roll angle. In no case should the minimum number of side blocks be less than four (two port and two starboard).

In the past, obtaining an accurate fit of side blocks has been a recurring problem. Contributing factors include inadequate drawings, bad offsets, damage to the hull of the asset, or landing the asset slightly out of position due to the dynamic environment in which these lifts were done. Placing side blocks in positions shown on the Navy Docking Drawing offers the best possibility of a correct fit, but wedging material, may still be needed. Air bags have been used on top of the side blocks and inflated by divers after the asset was landed. This has been effective in stabilizing the asset for the lift. With wedging or air bags, however, the blocks have an unknown compressive flexibility due to dynamic loading. If a significant change in the contact area or the compressive flexibility is observed, the number of side blocks required should be recalculated after the asset is loaded, taking into account the dynamic loading, maximum roll angles, and actual location and effective area of the side blocks. Additional side blocks or shores may be necessary.

The side blocks should be positioned as shown on the Navy docking drawing. This will ensure the best possible fit since the side block build has been based on hull offsets in these locations. This will also help to ensure stable blocks up to angles of 15°. This approach is somewhat conservative as the spur shores will share some of the deadweight.

Considering the above, and bearing in mind that side blocks work better in direct loading and spur shores are better to resist dynamic over turning loads, we can again look at the equation for the acceleration factor, in paragraph 8-7.2.4 to determine the number of side blocks to be used in combination with spur shores. The static, direct, loading for side blocks can be determined from the first term (sinR) in the equation

$$a_y = \sin R + \frac{0.0107Px}{Tp^2} + \frac{0.0002\dot{R}^2y}{Tr^2} + \frac{0.0214Rz}{Tr^2}$$

while the remainder of the equation can be used as a first estimate of the number of spur shores required.

8-7.4 Spur Shores

The number of side blocks needed to resist all of the loads experienced during a transport will likely be too large to fit the given space. In almost all cases, the number of side blocks that can be placed in a given area will be less than what is needed. They simply may not fit on the cargo deck of the heavy lift ship, particularly if more than one asset is transported. To make up for this difference and to resist dynamic forces associated with roll angles greater than 15 degrees, spur shores are used. A combination of spur shores and side blocks will be used to resist the total load.

Spur shores (roll bars) can be used in combination with side blocks to resist overturning moments due to dynamic motions of the heavy lift ship and high winds ($M_r + M_w$). Spur shores are tall, column like structures that are placed further outboard on the hull than side blocks (See Figure 8-15). They do not contribute significantly to supporting the weight of the vessel, but they can make a significant contribution to resisting overturning. The number of side blocks can be reduced if spur shores are used to help resist the dynamic moments associated with transit. Consider the following points when deciding to use spur shores:

- Spur shores are generally easy to install and take up less deck space.
- Roll angles in excess of 24 degrees have been observed during this type of lift/transport. Therefore, supports should be placed at various angles to encompass the total range of stability of the heavy lift ship. Spur shores are more suitable than side blocks for this duty.
- Spur shores are easily angled to resist the highest roll the ship is likely to encounter.
- Thrust blocks (base plates) must be provided at the base of all spur shores and be firmly secured to the cargo deck of the heavy lift ship.
- The shores must be suitably secured to prevent the shores on one side from falling out when those on the other side are compressed. This limits the bearing load per shore to the compressive load of the soft cap.
- A higher number of shores will likely be required to resist the same moment as fewer side blocks.
- Sufficient space will be required between multiple assets to install spur shores.
- Shores must be secured in the fore and aft, as well as the athwartships direction.
- Because of their point loading on the hull of the asset, the local structural limit must be evaluated in determining the number of spur shores to be used and designed with a top spreader to spread the load to the asset's hull structure.

8-7.4.1 Loading on Spur Shores

The number of shores required is dependent on several factors. Because the shores are slender, they will fail as columns before they will fail in direct compression. This is the opposite of the failure mode for side blocks. It is necessary to determine the maximum column stress that the shore can withstand to ensure that the shores do not buckle under a compressive load. The actual load that each spur shore will see will be dependent on the number of side blocks that are used and the local structural load limit on the side of the asset. If space limitations require only a few side blocks, than a larger number of spur shores will be needed.

NOTE
In no case shall the number of side blocks be reduced below the minimum number required for loading.

The equations will be based on the actual number of side blocks used. This number will likely be less than the number calculated above and is largely dependent on deck space and the hull of the asset. The docking drawing and structural details should be checked to determine suitable locations and places where spur shores are more appropriate. The following series of equations determine the maximum column stress for the shore based on its geometry and material. The maximum stress for each shore is found by:

$$S_c = C\left(1 - \left(\frac{1}{3}\right)\left(\frac{L_s}{d \cdot K}\right)^4\right)$$

where:

S_c = Maximum column stress (lb/in^2)

C = Proportional limit

= 3,000 psi for Douglas fir parallel to grain

L_s = Length of shore (ft)

d = Minimum dimension of shore cross section (ft)

K = Relationship between elasticity and proportional limit

This constant (K) is calculated by:

$$K = 1.11\sqrt{\frac{E}{C}}$$

where:

K = Relationship between elasticity and proportional limit

E = Modulus of elasticity of shore (lb/in^2)

= 1.6×10^6 psi for Douglas fir

C = Proportional limit (lb/in^2)

= 3,000 psi for Douglas fir parallel to grain

To prevent the shore from buckling, the shore reaction (R_s) must be equal to or less than:

$$R_s \le S_c A_s$$

where:

R_s = Maximum shore reaction (lb)

S_c = Maximum column stress (lb/in^2)

A_s = Cross sectional area of the shore (in^2)

NOTE
The R_s of a shore must be less than the local structural limit of the asset's hull structure.

8-7.4.2 Determining the Number of Spur Shores

To determine the number of shores required, for a given number of side blocks, it is necessary to evaluate the entire build. Information about the spring constants of both the blocks and the shores is required as well their locations. To calculate the spring constant of the shore use:

$$K_s = \frac{A_s E}{12 L_s}$$

where:

K_s = Spring constant of spur shores (lb/in)

A_s = Cross sectional area of shore (in^2)

E = Modulus of elasticity of shore (lb/in^2)

= (1.6×10^6 psi for Douglas fir)

L_s = Length of the shore (ft)

To test the suitability of a build (column stability of the shore and compression of the side block) one would use the following series of equations to determine the average reactions.

$$R_s = \frac{(M_w + M_r)(K_s L_1)}{L_1^2 N_s K_s + L_2^2 N_b K_b}$$

$$R_b = \frac{(M_w + M_r)(K_b L_2)}{L_1^2 N_s K_s + L_2^2 N_b K_b}$$

But since we know the maximum reaction that a particular shore can handle, we can rework the equation to find the minimum number of shores required. The equation then becomes:

$$N_s = \frac{(M_w + M_r)(K_s L_1) - R_s L_2^{\,2} N_b K_b}{R_s L_1^{\,2} K_s}$$

where:

N_s = Number of shores required on one side

M_w = Moment caused by wind for transit (ft-lbs)

M_r = Moment caused by rolling for transit (ft-lbs)

K_s = Spring constant of spur shores (lb/in)

L_1 = Average lever arm of the spur shore's reaction forces (ft) (see Figure 8-13)

R_s = Max allowable reaction of shores (lb)

L_2 = Average lever arm of the side blocking reaction forces (ft) (See Figure 8-13)

N_b = Number of side blocks required on one side of the ship

K_b = Spring constant of side blocks (assume 200,000 lb/in)

NOTE
For larger assets or to reduce the number of shores required, consider using steel shores.

8-7.4.3 Distribution of Spur Shores

NOTE
The locations for spur shores are estimated by hull shape and structural drawing. The actual positioning of each shore is dependent on determining local structure on the ship.

The above procedure determines the minimum number of spur shores to be used. This procedure assumes the number of side blocks used is determined by available spacing and for the direct support up to the maximum expected angle of roll. These sideblocks will generally be placed to resist rolls up to at least 15 degrees but preferrably to the maximum angle of roll. The spur shores must resist rolls beyond this angle. To help resist these rolls, the shores should be distributed throughout the range of angles.

Since spur shores need to support the load down the axis of the shore and tend to trip out, positioning the spur shores in increments of about 5 degrees should provide acceptable load sharing. They should be set up in pairs, fore and aft, to resist twisting. They need to be positioned perpendicular to the hull on local structure and high enough on the hull to resist the overturning moment yet be short enough or supported not to fail under buckling. While effective length dictates a higher angle, angles of 45 degrees or less should be chosen unless compensating for the overturning moment dictates placing the shores higher on the hull.

This method may produce a different number of spur shores than previously determined. To be conservative, the larger number should be used and a minimum of two shores (one fore and one aft) should be installed at each angle. The shores should be secured to the deck at the foot of the shore to ensure that they do not slide when loaded. They should also be placed normal (perpendicular) to the curvature of the hull.

Final verification of the compensation of the overturning moment (M_o) is accomplished by checking to see that the overturning moment about the attachment point of the spur shores is less than the righting moment (M_r) produced by the spur shores, that is

$M_o < M_r$

M_o is created by the transverse dynamic force working through the ship's center of gravity and its separation from the attachment point of the spur shore.

$M_o = (\text{displacement})(a_y)(L_o)$

where L_o = distance between the line of action of the dynamic force working transversely through the ship's center of gravity and the position of the shores on the hull in the vertical direction.

M_r is created by the resultant force that the spur shores can create in the transverse direction against the hull and its separation from the line of action of the weight of the vessel passing through the ship's center of gravity.

$M_r = (\text{displacement})(2 - a_z)\, L_r \cos R$
(R = maximum angle of roll)

where (a_z) is the dynamic load factor in the vertical direction which increased the load on the blocking when the heavy lift ship pitches up and decreases the loading on the blocks when the heavy lift ship pitches down, ($2-a_z$).

L_r is the distance between the line of action of the downward force through the ship's center of gravity and the position of the shore on the hull in the transverse direction. The cos R factor is to adjust the line of action of the weight from the vertical to account for the maximum angle of roll.

In practice, the Transport Manual will recommend a seafastening plan that will include, among other things, a plan for positioning spur shores. It is likely that the contractor will perform a detailed analysis to determine maximum loading for each spur shore through a variety of roll angles. This distribution should be similar to the distribution determined by the above method.

8-7.5 Seafasteners

Seafasteners must be designed to restrain the asset from movement at the high angles of pitch and roll anticipated during transits. Some resistance to these forces is provided by the friction between the keel and the blocks. Seafasteners must be installed at the forward and aft ends of the keel or some other reasonably accessible location of the asset to resist longitudinal movements due to the maximum angle of pitch of the heavy lift. They should also be installed on the port and starboard sides of the keel to help resist athwartships movement of the asset during rolling. It is prudent to install seafasteners at both the fore and aft ends of the keel to prevent twisting. A minimum of two seafasteners should be installed at each end (one port and one starboard) (see Figure 8-17). However, each seafastener should be capable of resisting the entire sliding force.

8-7.5.1 Dynamic Force

The dynamic force that must be restrained in each direction is equal to the weight of the asset times the dynamic load factor. This is similar to the procedure that was used to calculate the dynamic loading on the blocking (see 8-7.2.4). Here, the main concern is the asset sliding off the blocking. However, for the transverse direction, the dynamic load factor, a_y, will be the same. Therefore, the dynamic load in the transverse direction will be

$$DL_t = \Delta a_y$$

DL_t = Dynamic load in the transverse direction determined by the maximum angle of roll to be expected in route. (tons)

Δ = Displacement (tons)

a_y = Athwartship acceleration factor (g) (see 8-7.2.4)

Similarly, the dynamic load in the longitudinal direction will be:

$DL_l = \Delta a_x$

DL_l = Dynamic load in the longitudinal direction determined by the maximum angle of pitch to be expected in route. (tons)

Δ = Displacement (tons)

a_x = longitudinal acceleration factor (g),

$$= \sin P + S + \frac{0.0004Px}{T_p^2} + \frac{0.0214Pz}{T_p^2}$$

where:

P = Maximum angle of pitch (degrees) (Table 8-5)

S = Surge acceleration (g) (Table 8-4)

x = Distance of center of gravity of asset forward or aft from center gravity of heavy lift ship (ft)

z = Distance of center of gravity of asset above center of gravity of heavy lift ship

T_p = Period of pitch (sec) (Table 8-5)

Note that the commercial industry assumed a pitch of 15^o at a period of 10 seconds which is considerably higher than the value for pitch in Table 8-5.

8-7.5.2 Assumed Friction Factors

In practice, it has been observed that a ship slides transversely when heel exceeds roughly 15 degrees and longitudinally when pitch exceeds roughly 3 degrees. The dynamic frictional resistance of steel on wet or greased wood is approximately 22 percent. Depending on the weight and center of gravity of a ship on docking blocks, this equates to an angle of approximately 12 degrees before sliding will occur. These numbers work well for relatively flat bottom vessels as long as the vessel doesn't lift off the blocking due to being submerged.

The friction factor used for longitudinal sliding is less because there is a greater possibility of the vessel lifting off the blocks due to submergence. When a 500 foot heavy lift ship pitches 3 degrees, the trim increases by 26 feet. Other factors contributing to these conclusions include variations in materials, variations in hull shape, column stability of the blocks, and possible overhang of the asset. These approximations should be provide reasonable estimates for sizing seafasteners. To determine the amount of this load that is resisted by friction, multiply the weight of the asset by the frictional factor. For the transverse direction, assume a frictional factor of 0.15. Therefore, the frictional resistance (FR_t) can be found by

$$FR_t = 0.15\Delta$$

and

$$FR_l = 0.05\Delta$$

8-7.5.3 Sea Fasteners Resistance

The seafasteners must resist the force that is not carried by friction. Therefore, the force carried by the seafastener is equivalent to:

$$SF = DL - FR$$

In the transverse direction

$$SF_t = DL_t - FR_t$$

Where:

SF_t = Transverse Seafastener force (tons)

DL_t = Dynamic load in the transverse direction (tons)

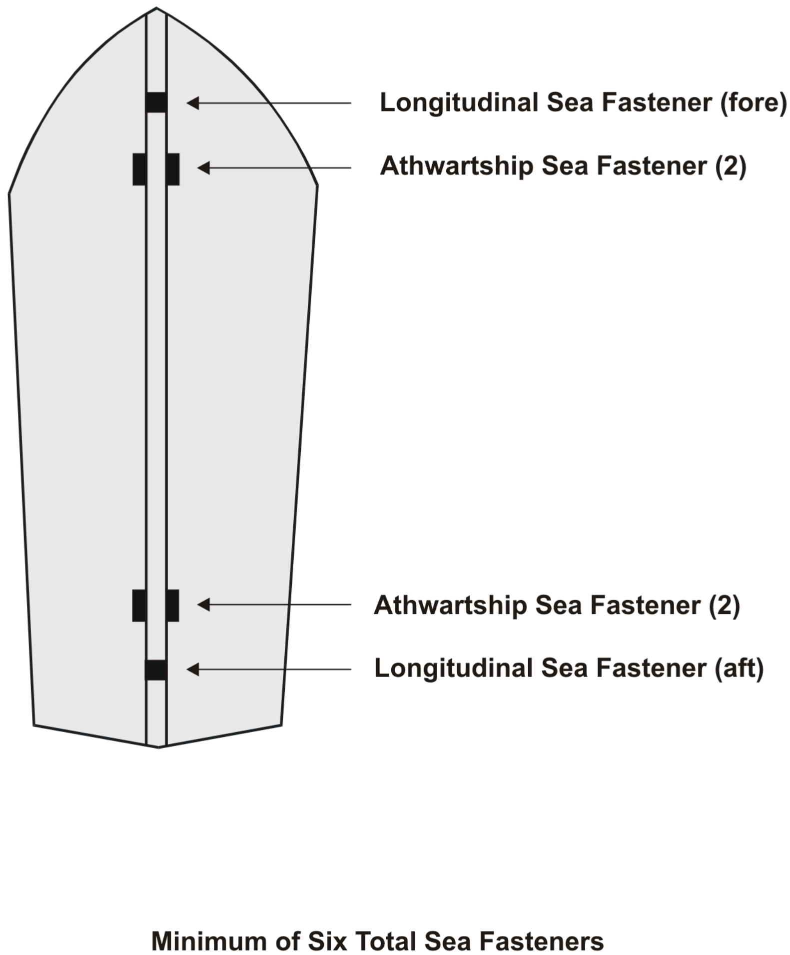


Figure 8-17. Sea Fasteners.

FR_t = Frictional resistance (tons)

In the longitudinal direction, assume a friction factor of 0.05. Therefore,

$$SF_l = DL_l - FR_l$$

Or,

$$SF_l = \Delta a_x - 0.05\Delta$$

Where:

SF_l = longitudinal seafastener force (tons)

DL_l = Dynamic load in the longitudinal direction (tons)

FR_l = Longitudinal frictional resistance (tons)

Δ = Displacement (tons)

a_x = longitudinal acceleration factor (g)

8-8 Surveys

Several surveys must be conducted to ensure that the vessel and its systems can adequately perform the FLO/FLO operation. These surveys will determine that all material and procedures are in accordance with the Transport Manual and conform to the requirements of this manual.

8-8.1 Hydrographic Survey

NOTE
Heavy lift ships in general, are not designated to make contact with the bottom. Adequate depth of water must be provided so that the heavy lift ship does not contact the bottom. Contact with the bottom may require dry docking or inspection of the heavy lift ship by divers in order to maintain its class certification.

The hydrographic survey must be conducted at the proposed loading and unloading sites and in the approach channel by an adequate number of soundings referenced to Mean Low Water. These surveys are part of the decision making on choosing the loading and unloading sites and dictate the operating procedures for each. A sounding chart must be included in the survey results. Complete tidal ranges, approach channel width and depth configuration, dredging frequency, and any regularities must be also noted. Where a history of hydrographic data is available, rates of siltation must be noted.

8-8.2 Acceptance Survey

An acceptance survey should be conducted by the contracting officer (generally the MSC area representative). This is a general survey that shows that the vessel and its systems are the same as those described in the Transport Manual. If possible, the Contracting Officer should observe a ballast/deballast sequence. If not, he should, as a minimum, review the time required for a complete sequence (this information should come from an actual operation and not just from published capabilities). The inspection should also include a general walk through of the vessel to verify sea worthiness and proper adherence to class society regulations. First and foremost, the heavy lift ship must be in class and must present the latest certificate of class and material condition survey. It is often prudent to have the Docking Observer, IMS and Loadmaster participate in these surveys as well.

After the vessel has been accepted, several detailed surveys should be completed to ensure all systems are in good working order. The surveys of the heavy lift ship, assets and blocking described below are conducted by the Docking Observer, the IMS, and the Loadmaster.

8-8.3 Structural Surveys

A thorough inspection of the heavy lift vessels primary structure should be completed. The plating, strength members, joints, foundations, seachests, entire cargo deck where blocking may be installed, and structure associated with mooring must be checked. Indications of excessive corrosion or local failure should be analyzed accordingly. In addition to this general walk around inspection, the latest material condition survey, records of repair, and design data should also be examined. These may alert the inspectors to any areas that might warrant a more thorough inspection. The information collected by the visual inspection should be analyzed and compared with the information contained in the past surveys to determine whether detail surveys and/or repairs are required in any area.

8-8.4 Indicators and Controls

An inspection of the heavy lift vessel's ballast/deballast control system shall be accomplished. This system is critical to completing a safe operation and should be in good working order prior to the start of the FLO/FLO procedure. In general:

- Draft indicators must be provided showing the draft of the heavy lift ship at all four corners of the ship and cargo deck. Backup systems such as visual observation should be addressed.
- Indicators must be provided to continuously display trim and heel of the heavy lift ship during docking and undocking ballast/deballast operations.
- Ballast tank level indicators must provide for controlling ballasting/deballast. The accuracy of these indicators must be adequate to prevent accidental overstressing of tank bulkheads by excessive differential heads and accidental overstressing of the overall ship structure in shear and bending.
- Ballasting system valve indicators must be provided that show the position of the valves.

The surveyor should observe at least one complete ballasting and deballasting cycle and provide a report on the below systems. If possible, this survey should take place at the same time that the Contracting Officer performs the acceptance survey to avoid duplication of effort.

Ballasting/Deballasting Systems and Gauges

- Actual ballasting and deballasting times. If these times are different from ballasting and deballasting times for which the system was originally designed, reasons for this variation must be explained in the survey results.
- Adequacy of the power supply, determined by operating all applicable pumps (and the fire pump, if installed on dock) at the same time.
- Effectiveness of the operation of all pumps, motors, valves, and generators by remote control and local control.
- The accuracy and reliability of water level indicators when compared with actual sounding of the water level in each tank.
- Tightness of air-cushioned boundaries, if they are required, in the tanks.

Controls

- Control panel: Check wiring, relays, bulbs and lenses for dust collection and abrasion of wires.
- Motor controls: Check contractors, relays electrical and mechanical interlocks and manual overhauls.
- Limit switches: Check panel limit switches and switch activator mechanisms.

8-8.5 Pre-loading Block Check

Before submerging the heavy lift ship, blocking should be inspected to ensure it is in accordance with the arrangements in the approved Transport Manual. As a minimum, the inspection should concentrate on the following areas:

- Location of first keel block (after most on the asset)
- Location of the alignment marks or columns for port and starboard alignment to the center of keel blocking
- Location of fore-and-aft centering markers
- Side clearance of the asset
- Rudder, propeller, and other hull projections clearances above the cargo deck and blocking
- Offsets from center line or from set keel blocks and side blocks

- Keel blocks levels for the length of the ship's keel (checked visually) to ensure there are no excessively high blocks
- Heights of side blocks and keel blocks, if not flat
- Special blocking arrangements for hull projections, hull openings, or special support blocks
- Removal of unnecessary blocks

8-8.5.1 Wooden Blocks

Inspect wooden blocks for deterioration resulting from excessive crushing, warping, cracking, checking, rotting, or damage from dogging. Check for loss of contact at edges resulting from checking and unequal shrinkage.

8-8.5.2 Block Securing Method

All blocks must be secured in place. Securings, supports, nuts, boltheads, and other fasteners should be sounded. If the blocking does not land on transverse strength members of the cargo deck, conduct an investigation to make sure that adequate grillage is being used to distribute loading to adjacent strength members. Inspect the securing and bolt connections through the wood where blocks are bolted to clip angles or plates that are welded to the cargo deck. When blocks are set on steel frame supports, inspect the bolts and supports as well.

8-8.6 Additional Systems

The two systems described above, structure and ballasting, are the two systems that make FLO/FLO vessels different from other ships. In addition to these systems, the surveyor should also conduct an inspection of the more traditional ship's systems. The survey should include a review of the following:

Communication Systems and Alarms

The communication systems and alarms must be checked thoroughly and tested for proper operation so that communications can be maintained between all operating stations.

Fire Protection Systems

The fire protection systems intended for fighting fire on the cargo deck or asset must be thoroughly checked and tested for conformance to all requirements of paragraph 5.3.14 of MIL-STD-1625. The capacity available to serve the asset's firemain (either permanent or temporary) shall also serve the fire stations on the cargo deck, but in no case shall be less than 1,000 gallons per minute. The supply pressure shall be capable of providing a minimum mozzle pressure of 60 psi when supplying fire nozzles at the specific capacities at the most remote and highest elevation hose connections.

Block Handling Systems

The block handling system must be observed in operation and must be inspected.

Mooring and Anchoring Systems

The mooring and anchoring systems must be inspected thoroughly for adequacy and for signs of local buckling and excessive loading.

Electric Power Systems

Both the primary and alternate electric power systems must be inspected. Power switches, converting panels, and cables for providing power to the asset must be inspected for material condition and proper fit and size.

Ship Positioning Gear

Bitts, bollards, winches and cleats must be inspected for fatigue, looseness, or other signs of excessive loading.

Ship Services

Compatibility of all connections (firemain, electrical, cooling water, etc.) should be verified as specified in the Transport Manual and identified at the Pre-Loading conference.

Safety Equipment

All safety equipment necessary to comply with the governing regulatory agency should be inspected. While some safety equipment from the asset can be used, most will not be suited for this purpose. To avoid delays, be sure that it is clear who is responsible for providing safety equipment for the riding crew.

8-8.7 Asset Inspection

It should be ensured that the assets are rigged for sea by completing a walkthrough of all compartments and soundings of all tanks. This survey should include an inspection of the watertight integrity of the hull and ensuring that Condition Zebra is set. The final condition of the asset's loading should be inspected and recorded just prior to its departure and copies made available to all parties. All tanks and voids must be accurately sounded and photographs should be taken of the topsides of all assets. These photos will accurately identify the nature and position of any items that may be have been added topside. They will be used to verify that the assets condition has not changed when it is time for off-loading. No weights, including liquids such as fuel or water, should be shifted, added, or removed from the asset unless authorized by the heavy lift ship's master and the OIC. A checklist is provided in Appendix H.

8-8.8 Post Float-On Inspection

When the asset lands on the blocks as deballasting begins, the condition of this landing should be examined. Divers should be used to ensure that no blocks have tipped, that the asset is in the predicted location, and that there are no interferences. Divers from the local drydock facility should be proficient in this type of inspection. Appropriate safety precautions must be taken as these operations will be taking place in open water instead of within a drydock.

WARNING
All sea suctions for the asset and the heavy lift vessel should be secured during diver operations.

WARNING
All parties must be informed when divers are being used. Extreme caution must be used to ensure the safety of these individuals. No deballasting or other ship movements should occur while divers are working under the asset.

When the divers have reported that assets have landed satisfactorily on the blocks, the deballasting operation should continue until the cargo deck emerges from the water. A thorough examination of the condition of the landing should be completed by the Loadmaster, Docking Officer and the IMS. A decision whether to continue deballasting or to refloat the assets should be made. Any irregularities found should be noted and corrected, and any necessary wedging and/or shoring must be placed.

If the decision is made to continue with the deballast procedure, this effort should be completed immediately and the remainder of the build should commence.

8-8.9 Examination of the Seafastening

8-8.9.1 Prior to Transit

Following the completion of the build, all components, keel blocks, side blocks, and spur shores should be surveyed by the Loadmaster, Docking Officer, and IMS. They should inspect the spur shores and seafastening before departure to make sure that they are satisfactorily installed and in accordance with the Transport Manual. Any agreed to changes should be noted.

8-8.9.2 During Transit

The seafastening and blocking should be inspected daily by the OIC of the asset and the heavy lift ship's Master, or more frequently if rough weather is encountered during transit.

8-8.9.3 Upon Arrival

Upon arrival, the Heavy Lift Project Team should inspect blocking, spur shores, and seafastening and note any movement and/or damage that may have occured.

8-9 Offloading Operations

The final phase of the operation is the offload of the vessels. While this is less complicated than the loading procedures, it is still a critical phase of the operation and demands careful planning. Selection of an appropriate offloading site will allow the operation to proceed without incident.

8-9.1 Prior to Arrival at Destination

All parties involved in the offload procedures should be available at the discharge location at least two days prior to the arrival of the heavy lift ship. A pre-arrival conference with all parties represented should be held to review off-loading details. This meeting is in advance of the conference held after the arrival of the heavy lift ship. Many of the off-loading details, including the off-loading site, number of assist tugs, and a rough time line can be determined or confirmed at this time.

Arrangements should be made for pier space for the assets after they are unloaded. These arrangements should be in place prior to the arrival of the lift ship. If the assets are to transit under their own power, sufficient manning needs to be arranged. If the assets are to be towed, sufficient tug assets need to be provided.

8-9.2 Arrival Activities at Off Loading Site

When the heavy lift ship is safely at anchor, each asset and all cargo should be inspected by Navy and contractor personnel as well as the Independent Marine Surveyor. Any voyage related damage should be recorded in a post transit report and made available to all parties. The assets should be returned to the float on conditions of loading prior to float off. All tanks and cargos should be in the same condition as prior to float on. The OIC of the riding crew should prepare an updated loading condition report. If this is not possible, as in the case of a damaged asset, e.g., USS COLE, a deadweight survey of the asset should be conducted.

The heavy lift contractor should prepare to remove the seafasteners and any "Lift-On/Lift-Off" deck cargo and prepare the ship and assets for off loading. The seafasteners should not be removed until the lift ship is at the final off load site.

An off loading conference should be held as soon as practicable before or immediately following arrival of the heavy lift ship. Again, any unnecessary delays in releasing the heavy lift ship can be very costly. All parties involved in the off loading operation, including any local tug captains and pilots, should attend this meeting. A detailed review of the off loading procedure should be made and agreed to by all parties.

8-9.3 Off Loading

The off loading operation proceeds in essentially the reverse order of loading, with all the individuals performing the same tasks as at loading. Any deviation from the approved Transport Manual should be agreed on by representatives from all parties.

If the assets are to be towed to their final destination, sufficient tugs to complete the unloading and transport the vessels need to be provided. Having an excess of tugs may be a cheaper alternative to delaying the off-loading procedure.

Appendix A

SAFETY CONSIDERATIONS IN TOWING

A-1 Introduction

The purpose of this appendix is to supplement the specific safety precautions for towing operations discussed in this manual with the general safety precautions published in OPNAVINST 5100.19C, N45, 0579LD057 1210, *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat* (Ref. X).

A-2 Scope and Applicability

The safety information contained in this manual shall apply to all afloat Naval Commands that are involved in towing operations. It shall also apply to United States Naval Ships (USNS) of the Military Sealift Command (MSC) and its activities and the Marine Corps, when embarked in the aforementioned vessels and to the extent otherwise determined by the Commandant of the Marine Corps. This information, in combination with the OPNAVINST 5100.19 series, comprises the Navy Occupational Safety and Health (NAVOSH) standards for towing operations as required by the OPNAVINST 5100.23C, *Navy Occupational Safety and Health (NAVOSH) Program* (Ref. Y). For additional salvage safety information, consult the US Navy Salvage Safety Manual 0910-LP-107-7600 (Ref. Z).

A-3 Basic Safety Philosophy

Many safety studies have indicated that human error is a common cause of mishaps. Even though the failure of some item of equipment may be listed as the "cause" of a mishap, the equipment often has failed because of an earlier human error or oversight in design, manufacture, maintenance, or use of the equipment.

Therefore, all personnel must be trained in the use of, and have ready access to, appropriate Navy technical manuals and other publications to guide them in their operations. Consequently, the approach to achieving safety in towing operations is to:

- Comply with existing Navy parent documents, such as the OPNAVINST 5100.19 series for general policy and procedural guidelines, and refer to the pertinent technical manuals and Planned Maintenance System (PMS) cards for specific information on operation and maintenance of commonly used gear and equipment.
- Comply with Navy technical manuals, such as this volume on towing, and manufacturers' operating manuals for more detailed information on specialized operations. Use PMS cards and data for information on gear and equipment that are primarily or peculiarly associated with such specialized operations.
- Encourage the use of systems safety analyses, in which the overall system or activity of concern is planned and reviewed from the standpoint of safety. Factors such as the specific environment in which an operation is to be conducted should be considered and accounted for in planning. Consequently, fewer omissions should occur and safety awareness among all personnel who may be involved should increase. See Section 3-4.1.5 and Table 3-2 for a discussion of factors of safety in the selection of towing components.

No list of safety precautions in towing can be comprehensive without the principles of good seamanship. The precautions stated here and in the OPNAVINST 5100.19 series are basic and must be followed.

Personnel involved in towing operations must be thoroughly trained, disciplined, and equipped not only to perform routine duties, but also to react appropriately to unusual or nonroutine situations. The officers and crew of vessels involved in towing operations should continuously conduct safety indoctrination lectures and exercises aimed at reducing unsafe conditions or practices and at reacting appropriately to unusual circumstances through professional knowledge of their duties and towing procedures.

A-4 Specific Safety Precautions

In addition to the safety precautions in the OPNAVINST 5100.19 series, many paragraphs within this manual also contain specific notes of safety-related information. Rather than repeating notes from these two sources, the following paragraphs discuss only the approaches that are recommended specifically for towing operations.

A-4.1 Specific Approaches

A-4.1.1 General Specifications

The *General Specifications for Ships of the United States Navy* (Ref. D) mandates that any ship that is likely to require towing, especially emergency towing, should be equipped to "tow or be towed." The equipment inventory should be such that in an emergency nothing is required to be brought on board the tow or fabricated on the tow. Each ship must be capable of receiving or rigging an emergency towing rig designed so that the ship can tow or be towed.

A-4.1.2 Non-Emergency Towing

For non-emergency situations (and for emergencies, to the extent that time permits) the preparation procedures outlined in this manual and in appropriate Type Command Directives or Instructions must be completed. Even for missions that are repetitions of previous tows, the preparation phase must be repeated to ensure that nothing is overlooked. In both the preparation and operational phases of any tow, it is essential that full and open communication exists between the preparing activity and the towing vessel.

A-4.1.3 Safety

Safety is paramount in the preparation of individual Command Instructions and Towing Bills, as well as in the preparations for individual towing tasks.

Appendix H includes checklists to help in the operational planning and preparations for tows. All hands must fully understand that good planning and preparation for emergency situations are just as important for safe towing as correct ship handling and good seamanship. Planning is not a simple paperwork drill. The preparation phase of a towing operation demands the same knowledge and seamanship skill as the actual at-sea phase.

Past experience has amply demonstrated that, from the very onset of the tow tasking, it is imperative that the plan for preparing the tow for the transit be thoroughly conducted and reviewed before implementation. In some instances, such as ocean tows of complex units like dry docks, the plans and the tow may be prepared by a civilian marine contractor and supervised by the Supervisor of Shipbuilding and Repair at an appropriate Navy facility.

In a peacetime Navy (or in the early stages of war) the availability and quality of "in-house" expertise in the field of towing and tow preparations can vary widely. The towing unit must therefore monitor the efforts of the activity preparing the tow. The towing unit must make continuous inspections and take positive action immediately to correct identified deficiencies. The towing unit Commanding Officer or a representative should attend any meeting held by the cognizant activity for the tow and the preparing activity and should make any comments or recommendations necessary.

A-4.1.4 Planning

Although this manual presents planning procedures in considerable detail, extreme care and judgment must be exercised. Blind dependence upon the results of routine calculation methods, especially computerized procedures, without careful cross-checking can lead to major errors and possibly extreme operational difficulties.

Even a poor choice of location for conducting pre-tow preparations can lead to major problems. If available, the tow should be prepared at a full-service, easily accessible location and then moved to a staging area once fully prepared and made ready for sea.

Few Navy tows will be exact duplicates of earlier tows. Even though some tows may appear to be duplicates, there will be differences in weather, route, and configuration of the towed vessel. Thus, the pre-tow planning and preparations must be conducted each time a towing task is undertaken to ensure a minimum of oversights and mishaps.

A-4.2 Contingency Planning

Contingency planning is very similar to operational planning, except that it concentrates on the aspects of being prepared to respond to emergency conditions. Being prepared includes both knowing what to do and having the appropriate supplies and equipment available to do it. The Navy “tow-and-be-towed” instructions, including individual ships’ bills and equipment, are one example of contingency planning.

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Appendix B

WIRE ROPE TOWLINES

B-1 Introduction

The towing hawser is the key element in the tug-tow connection. For Navy towing ships, the hawser is usually wire rope. It is especially important to keep a wire rope hawser in excellent condition, to protect it against excessive wear, and to inspect and lubricate it regularly.

To maintain a written reference of a wire rope towline's history, the Naval Sea Systems Command requires that all U.S. Navy and MSC vessels regularly engaged in towing operations keep a Towing Hawser Log. Appendix F includes instructions for keeping this log.

B-2 Traceability

The ability to trace a rope's history is an important element in accident investigation, as well as in general product improvement efforts. Some of this information is maintained in the Towing Hawser Log (see Appendix F). American made wire rope and some brands of foreign made rope can be identified by special core marker materials used as a part of, or layered around, the core of the wire rope, as well as by the metal tags and other information on the reel upon which the rope is delivered. Identification of manufacturing source through core markers is particularly useful in cases where the color coding has not been applied to a strand. Additional information on a specific domestic wire rope producer's core color marking practices is available on request from the manufacturer.

B-3 Strength

Steel wire rope currently provides the strongest towing hawser for a given diameter and is usually specified by the Navy as the preferred hawser for towing.

CAUTION
Aramid fiber lines (Kevlar, Spectra) have a similar strength to diameter ratio as wire rope and offer a considerable weight savings, but this light line provides no catenary and aramid fibers do not possess the stretch characteristics of polyester. Therefore, these lines are not well suited for ocean towing.

Target sleds are virtually the only tows for which a synthetic fiber line hawser is currently specified.

Wire rope strength varies with the type of construction and material as well as with size. Consequently, it is important to be certain that all wire ropes used in towing are of the proper construction, core, and required material.

B-3.1 Elongation (Stretch)

WARNING
Wire rope stretches under load far less than most natural and synthetic fiber lines and thus presents <u>less</u> danger to bystanders from loose ends "snapping back" if it fails under high loads. The elongation under load is sufficient, nonetheless, to be dangerous. The recoil can be extremely violent and all personnel should stay well away from any potential recoil path.

In addition to the above noted danger, the sudden release of tension can sometimes cause a popped core or a "birdcage" in the

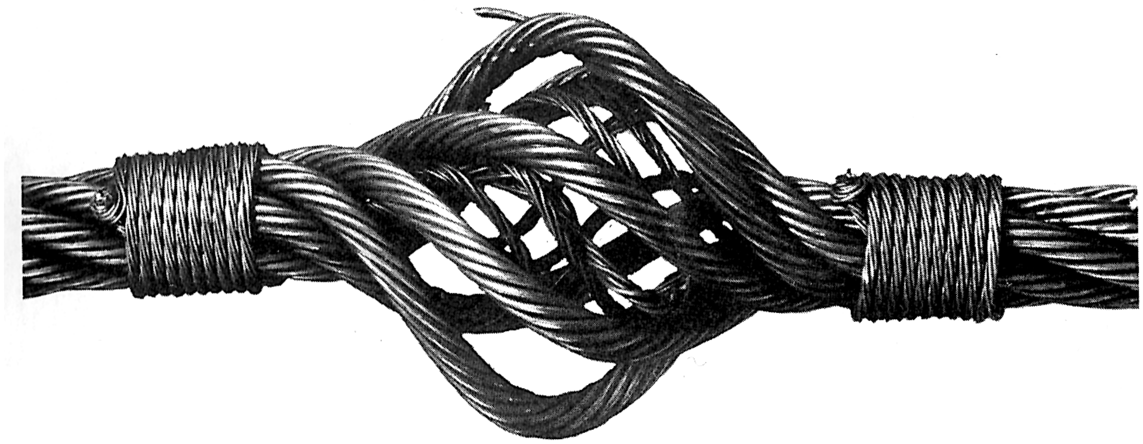


Figure B-1. Bird Caging.

Figure B-2. Popped Core.

rope when a failure in the towline or its connections allows the rope to rebound from an overload. These conditions also can result from operating a wire rope through an undersized sheave groove (see Figures B-1 and B-2).

B-4 Maintenance, Cleaning, and Lubrication

Wire rope, like a machine, is made up of many moving parts. The individual steel wires slide independently and must be kept clean and protected against the effects of movement and pressure by adequate lubrication.

Corrosion damage is also a danger. The exact loss of strength resulting from corrosion of wire rope cannot be estimated. Washing the tow hawser down with fresh water and lubricating it during retrieval after each use can help retard corrosion. This, however, is not a "cure-all" since the core remains saturated with salt water.

Properly specified and procured wire rope is lubricated during manufacture. Since the time in storage may not be known, the towing ship should clean and relubricate a new towing hawser upon receipt. Relubrication will be required, based on frequent inspection, and may be required as often as after each use of the hawser. Procedures for inspecting and lubricating wires are detailed in NSTM CH-613 (Ref. F).

A pressure lubricator has been developed for wire rope and is the preferred method of lubrication. Grease (MIL-G-18458) is currently specified. This product contains a corrosion preventive and can be thinned with solvents such as JP5 or turbine oil 2190 (MIL-L-17331) for cold application.

Take care that all sections, including dead layers on the drum, are kept lubricated. These inner layers can be lubricated at such opportune times as:

- Overhauls
- When the hawser is reversed, end-for-end, on the drum
- When towing in good weather, at which time extra line may be run out to expose the inner layers for lubrication.

The Navy procedures for wire rope lubrication are currently being modified. The most recent guidance is contained in NAVSEA Interim MRC for ARS 50 Class Running Rigging (Ref. AA).

B-5 New Hawsers

Wire rope for towing hawser is shipped in cut lengths on reels.

B-5.1 Unreeling

CAUTION
Remove rope from the shipping package very carefully. Improper unreeling can cause permanent damage, such as kinks and hockles (see Figure B-3).

Unreeling wire rope requires careful and proper procedures. Mount the reel on a horizontal shaft supported high enough for the reel to clear the deck so the reel is free to rotate. To begin the unreeling process, hold the rope end and walk away from the reel as it unwinds. Use a braking device to keep the rope taut and prevent the reel from overrunning the rope. This is particularly necessary with powered reeling equipment.

B-5.2 Reeling

When reeling a wire rope hawser from a reel to a towing machine drum, it is best for the rope to travel from the top of the reel to the top of the drum, (see Figure B-4). This method avoids putting a reverse bend into the rope

Figure B-3. Kinks and Hockles.

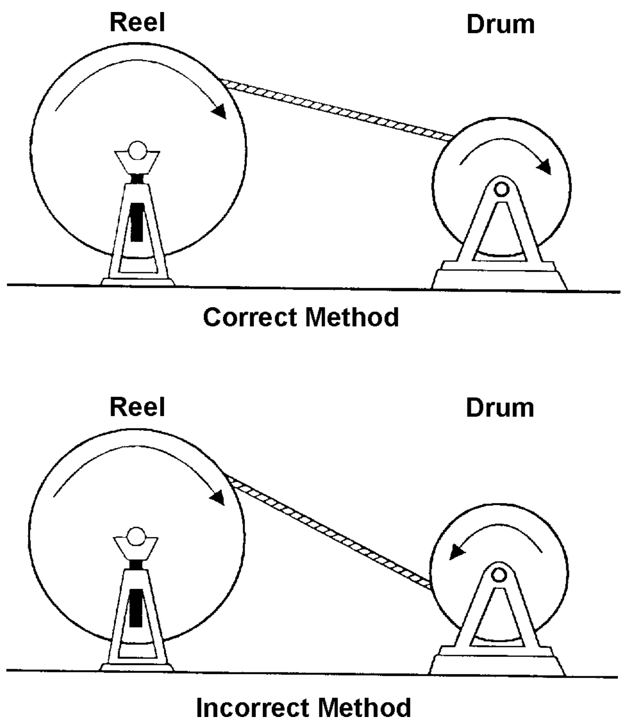


Figure B-4. Re-reeling.

as it is being installed. A reverse bend can make a rope less stable and, consequently, more difficult to handle.

B-5.3 Installing New Wire Rope

CAUTION
Rapid acceleration can cause significant stress on a wire rope. Avoid such stress on the rope by accelerating gradually.

Wire rope should be installed on a towing machine drum under a tension of at least five percent of its breaking strength. Each wrap must be positioned tightly against the neighboring wrap. A tight fit will help prevent the wire rope from becoming buried between wraps when used under heavy loading. Burying the wire between wraps is likely to result in serious damage. Loose or poorly spaced wires may cause movement in underlying layers during towing. In practice, the wire rope is initially installed on the towing machine drum under as high a tension as practical.

NOTE
For both smooth and grooved drums, the towing hawser must be wound on the drum under fairly high tension, approximately 5 percent of the breaking strength.

Using stoppers to load the wire bight by bight is one way to maintain tension, but it is cumbersome and time consuming. During the construction of the first four ARS-50 Class ships, a cable brake called a Wallis Brake was used to help install the wire rope towing hawsers (see Figure B-5). This cable brake is designed for the continuous loading of the wire rope under tension.

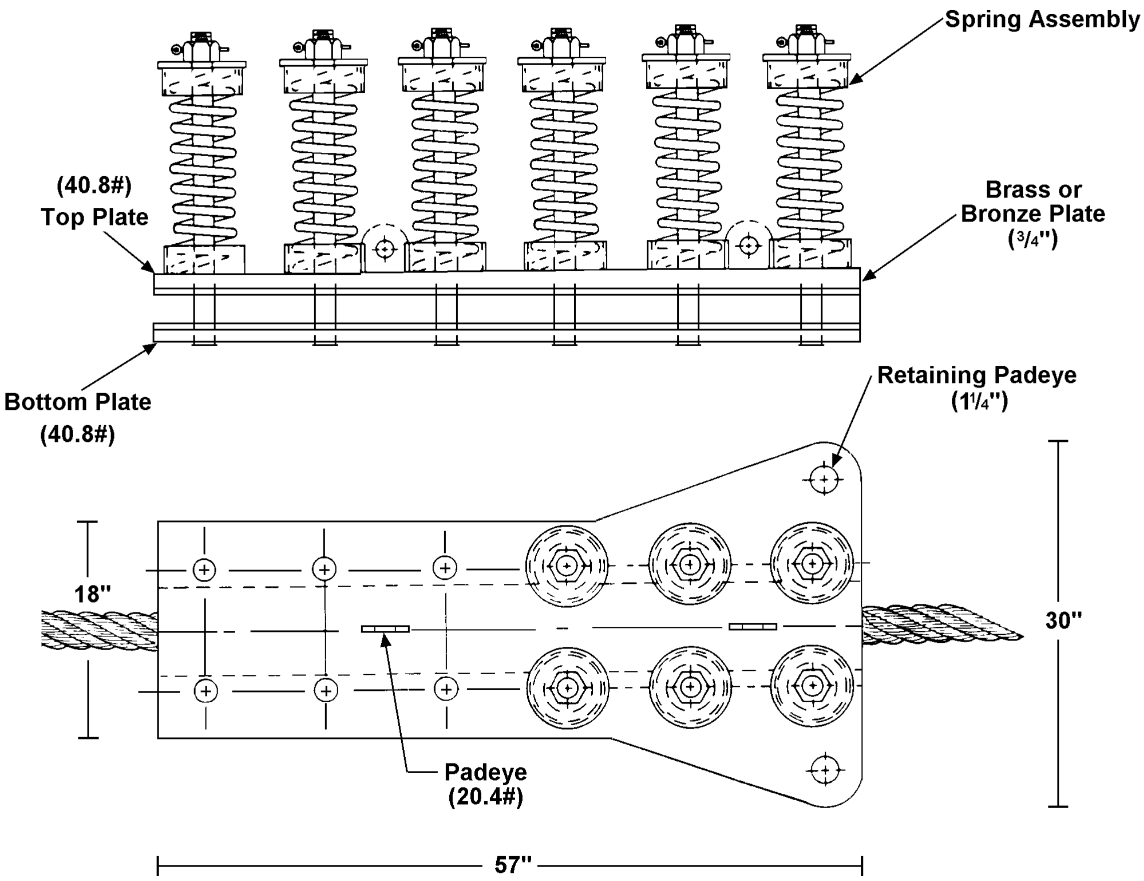
NAVSEA 00C has detailed plans for construction of a Wallis Brake. The Wallis Brake is first tied down to a strong point aft of the drum. In the case of a towing machine or winch, there is usually a strong point on the fantail such as an H-bitt or a heavylift roller. These devices are not intended to be pulled on in the forward direction, but they are built for much heavier loads than they will be required to withstand while supporting a cable brake.

To install the wire, pass the bitter end through the brake and onto the winch or open the brake by removing the spring assemblies and the top plate. Place the wire to be loaded on the bottom plate of the brake and reinstall the top plate and spring assemblies. Next, tighten the spring assemblies with the clamp nuts until the proper tension is reached. Once the cable brake has been properly adjusted, wind the rope onto the winch in a continuous manner until all the wire is on the winch drum.

Take care to keep the wraps tightly together. Wind the first layer slowly, using a heavy maul or hammer to obtain a tight fit. Protect the wire as necessary during any hammering by using soft-faced hammers or wooden blocks. Once the first layer is installed it should be retained as the foundation for subsequent layers and not disturbed during towing operations.

If a Wallis Brake is not available, or if the wire rope could not be initially installed under sufficient tension even with the brake, it can be shackled to a bollard or a mooring buoy, payed off the drum, and then hauled in under the correct tension.

When new wire ropes are put in service as towing hawsers or pendants, record their identification (see Section B-2 for Identification Markings) in the Towing Hawser Log (See Appendix F).



NOTE
Wallis Brake sized for a family of wire rope sizes. The approximate dimensions for a 2-inch Wallis Brake are shown. NAVSEA 00C has details for construction.

Figure B-5. Wallis Brake.

B-6 Stowing

When the towing hawser is removed from the drum, wind it neatly on a reel and store it in an acid free, dry, protected location. Whenever a wire rope towing hawser is to be stored, lubricate it first with MIL-G-18458 grease (preferably with a pressure lubricator) and then keep the outer layer lubricated with the same grease throughout the storage period.

B-7 Inspection

CAUTION
In general, wear gloves when handling wire rope, except when it is moving under load. In this case, the gloves can get snagged and can drag the hands into danger. Wire rope should not be handled when it is moving under load.

B-7.1 General Criteria

Inspect the rope thoroughly as it is being wound after each use. Refer to Figure B-6 for nomenclature of wire rope and Figure B-7 for measuring guidelines.

The inspection criteria for general usage running rope are as follows:

- Reduction of nominal rope diameter due to loss of core support, internal or external corrosion, or wear of individual outside wires
- Number of broken outside wires and degree of distribution or concentration of broken wires
- Corroded, pitted, or broken wires at end connection
- Corroded, cracked, bent, worn, or improperly applied end connections
- Severe kinking, crushing, or distortion of rope structure
- Evidence of heat.

B-7.2 Specific Steps

Detailed steps for inspection and maintenance of wire rope are specified in NSTM 613. The principal steps in wire rope inspection are:

a) Clean the rope by wire brushing and wiping with rags.

b) Inspect wire rope for rust, deterioration, corrosion, wear or flattening, broken strands, and weakened splices.

c) Count number of broken or protruding wires in each wire rope lay length.

d) Measure wire rope diameter with vernier calipers.

Replace wire rope when one or more of the following conditions exists:

- The nominal rope diameter is reduced by more than the amount shown in Figure B-7 for the applicable size rope for measuring rope diameter
- Six wires are broken in one rope lay length or three wires are broken in one strand lay length
- One wire is broken within one rope lay length of any end fitting (cut wire and replace with new fitting)
- The original diameter of outside individual wires is reduced by one-third
- Pitting due to corrosion is evident
- Heat damage is evident
- Kinking, crushing, or any other damage resulting in distortion of the rope structure is evident.

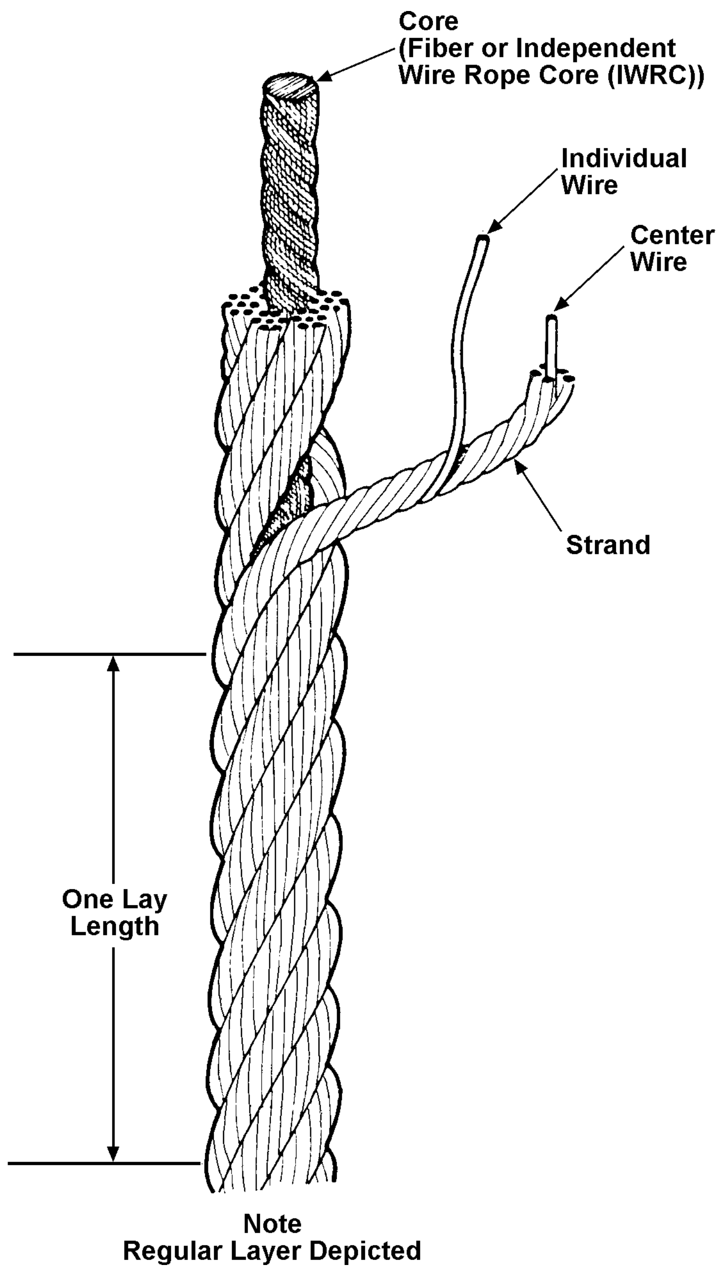
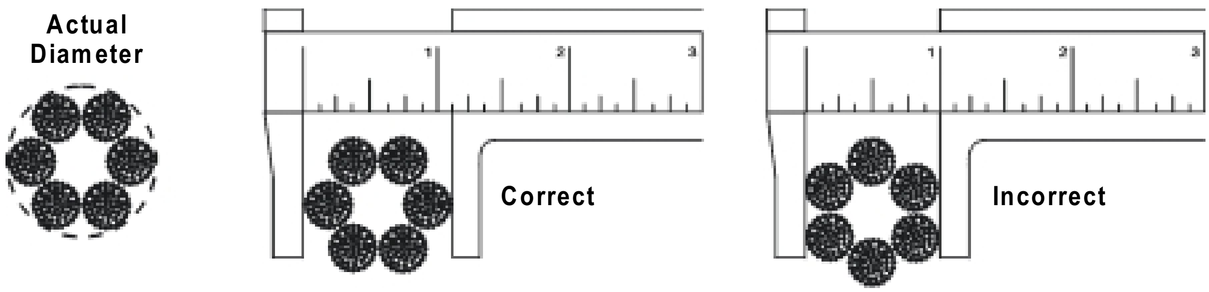


Figure B-6. Nomenclature of Wire Rope.



Rope Diameter (Inches)	Maximum Allowable Nominal Diameter Reduction (Inches)
5/16 and smaller	1/64
3/8 to 1/2	1/32
9/16 to 3/4	3/64
7/8 to 11/8	1/16
11/4 to 11/2	3/32
19/16 to 2	1/8
2 to 2-1/2	5/32

Figure B-7. Measuring Wire Rope.

Table B-1. Wire Hawsers Carried by U.S. Navy Towing Ships.	
Ship Class	Wire Rope Hawser Diameter by Length
T-ATF 166*	2¼″ x 2500′ 6 x 37
ARS 50	2¼″ x 3000′ 6 X 37
* T-ATFs are being refitted with wire core rope when hawsers are due for replacement.	

B-8 Special Precautions

WARNING
Proper maintenance is extremely important for wire rope used in critical or potentially dangerous applications such as towing.

Wire rope must be properly maintained when used in critical or potentially dangerous situations. It should not be subjected to any of the following common abuses:

- Chafing
- Impact loads or rapidly changing loads
- Incorrect size of groove on drum or sheave
- Drum or sheave grooves that have become rough or corrugated through wear
- Inadequate diameter of drum or sheave
- Improper winding on drum
- Improper or insufficient lubrication
- Exposure to corrosive fluids
- Exposure to excess heat or electric arcing
- Lack of protection against moisture and salt water
- Kinks or hockles.

If wire rope is struck by lightning, inspect it and consider replacing it

It is important to maintain minimum and evenly distributed wear. Pay special attention to possible chafing points where the wire rope passes over chocks, bitts, stern rollers, and so forth. Even though no particular wear may be noticed, it is advisable to freshen the nip at least once per watch to change the location of possible wear.

B-9 Wire Rope Hawsers for Navy Tow Ships

Navy towing hawsers are of two types:

- 21/4-inch diameter, fiber core
- 21/4-inch diameter, Independent Wire Rope Core (IWRC).

Table B-1 lists the wire hawsers carried by each Navy towing ship class. T-ATF-166 class vessels are replacing fiber core wire with IWRC wire during normal replacement cycles. Table B-2 provides the strength and weight per foot of 6 x 37 class IPS marine ropes.

B-10 Wire Rope Terminations

Wire rope towing hawsers are terminated with a closed, poured socket. The dimensions and weights of four common sizes of open and closed Spelter sockets are shown in Figure B-8. The strength of these sockets, when properly made, exceeds the strength of the wire rope for which they are designed. The dimensions are given in detail to assist in selecting the appropriate mating jewelry.

Table B-2. Nominal Breaking Strength of Wire Rope 6x37 Class, Hot-Dipped Galvanized.

Fiber Core[2]		Nominal Diameter (inches)	Independent Wire Rope Core[3]		
Weight in Air (lbs/ft)*	Improved Plow Steel (lbs)**		Weight in Air (lbs/ft)	Improved Plow Steel (lbs)**	Extra Improved Plow Steel (lbs)**
0.11	4,932	1/4	0.12	5,292	6,100
0.16	7,668	5/16	0.18	8,240	9,500
0.24	10,980	3/8	0.26	11,800	13,600
0.32	14,886	7/16	0.35	16,000	18,400
0.42	19,260	1/2	0.46	20,700	24,000
0.53	24,300	9/16	0.59	26,100	30,250
0.66	30,060	5/8	0.72	32,200	37,100
0.95	42,840	3/4	1.04	48,100	53,000
1.29	57,960	7/8	1.42	62,300	71,100
1.68	75,240	1	1.85	80,800	93,000
2.13	94,680	1 1/8	2.34	101,700	117,000
2.63	116,280	1 1/4	2.89	125,000	144,000
3.18	139,860	1 3/8	3.50	150,300	172,800
3.78	165,600	1 1/2	4.16	178,000	205,200
4.44	192,600	1 5/8	4.86	207,000	237,600
5.15	223,200	1 3/4	5.67	239,400	275,400
5.91	253,800	1 7/8	6.50	273,600	313,200
6.72	288,000	2	7.39	309,600	356,400
7.59	322,000	2 1/8	8.35	345,600	397,800
8.51	360,000	2 1/4	9.36	387,000	444,600
9.48	339,600	2 3/8	10.4	430,200	493,200
10.5	439,200	2 1/2	11.6	471,600	543,600
11.6	482,400	2 5/8	12.8	518,400	595,800
12.7	525,600	2 3/4	14.0	565,200	649,800
13.9	570,600	2 7/8	15.3	613,800	705,600
15.1	619,200	3	16.6	666,000	765,000
16.4	687,800	3 1/8	18.0	718,200	824,400
17.7	718,200	3 1/4	19.5	772,200	885,600
		3 1/8	21.0	826,200	952,200
		3 1/2	22.7	883,200	1,015,206
		3 5/8	24.3	941,400	1,083,600
		3 3/4	26.0	1,002,600	1,153,800

* Weights are given in air. To obtain net weight in water, multiply air weights by 0.87.
** Nominal breaking strength in pounds.

NOTES:

1. All data shown is for hot-dipped galvanized wire. Bright (uncoated) wire strengths are 10% higher and are listed in the same tables in Notes (2) and (3). Drawn galvanized wire rope has the same strength as bright wire.
2. Data for fiber core wire rope is taken from RR-W-410D, Table X.
3. Data for Improved Plow Steel IWRC wire rope is taken from RR-W-410D, Table XI. Data for Extra Improved Plow Steel IWRC galvanized wire rope is taken from RR-W-410D, Table XII.

WARNING
When using a termination of less than 100 percent efficiency, the base strength to which the factors of safety are applied must be adjusted accordingly.

See Table B-3 and NSTM 613 for efficiency of wire rope terminations.

Poured socket wire terminations are not tested because they are presumed to be stronger than the safe working strength of the wire. Instead, reliance is placed on the skill of the operator, who is initially qualified and maintains that qualification as described in NSTM 613. Factors of safety listed in Table 3-2 and discussed in Appendix M are applicable to the nominal breaking strength of new wire. If, under an emergency towing situation, a termination other than a poured socket is used, the reduced efficiency of the termination must be included in the allowable load calculations. Furthermore, if the reason for alternate termination is to replace a failed termination or a parted wire, it must be assumed that the balance of the hawser has been overstressed as well. If it is necessary to continue using the questionable hawser, doubling the factor of safety against the lowered system strength would be appropriate.

B-11 Wire Rope Procurement Requirements

This section discusses the applicable specifications for the purposes of procuring wire hawsers for ARS 50 and T-ATF 166 class vessels. For detailed information, consult the below list of documents.

Federal Specifications

RRW410 Wire Rope and Strand

RS550 Sockets, Wire Rope

Manuals

Naval Ship's Technical Manual S9086-UU-STM-010, Chapter 613, "Wire and Fiber Rope and Rigging," S9086-UU-STM-010/CH613, Second Revision, 1 May 1995.(Ref. F)

Copies of Military and Federal Specifications and Standards may be obtained from the following facility:

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(NPFC)
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Philadelphia, PA 19120

Tel: (215) 697-2179

B-12 Requirements

B-12.1 Wire Rope Characteristics

Independent wire rope core may be substituted for fiber core and Extra Improved Plow Steel (EIPS) for Improved Plow Steel (IPS) in any of the cases below if deemed prudent by the purchasing activity. The information below may reflect the original configuration, but availability at the time of replacement may dictate an IWRC.

B-12.2 Wire Towing Hawsers for T-ATF 166 Class Ships

Wire rope shall be 2 1/4-inch diameter cut to 2500-foot lengths (see 3-4.1.3 for tolerances in lengths), IPS (or EIPS), drawn galvanized, preformed, regular (R.H.) lay, polypropylene fiber core (or Independent Wire Rope Core (IWRC)), Type I, Class 3, Construction 6, 6 x 37 (Warrington Seale) IAW Specification RRW410. Documentation of all test results (as required by RRW410) from each Master Reel used in fabrication of wire lengths shall be submitted for the production assemblies (one data set included with the report in Section 4-2.2)

Table B-3. Efficiency of Wire Rope Terminations.

Type Terminations	Efficiency*
Poured Spelter Socket	100 percent
Wire Rope Clips (See Table 4-1 for number)	80 percent
Swaged Socket**	100 percent
Eye splice (hand-spliced)	
2 1/4″ and larger wire	70 percent
1 5/8″ to 2″ wire	75 percent
1 1/8″ to 1½″ wire	80 percent
7/8″ to 1″ wire	80 percent
Flemish Eye (“Molly Hogan”) (with sleeve and thimble)	90 percent

* Efficiency is the strength of the termination divided by the nominal breaking strength of the wire.
** Not recommended for fiber core ropes.

Each of the 2500-foot lengths of 2-1/4-inch wire rope shall have a closed zinc-poured socket on one end and a permanent seizing on the other end (See Section B-13).

Wire rope shall be wound on reels, closed socket first. Reel drums shall be modified as required to allow the closed socket to be inserted into the drum and held so wire can be uniformly wound and tightly secured. Presence of the closed socket must be verifiable by visual examination without disturbing the stowage of wire on the reel. Marking for shipment and storage shall be in accordance with best commercial practices. Each reel shall be clearly marked on each side with the diameter and length of wire in a three-inch size letters as follows: “2 1/4-in x 2500-ft w/closed socket termination.”

B-12.3 2-1/4-Inch Towing Hawsers for ARS-50 Class Ships

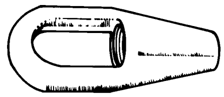
Wire rope shall be 2 1/4-inch diameter cut into a 3000-foot length, EIPS, drawn galvanized, preformed, regular (R.H.) lay, IWRC, Type I, Class 3, Construction 6, 6 x 37 (Warrington Seale) procured IAW Specification RRW410. Documentation of all test results (as required by RRW410) from each Master Reel used in fabrication of wire lengths shall be submitted for the production assemblies (one data set included with the report in Section 4-2.2)

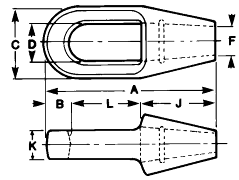
Each of the 3000-foot lengths of 2 1/4-inch wire rope shall have a closed zinc-poured socket on one end and a permanent seizing on the other end (See Section B-13).

Wire rope shall be wound on reels, closed socket first. Reel drums shall be modified as required to allow the closed socket to be inserted into the drum and held so wire can be uniformly wound and tightly secured. Presence of the closed socket must be verifiable by visual examination without disturbing the stowage of wire on the reel. Marking for shipment and storage shall be in accordance with best commercial practices. Each reel shall be clearly marked on each side with the diameter and length of wire in three-inch size letters as follows: “2 1/4-in x 3000-ft w/closed socket termination.”

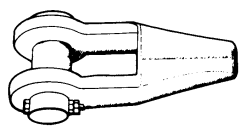
B-13 Sockets

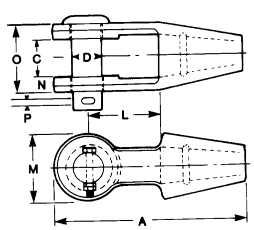
Each towing hawser shall have a closed zinc-poured socket on one end and a permanent seizing on the other end. Closed sockets shall be Type B, procured IAW Specification





WIRE ROPE DIAM INCHES	DIMENSION IN INCHES								WEIGHT POUNDS EACH
	A	B	C	D	F	J	K	L	
1 5/8	15/1/8	2 1/8	5 3/4	3 1/4	1 3/4	6 1/2	2 3/4	6 1/2	36
2 - 2 1/8	19 1/2	2 7/18	7 5/8	3 25/32	2 1/4	8 1/2	3 1/4	8 9/16	80
2 1/4 - 2 3/8	21 1/8	2 5/8	8 1/2	4 9/32	2 1/2	9	3 5/8	9 1/2	105
2 1/2 - 2 5/8	23 1/2	3 1/8	9 1/2	5 1/2	2 7/8	9 3/4	4	10 5/8	140





WIRE ROPE DIAM INCHES	DIMENSION IN INCHES								WEIGHT POUNDS EACH
	A	C	D	L	M	N	O	P	
1 5/8	16 1/4	3	3	6 1/2	5 3/4	1 5/16	6 5/8	1/2	55
2 - 2 1/8	21 1/2	4	3 3/4	9	7	1 13/16	8 3/4	1/2	125
2 1/4 - 2 3/8	23 1/2	4 1/2	4 1/4	10	7 3/4	2 1/8	10	1/2	165
2 1/2 - 2 5/8	25 1/2	5	4 3/4	10 3/4	8 1/2	2 3/8	11	1/2	252

Figure B-8. Poured Sockets FED Spec. RR-S-550D Amendment 1.

RRS550. Documentation of results of tests required by RRS550 shall be delivered with each wire rope assembly. Closed zinc-poured sockets shall be attached to the wire in accordance with the NSTM, CH-613 (Ref. F). Testing and proof of personnel qualifications shall be as required by the Naval Ships Technical Manual. A report of tests and personnel qualification documents shall be provided with the wire rope assembly.

Tolerances on 2 1/4-inch wire rope lengths after sockets have been attached shall be plus or minus five feet from the center of socket eye to the bare end of the wire rope.

B-14 Lubrication

All wire towing hawsers shall be lubricated with MIL-G-18458 grease in accordance with the NSTM CH-613 (Ref. F) prior to being placed on the towing machine drum. The use of a pressure lubricator is preferable when one is available.

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Appendix C

SYNTHETIC FIBER LINE TOWLINES

C-1 Introduction

The material presented in this appendix does not supersede any Fleet or NAVSEA directives on the operational use or care of synthetic towlines. The use of single- and double-braided polyester is approved for all routine and emergency towing applications. Nylon line is only approved for operations with craft of less than 600 tons displacements, or other unique or special tows as approved by NAVSEA on a case-by-case basis.

Existing nylon line should be replaced on a size for size basis with double or single-braided polyester. This includes emergency tow and be towed hawsers.

Fiber lines, either natural or synthetic, can be found serving two functions in towline systems. In some systems the main towing hawser is made of fiber line. In other systems the hawser is wire rope and fiber lines are used as springs to provide relief from dynamic tension loads. In both uses, the fiber line should be kept in excellent condition, protected against wear, and inspected regularly.

When fiber line is used as the main towing hawser or as a spring, a written record of its history is required by the Naval Sea Systems Command in the form of the Towing Hawser Log (see Appendix F).

C-2 Traceability

The ability to trace a line's history is an important element in accident investigation as well as in general product-improvement efforts. Some of this information is maintained in the Towing Hawser Log. American-made fiber line and some brands of foreign-made rope can be identified by special marker tapes inserted into the fiber lines, special-colored monofilaments and metal tags, and other data on the reel upon which the line is delivered. Identification of manufacturing source through the marker coding is particularly useful in cases where the reel markings have been lost. Additional information on a specific domestic rope producer's identification marking practices is available on request from the Cordage Institute, Suite 115, 350 Lincoln Street, Hingham, MA 02043. Telephone (617) 749-1016.

C-3 Strength and Lifetime

WARNING
The failure of synthetic fiber lines under high tension loads can be extremely dangerous. Synthetic lines, particularly polyester and nylon, retain high amounts of energy when under tension. These lines will have severe snapback if they fail under load. Personnel should stay clear of areas through which the end of a failed line may whip.

C-3.1 General

Most synthetic fiber lines are stronger than natural fiber (manila) lines, and they usually have longer lifetimes because of their resistance to rot and other forms of environmental deterioration.

C-3.2 Specific

The primary type of fiber line currently used by the Navy for towing is polyester. The use of nylon in towing is currently restricted in towing applications. Polypropylene is used in some applications but does not have the superior characteristics of polyester or nylon. Table C-1 presents a qualitative summary of

Table C-1. Fiber Comparisons.						
Fiber Type	**Strength[1]**	**Cyclic[2] Fatigues**	**Bending[2] Fatigue**	**Abrasion Resistance**	**Heat Resistance**	**Creep**
Nylon (dry)	VG	VG	G	E	G	G
Nylon (wet)	G	F	F	F	—	G
Polyester (dry)	VG	VG	VG	VG	G	VG
Polyester (wet)	VG	VG	G	G	—	VG
Polypropylene (dry)	F	F	P	P	P	F
Polypropylene (wet)	F	F	P	F	—	F

E = Excellent, VG = Very Good, G = Good, F = Fair, P = Poor

NOTES:
1. Tensioned between two limits without bending.
2. Usually running over pulleys. Some line wears out before failing from fatigue because of abrasion.

pertinent characteristics of the three types of fiber lines.

As one may note from Table C-1, nylon's water-absorption characteristic changes its comparative rating from best to intermediate in nearly every category. Consequently, the Navy has phased out the use of nylon in favor of polyester. Where springs are required in towline systems, polyester fiber will be used. Polypropylene will also continue to be used for certain purposes because it is the only one of the three fiber lines that floats.

The Navy also employs synthetic lines in some of its lifting operations. These applications demand lightweight, high strength, small diameter lines in very long lengths. Aramid fibers such as Kevlar, Spectra, and Vectran are well suited for this need. These types of fiber are not approved for Navy towing, however. They have extremely low elongation and, because of their light weight, do not provide the catenary of wire rope. These fibers, therefore, do not provide the same extreme tension mitigation as the other hawser types.

C-4 Elongation

The elongation or stretch of fiber line under tension has both advantages and disadvantages. Elongation tends to greatly reduce dynamic loads in the towline such as shock loads and wave-induced loads. Unfortunately, elongation also stores a great deal of energy in ropes under tension and the release of this energy when a rope fails causes a very dangerous whipping or "snap back" of the line. The stored energy, and potential danger, is much greater in the case of synthetic lines than for wire rope under the same load. For this reason, extreme caution is required when working near fiber lines that are under load. Under heavy tension loads, nylon line can snap back at speeds up to 700 feet per second (500 m.p.h.). Braided fiber lines tend to stretch about one-half to two-thirds as much as plaited or stranded ropes of the same size.

C-5 Maintenance and Cleaning

Although fiber lines are not subject to corrosion as wire ropes are, they still require careful maintenance and cleaning. If the line becomes oily or greasy, scrub it with fresh water and a paste-like mixture of granulated soap. For heavy accumulations of oil and grease, scrub the line with a solvent such as mineral spirits, then rinse it with a solution of soap and fresh water.

The three different synthetic fibers show different responses to various chemicals. In brief:

- Nylon weakens if exposed to acids, particularly mineral acids. Its resistance to alkalis is good at normal temperatures.
- Polyester line will deteriorate with exposure to hot, strong alkali solutions. It is particularly vulnerable to very strong acid solutions; therefore, even diluted acid solutions should not be allowed to dry on the rope.
- Polypropylene is resistant to both acids and alkalis at normal temperatures, but is affected by some organic solvents such as xylene and metacresol and by coal tar and paint-stripping compounds. These types of chemicals are most likely to be found in the paint locker in thinners and cleaning compounds.

All synthetics are weakened by exposure to strong sunlight and should therefore be stored out of the sun. Polyester has the best resistance to ultraviolet rays.

To extend the life of synthetic line, maintain minimum and evenly distributed wear. Pay special attention to possible chafing points where the line passes over chocks, bitts, stern rollers, and so forth. Even though no particular wear may be noticed, it is advisable to freshen the nip at least once per watch to change the location of possible internal wear.

Do not subject fiber lines to any of these other common abuses:

- Incorrect size of groove on drum or sheave
- Drum or sheave grooves that have become rough or corrugated through wear
- Inadequate radius on fairlead or stern roller
- Rough or abrasive surfaces on fairlead or stern roller
- Improper winding on drum
- Exposure to excessive heat
- Kinks or hockles.

C-6 Stowing

Stow synthetic line away from strong sunlight, heat, and strong chemicals, and cover it with tarpaulins. If the line becomes iced over, thaw it carefully and drain it before stowing. If feasible, store the line on appropriately treated wooden dunnage. Nylon is susceptible to a rapid reduction in strength when exposed to rust; make sure that it is not exposed to rust-prone bare steel surfaces.

C-7 Uncoiling or Unreeling New Hawsers

Synthetic line is shipped in cut lengths, either in coils or on wooden reels. It must be uncoiled or unreeled very carefully to avoid abrasion and permanent damage to the fibers. Looping the line over the head of the reel or pulling the line off a coil while it is lying on the deck may create kinks or hockles in the line. Never allow synthetic line to drag over rough surfaces since this will tend to abrade and cut the outer fibers.

CAUTION
A common method of uncoiling wire rope by rolling the coil along the deck is not recommended for fiber lines because of the potential for abrading or cutting the outer fibers, and also because the coil will collapse when the bands are removed.

Synthetic lines are unreeled the same way that wire ropes are unreeled (see Section B-5).

C-8 Breaking in New Hawsers

CAUTION
New synthetic hawsers should not be subjected to heavy strain prior to breaking them in. Limit the towing loads applied to a new hawser until it has been cycled up to its working load.

NSTM CH-613 (Ref. F) suggests that a synthetic hawser is adequately "broken in" after five cycles of loading/unloading up to its working load or to within 20 percent of breaking strength, whichever is less. This works the construction stiffness out of the line. When new lines are strained, they sometimes produce a sharp crackling sound. This is the result of readjustment of the line's strands to stretching and should not be cause for alarm.

It is not always possible to get new line to lay flat due to turns set into the line during storage on a reel. Never tow with a synthetic hawser just to get the hockles or kinks out. Stream the line, controlling its payout with a capstan, until the bitter end is reached. Retrieve it with the aid of the capstan and it will then lay flat as the excess turns will run out of the line as it is being hauled in. The ship should be stopped during retrieval of the line.

When a new line is put into service as a towing hawser or spring, its identification information (see Section C-2) should be recorded in the Towing Hawser Log (see Appendix F).

C-9 Inspection

Regular inspection is essential to ensure that synthetic lines remain serviceable and safe.

Keep in mind that no matter what has weakened the line, the effect of the same injury will be more serious on a small line than a large line. Therefore, always consider the relationship of the surface area of the line to its cross section.

Examining the line about one foot at a time is usually practical. Turn the line to reveal all sides before continuing. At the same intervals, untwist the rope slightly to examine between the strands of three-strand and plaited rope.

Synthetic lines should be inspected after each use. Look for broken fibers in the outer layer and for discoloration or appearances of melting. When examining between the strands, look for these same evidences of wear and look also for any appearance of a powdery substance between the strands. Broken outer fibers may indicate that the line has been dragged over sharp or rough surfaces. Discoloration or melting may indicate excessive frictional heat from either dynamic loads or from rubbing over smooth surfaces. Internal wear, sometimes indicated as a fuzzed or fused condition between strands, may indicate fatigue damage from repeated or cyclic loads and overloading.

If the examination raises any doubts about the safety of the line, discard it. Again, keep in mind that the effects of wear and mechanical damage are relatively greater on smaller lines which, therefore, require more stringent standards of acceptance.

The following section on types of wear should be helpful during the inspection of synthetic lines.

C-10 Types of Wear or Damage

The usual types of wear exhibited by synthetic lines are as follows:

- ***General external wear.*** External wear due to dragging over rough surfaces causes surface chafing. In the extreme, the strands become so worn that their outer faces are flattened and the outer yarns are severed. In ordinary use some disarrangement or breakage of the fibers on the outside of the line is unavoidable and harmless if not extensive. Generally, nylon and polyester filament lines have very good abrasion resistance.

- ***Local abrasion.*** Local abrasion, as distinct from general wear, is caused by the passage of the line over sharp edges while under tension and may cause serious loss of strength, especially if accompanied by fused areas signifying high heat generated by rope surges under heavy load. Slight damage to the outer fibers and an occasional torn yarn may be considered harmless, but serious reduction in the cross-sectional area of one strand or somewhat less serious damage to more than one strand should warrant rejection. When such damage is noticed, preventive measures should be taken. Typical protective steps are to smooth and round off all rough or sharp areas on the surface that are chafing the line and apply chafing gear such as rubber or plastic sleeves or cloth material secured by small stuff around the line.
- ***Cuts and contusions.*** Cuts and contusions are caused by rough or sharp surfaces. Such careless use may cause internal as well as external damage. This may be indicated by local rupturing or loosening of the yarns or strands.
- ***Internal wear.*** Internal wear may be indicated by excessive looseness of the strands and yarns or the presence of fuzzed or fused internal areas. It is caused by repeated flexing of the line and by particles of grit that have been picked up. Ice crystals can also cause internal wear. This condition results from towing in very cold weather and will most likely occur at the stern of the tug and at the tow where the hawser is occasionally wetted, but generally exposed to the cold air.

WARNING

Surging of synthetic line under tension can cause sufficient frictional heat at the contact surfaces to melt the surface of the line. The melting point of polypropylene line, for instance, is 320°F to 340°F, while the softening point is around 300°F. Comparable temperatures for polyester are only moderately higher. These temperatures are quite quickly produced when a line is surged on a winch or capstan.

- ***Repeated loading.*** Although polyester filament line resists damage from repeated loading, permanent elongation will occur over time in heavily loaded ropes. If the original length of the rope is known exactly, remeasuring under exactly the same conditions indicates the total extension of the rope. This method, however, may not reveal severe local permanent elongation that may cause breaking on subsequent loading. Measuring the distance between regularly spaced indelible markers on the rope can help reveal this problem.
- ***Heat.*** Heat may, in extreme cases, cause melting. Any signs of melting should obviously warrant rejection, but a line may be damaged by heat without any such obvious warning. The best safeguard is proper care and storage. A synthetic line should never be dried in front of a fire or stored near a stove or other source of heat.
- ***Strong sunlight.*** Strong sunlight causes weakening of synthetic fibers, but is unlikely to penetrate beneath the surface. Unnecessary exposure should be avoided, however. Solar degradation should be checked by rubbing the surface of the line with the thumb nail. If degradation has tak-

en place, the surface material will come off as a powder. In addition, the surface of the line will feel dry, harsh and resinous.

C-11 Special Precautions

WARNING
Listed below are three precautions to be considered when using synthetic tow hawsers. They should be taken as warnings as they are critical to safety of personnel.

- When using heavily loaded synthetic lines, the major precaution to be taken is to be constantly alert to the potential danger of line "snap back" during failure. Personnel must remain clear of the areas through which the ends of a failed line may whip or snap.
- To avoid damage from rough surfaces, synthetic line should not be used in areas where chafing potential is high. Use of a wire rope or chain pendant is preferred. This is particularly important on the tow, as the conditions of the tow's chocks, bitts, etc. may be unknown and contact with these may cause extensive chafing. Barges usually have very rough chocks caused by previous repetitive use of wire rope or chain. Special attention should be paid to where the hawser crosses the stern of the tug.
- Since their coefficient of friction is below that of manila, synthetic lines may slip when eased out under heavy loads, causing personal injury. Make sure that personnel are thoroughly instructed in these lines' peculiarities. Take two or three turns on a bitt before you "figure 8" the line; this provides closer control. Stand well clear of the bitts.

C-12 Fiber Rope Characteristics

- Table C-2 provides the strength and weight of several sizes and types of fiber ropes. See NTSM CH-613 (Ref. F) for additional data on fiber lines.

Table C-2. Synthetic and Natural Line Characteristics.

Size (Inches)	Dry Nylon Double-Braid (MIL-R-24050 D)		Polyester Double-Braid (MIL-R-24667 A)		Polyester Single Braided 12-Strand (MIL-R-24750)	
	BS (lbs)	WT/100 ft	BS (lbs)	WT/100 ft	BS (lbs)	WT/100 ft
3	27,825	24.3	29,480	31.9	25,600	30
5	78,110	67.6	74,000	84	67,200	78
6	109,675	97.1	105,000	128	96,000	112
7	149,800	132	133,600	161	131,200	153
8	192,600	173	180,000	220	172,000	200
9	243,000	219	232,000	287	215,200	253
10	284,840	270	277,000	337	264,800	312
11	351,000	327	335,000	419	319,200	378
12	415,800	389	396,150	510	376,800	449
13	475,200	450	446,500	576	440,800	527
14	548,640	524	500,650	646	508,800	612

BS = Breaking Strength WT = Weight

Strength shown for nylon is for new dry nylon. Nylon wet strength is about 15% less. Multiply figures listed by 0.85 to obtain the new breaking strength of wet nylon.

Appendix D

CHAINS AND SAFETY SHACKLES

D-1 Introduction

Chain is an important component in the connection between the towed vessel and the tug. It usually appears in the form of pendants or bridles at the towed-vessel end of the towline. The chain components serve one or more of the following purposes:

- A chafing-resistant strong terminal connection to the towed vessel
- An equalizing device (bridle) to share the towing load between two strong points located port and starboard of the towed vessel's bow (or stern)
- A means of absorbing dynamic loads in the towline, by virtue of its weight, which increases catenary in the towline.

Chain, like other marine tension members, has evolved over the years. The Boston Naval Shipyard led U.S. Navy chain development and manufacture for many years. Two major developments and manufacturing responsibilities at the Shipyard were die lock chain and the Navy detachable link. With the deactivation of the Boston Naval Shipyard in 1972, this capability was lost to the Navy, although similar products were commercially manufactured until the mid-1980s. Nonetheless, large amounts of die lock chain remain throughout the Fleet and this type chain is perfectly acceptable for all uses for which it was designed. The Navy now purchases "flash butt welded stud link" chain that is similar in appearance to high quality, commercial anchor chain, usually referred to as "welded" or "stud link" chain. In this appendix, this new Navy chain will be called "stud link" chain for the sake of simplicity. Navy stud link chain is slightly stronger than standard Type 1 die lock chain; they may be used interchangeably.

Until recently, commercial "DiLok" chain was made by one manufacturer, Baldt. It is slightly stronger and heavier than Type 1 standard Navy die lock chain. Section D-11 discusses the strengths of the various chains that may be used in towing.

D-2 Traceability and Marking

D-2.1 Traceability

The ability to trace a chain's history is an important element in accident investigation as well as in general product-improvement efforts. For identification, a corrosion-resistant metal tag is attached to the end link at each end of each shot or length of Navy chain. Included among data plainly marked on the tag is a manufacturer's serial number, which permits tracing the chain back to its manufacturing source. The manufacturers also provide information with new chain regarding size, type, material, proof tests, certification, and so forth. This information should be maintained in the Towing Hawser Log (see Appendix F) and updated as necessary for chain that is used as an integral part of the towline connection.

D-2.2 Marking

Navy chain, whether die lock or stud link, is marked in accordance with MIL-C-24633A Notice 1, Chain, Stud Link, Anchor, Low Alloy Steel, Flash Bolt Welded (Ref. AB).

Commercial chain used in marine service, including DiLok, is controlled and certified by various marine classification societies such as the American Bureau of Shipping (ABS), which certifies all U.S. flag vessels and many foreign ships. Marine stud link chain is made in three grades. Grade 2 is most prevalent. ABS requires chain to be marked on the end link of each shot, or every 15 fathoms if the chain is continuous (without connecting links). The markings include:

- Certificate number
- Chain size
- Classification society stamp (such as a Maltese Cross for ABS)
- Designation of the grade of chain, for example: AB/1, AB/2, or AB/3. The other classification societies have marking requirements and grading systems that are similar to those of ABS.

When towing a commercial ship, if it is intended to use the ship's anchor chain for a bridle or pendant, the chain should be carefully inspected in accordance with the requirements of Section D-8. If the classification society grade marking cannot be determined, the chain should be assumed to be Grade 1, which is roughly one-half as strong as standard Navy chain.

Chain from unknown or non-marine sources that is unmarked or cannot otherwise be identified should not be used in towing.

D-3 Strength and Lifetime

Chain, properly used, should be the strongest and longest-lived element in the towing system. Because of its construction and generally rugged configuration, chain is considerably stronger than wire or fiber rope of the same nominal size.

D-4 Elongation

The rugged, large-diameter, individual strength members of chain give it the least elongation, or stretch, under load of any towline component. This characteristic of chain is one of the prime reasons it is used as an element in the towline system. Because it does not stretch, working at chafing points, under constantly changing tension, is minimized. Additionally, the weight and flexibility of the chain promotes the towline catenary and mitigates the effects of dynamic loading on the rest of the towing system.

D-5 Maintenance and Cleaning

As with other elements of the towline, chain must be properly maintained and cleaned. Perhaps the most important element of chain maintenance is corrosion prevention. Corrosion leads directly to loss of chain strength by reducing the diameter of the load-carrying rods that form the links. In stud link chains, corrosion can also loosen the studs and eventually lead to their loss.

Corrosion prevention is best achieved by a fresh-water washdown of the chain after each use, coupled with visual inspection for initial signs of corrosion. During the required annual inspection, the chain should be carefully cleaned, inspected, and re-preserved as necessary; see Naval Ship's Technical Manual (NSTM) S9086-TV-STM-010, Chapter 581, *Anchoring* (Ref. AC).

Cleaning should be done by scaling, sandblasting, or wire brushing. Penetrating oil should not be used to loosen the rust because it is difficult to remove and may reduce the effectiveness of corrosion prevention coatings. After cleaning, a careful inspection should be made in accordance with Section D-8. All suspected links should be checked by non-destructive test methods, careful measurement, sounding, and so forth.

Preservation after cleaning and any necessary repairs should be performed in accordance with Section D-8 and with NSTM CH-074 (Ref. K). For most chain, the use of TT-V-51 paint (asphalt varnish) or MIL-P-24380 paint (anchor chain gloss black solvent type paint) is satisfactory.

D-6 New Chain and Links

New or reissued chain or links that will be used as components of towline connections should be treated in the same manner as new towing hawsers. The chain and links should be inspected and pertinent data entered in the Towing Hawser Log (see Appendix F).

D-7 Stowing

No special stowing precautions are needed beyond attempts to prevent corrosion, such as trying to avoid moisture and salt. Again, oil and grease should be avoided.

D-8 Inspection

D-8.1 General

Annual inspection of chain components of a towline system should follow the Navy practices for anchor chain detailed in NSTM 581. After cleaning by scaling, wire-brushing, or sandblasting, each link should be checked by sounding with a hammer. Give particular attention to locating possible loose studs, bent links, excessive corrosion, and sharp gouges.

D-8.2 Specific

Proper reactions to various conditions noted in the inspection are indicated in the following notes, most of which apply to stud link chain:

- Missing stud: discard link.
- Out-of-plane bending of more than three degrees: discard link.
- Average of the two measured diameters at any point less than 95 percent of nominal diameter, or a diameter in any direction less than 90 percent of nominal diameter: discard link.
- Crack at the toe of the stud weld extending into the base material: discard link.
- Surface cracks or sharp gouges: attempt to eliminate by light grinding. If the chain diameter is reduced to less than 90 percent of the nominal diameter after grinding: discard link.
- Excessively loose stud: since it is difficult to quantify excessive looseness of chain studs, the decision to reject or accept a link with a loose stud depends on the experience and judgment of the inspector. Consider discarding a link if:
  - The stud can move more than 1/8 inch (3 mm) axially or more than 3/16 inch (5 mm) laterally in any direction, or
  - A gap of more than 1/8 inch exists between the stud end in a link with a stud welded only on one end.
- Cracks detected by magnetic particle inspection in the internal locking area of detachable link: discard link. External surface defects in detachable links are not cause for rejection if they can be eliminated by grinding to a depth of no more than 8 percent of the nominal diameter of the chain.
- Length over six links exceeding 26.65 times nominal chain diameter or length of individual link exceeding 6.15 times nominal chain diameter: discard links.
- Excessive wear or deep surface crack on shackles, open links, or swivels: Attempt to eliminate by light grinding. If the cross-section area, diameter or critical thickness in any direction is reduced more than 10 percent by wear and grinding: discard the chain.

If a substantial number of adjacent links in a chain section meet the criteria for discarding, the chain section should be removed and the chain joined again by detachable links that have been examined and found to be in acceptable condition.

If a large number of links meet the criteria for discarding and these links are distributed throughout the chain's whole length, replace the chain with a new one.

Rewelding of loose studs in the field is undesirable for the following reasons:

- Welding in the field may produce hard heat-affected zones that are susceptible to cold cracking.
- Hydrogen brittleness may occur from absorption of moisture from the atmosphere or welding electrodes.

Weld repairs on loose studs should be delayed as long as possible. Where a few links are found with loose studs in a short section of a chain, it is recommended that this portion of the chain be cut out and a detachable link inserted. If the major portion of the chain has loose studs, the chain should be scrapped.

Any grinding to eliminate shallow surface defects should be done parallel to the longitudinal direction of the chain, and the groove should be well rounded and should form a smooth transition to the surface. The ground surface should be examined by magnetic-particle or dye-penetrant inspection techniques.

D-9 Types of Wear

The rough treatment to which chain items of towing gear are exposed can lead to various chain problems. Eight common problems for which towing personnel should be alert are described below:

- **Missing studs.** The stud contributes about 15 percent of the chain's strength. A chain link without a stud may significantly increase the possibility of link failure. High bending stresses and low fatigue life in links are predictable consequences of missing studs.
- **Bent links.** A bent link is the result of chain handling abuse. The link may have been excessively torqued when traversing a sharp, curved surface or the chain may have jumped over the wildcat, making point contacts between the link and the wildcat.
- **Corrosion.** Excessive corrosion reduces the cross sectional area of the link, increasing the possibility of chain failure from corrosion fatigue or overloading.
- **Sharp gouges.** Physical damage to the chain surface, such as cuts and gouges, raises stress and promotes fatigue failure.
- **Loose studs.** Loose studs, caused by abusive handling or by excessive stretching of chain, result in lower bending strength of the chain.
- **Cracks.** Surface cracks, flash weld cracks, and stud weld cracks propagate under cyclic loading and result in premature chain failure.
- **Wear.** Wear between links in the grip area and between links and the wildcat reduces the chain diameter. The diameter reduction decreases the load-carrying capacity of the chain and invites failure.
- **Elongation.** Excessive permanent elongation may cause the chain to function improperly in the wildcat, resulting in bending and wear of the links. Wear in the grip area of the chain as well as working loads in excess of the original proof load will result in a permanent elongation of chain.

D-10 Special Precautions

Because chain is generally the most rugged component of the towline system, there is a tendency to become overconfident in its capability and somewhat less rigorous in inspection. Avoid overconfidence when using chain.

Personnel tend not to check carefully enough on such items as:

- Adequate radius of curvature on surfaces of fairleads, chocks, and so forth. A ratio of 7:1 is generally accepted as the minimum D:d ratio of bearing surface to chain size for heavy loads when the chain direction is changed significantly over the surface.
- Wear in the grip (partially hidden contact) area between chain links.
- Looseness from excessive wear in shackles, swivels, and detachable links.
- Presence of detachable links that are not equipped with safety-lock hairpins.

D-11 Chain Specifications

Navy die lock chain characteristics are included in Table D-1. The similar Baldt “DiLok” chain is 11 percent stronger and 1 percent heavier. Table D-2 provides the characteristics of Navy stud link chain. Navy stud link chain is equivalent to commercial Grade 3 as shown in Table D-3. Commercial Grade 3 chain is about 3 percent stronger than Navy standard die lock. Grade 2 is only about 70 percent as strong as Navy standard die lock and Grade 1 is only about 50 percent as strong.

D-12 Connecting Links

Detachable chain connecting links are frequently used in lieu of more traditional shackles, because they will pass through a smaller space and are less likely to “hang up” during the rigging process. Pear-shaped detachable links fit two chain sizes. The strength of this link is identical to the breaking strength of the larger chain size that it is designed to accommodate. Figures D-4 through D-5 and Tables D-4 and D-5 describe detachable links and an improved locking system for use with the tapered link pins. End links (see Table D-6) are special studless links 1/8 inch to 1/4 inch larger than the chain size. They are larger than the chain size to compensate for the lack of a stud. They have the same strength as the parent chain system.

D-13 Safety Shackles

CAUTION
Screw-pin shackles, other than the special forged shackles for stoppers, must never be used for connections in towing rigs. The pin could back out due to the constant vibration on the towline.

A safety shackle is characterized by a pin that is secured by a bolt on the outside of the shackle. For towing use, the bolt itself is secured by a small machine bolt with two nuts jammed together to prevent rotation of the large nut. Screw-pin shackles, which use a threaded pin that screws into the body of the shackle, are not approved for Navy towing. Some deck layouts present no alternative due to location and size of attachment padeye. Contact NAVSEA 00C for further guidance.

Navy shackles are manufactured in two types, two grades, and three classes of shackles. Mechanical properties can be obtained from Fed Spec RR-C-271D (Ref. E). Tables D-7 through D-9 provide the physical dimensions and strengths of safety shackles. Note the significant difference in strength between Grade A and Grade B shackles. The shackle size and safe working load will be shown in raised or stamped letters on the shackle. The pins and bolts of Grade A - Regular Strength shackles are unmarked, but Grade B pins and bolts are marked “HS.”

D-14 Proof Load, Safe Working Load, and Safety Factor

Calculated or predicted design loads are compared to a baseline strength in computing the safety factor. Conversely, the baseline strength is divided by the recommended safety factor to determine the allowable design load. Table 3-2 provides the recommended factors of safety for use in designing towing systems. Note that safety factors, for a given type design and service, are referenced to different baselines such as breaking strength, yield strength, or proof load.

For chain, safety factors are referred to as "proof load," a load demonstrated as part of the manufacturing process, which intentionally introduces a permanent stretch that improves the strength of the chain. Proof load for chain is 66 percent of minimum break strength.

For other forged-type hardware, such as shackles, proof load is a load at which no permanent deformation is observed after the load is released. This is important where the component must mate with other components or where the component has parts that must fit together. In the case of shackles, it is important to be able to remove the pin after use. Unlike chain, however, there is no consistent relationship between proof load and breaking load. The relationship depends upon the metallurgical properties of the material.

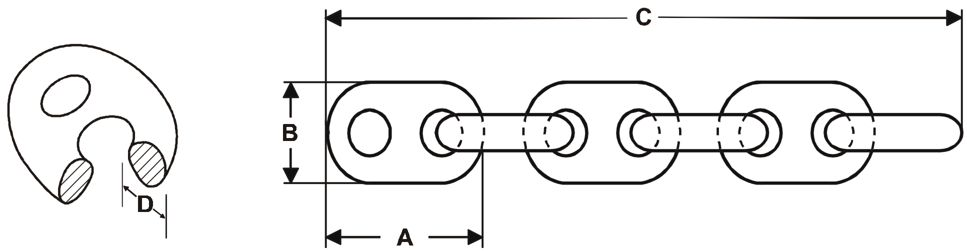
Safe Working Load (SWL) is frequently used for rigging components and systems including such material. The concept of SWL is similar to the use of a "safety factor" and is appropriate where the load is fairly well known and dynamic loads are limited. The typical use of SWL is for lifting purposes. The safety factor inherent in SWL for Navy safety shackles, compared to proof load, is 2 for Grade A and 2.5 for Grade B shackles. This is insufficient for use in towing systems, where the dynamic loads are more difficult to predict, than for simple rigging purposes. Applying the safety factors from Table 3-2 in addition to SWL, however, is overly conservative and will result in unacceptably large components. Therefore, when designing towing systems for strenuous conditions, the safety factors listed in Table 3-2 for shackles should be applied to proof loads listed in Table D-9.

Consider, for example, a predicted steady state tow resistance of 80,000 pounds. This is appropriate for a 2-inch fiber core towing hawser under automatic towing machine control. Table 3-2 requires a safety factor of 3 for shackles. If this factor is applied to SWL, 3 1/2-inch Grade B safety shackles, weighing 310 pounds, would be required in the rig. Applying the required factor of safety to proof load requires more reasonable 2 1/4-inch Grade B shackles.

D-15 Plate Shackles

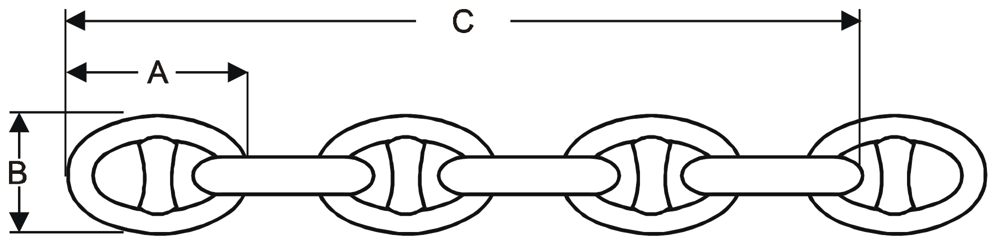
Plate shackles are frequently used in salvage and towing operations because they are simple, efficient, and easily fabricated from commonly available materials. Plate shackles are efficient because many connections of chain to wire and chain to chain would require two safety shackles, back-to-back, whereas one plate shackle will accomplish the task. The cheeks of towing plate shackles are fabricated from "medium" (ABS Grade A or ASTM A-36) steel, the most readily available classification, and the pins are fabricated from 150,000 psi minimum yield strength bar stock, also readily available. Appendix I includes drawings of plate shackles for use in towing. Certain salvage ships can be outfitted for heavy-lifting operations. In this case, stronger plate shackles than shown in Appendix I may be required. Check the specific rigging plans for the specified shackles for heavy lifting.

Table D-1. Die Lock Chain Characteristics (MIL-C-19944).



CHAIN SIZE Inches	CHAIN SIZE mm	Link Length (Inches) A	Link Width (Inches) B	Length Over Six Links (Inches) C	Number of Links Per 15-Fathom Shot	Approx. Weight Per 15-Fathom Shot (Pounds)	Approx. Weight Per Link (Pounds)	Proof Test (Pounds)	Break Test (Pounds)
TYPE I: STANDARD									
3/4	19	4–1/2	2–5/8	19–1/2	359	490	1.4	48,000	75,000
7/8	22	5–1/4	3–1/8	22–3/4	305	680	2.2	64,000	98,000
1	25	6	3–3/16	26	267	890	3.3	84,000	129,000
1–1/8	29	6–3/4	4	29–1/4	237	1,130	4.8	106,000	161,000
1–1/4	32	7–1/2	4–1/2	32–1/2	213	1,400	6.6	130,000	198,000
1–3/8	34	8–1/4	4–13/16	35–3/4	193	1,690	8.8	157,000	235,000
1–1/2	38	9	5–3/8	39	177	2,010	11.4	185,000	280,000
1–5/8	42	9–3/4	5–7/8	42–1/4	165	2,325	14.1	216,000	325,000
1–3/4	44	10–1/2	6–3/16	45–1/2	153	2,695	17.6	249,000	380,000
1–7/8	48	11–3/4	6–3/4	48–3/4	143	3,095	21.6	285,000	432,000
2	51	12	7–3/16	52	135	3,490	25.9	289,800	439,200
2–1/8	54	12–3/4	7–5/8	55–1/4	125	3,935	31.5	325,800	493,200
2–1/4	58	13–1/2	8–1/8	58–1/2	119	4,415	37.1	362,700	549,000
2–3/8	60	14–1/4	8–3/16	61–3/4	113	4,915	43.5	402,300	607,500
2–1/2	64	15	9	65	107	5,475	51.2	442,800	669,600
2–5/8	67	15–3/4	9–3/16	68–1/4	101	6,050	59.9	486,000	731,700
2–3/4	70	16–1/2	9–7/8	71–1/2	97	6,660	68.7	531,000	796,500
2–7/8	73	17–1/4	10–3/8	74–3/4	93	7,295	78.4	576,000	868,500
3	76	18	10–13/16	78	89	7,955	89.4	623,700	940,500
3–1/8	79	18–3/4	11–1/4	81–1/4	87	8,700	100.0	673,200	1,015,200
3–1/4	83	19–1/2	11–11/16	84–1/2	83	9,410	113.4	723,700	1,089,000
3–3/8	86	20–1/4	12–1/8	87–3/4	79	10,112	128.0	776,000	1,166,400
3–1/2	90	21	12–5/8	91	77	10,900	141.6	829,800	1,244,800
3–3/4	95	22–1/2	13–3/8	97–1/2	71	12,500	176.1	1,008,000	1,575,000
4–3/4	121	28–1/2	17–1/8	122–1/2	57	20,500	359.7	1,700,000	2,550,000
TYPE II: HEAVY DUTY									
2–3/4	70	16–1/2	9–7/8	71–1/2	97	7,000	72.2	584,100	882,900
3	76	18	10–13/16	78	89	8,100	91.0	685,800	1,035,000
3–1/2	90	21	12–5/8	91	77	12,000	155.8	972,000	1,530,000
TYPE III: HIGH STRENGTH									
3/4	19	4–1/2	2–5/8	19–1/2	359	550	1.5	67,500	91,100
1	26	6	3–3/16	26	267	1,000	3.8	116,100	156,700
1–1/8	29	6–3/4	4	29–1/4	237	1,270	5.4	145,000	195,000
1–3/8	34	8–1/4	4–15/16	35–3/4	193	1,900	9.9	211,500	285,500
1–1/2	38	9	5–3/8	39	177	2,260	12.8	252,000	340,200
1–5/8	42	9–3/4	5–7/8	42–1/4	165	2,620	15.9	292,500	395,000

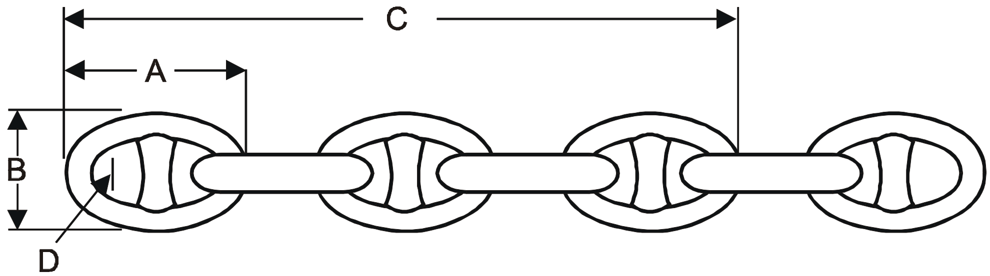
Table D-2. Navy Stud Link Chain Characteristics (MIL-C-24633).



Chain Size (Inches)	Link Length (Inches) (A)	Link Width (Inches) (B)	Length Over 6 Links (C) (Inches)			Number of Links per 15-Fathom Shot	Proof Test Load (Pounds)	Break Test Load (Pounds)	Nominal Weight per 15-Fathom Shot (lb.)*
			Minimum	Nominal	Maximum				
3/4	4-1/2	2-5/8	19-3/8	19-1/2	19-13/16	359	48,000	75,000	480
7/8	5-1/4	3-1/8	22-5/8	22-3/4	23-1/16	305	64,400	98,000	660
1	6	3-9/16	25-7/8	26	26-3/8	267	84,000	129,000	860
1-1/8	6-3/4	4	29-1/16	29-1/4	29-5/8	237	106,000	161,000	1,080
1-1/4	7-1/2	4-1/2	32-5/16	32-1/2	32-15/16	213	130,000	198,000	1,350
1-3/8	8-1/4	4-15/16	35-9/16	35-3/4	36-1/4	193	157,000	235,000	1,630
1-1/2	9	5-3/8	38-13/16	39	39-1/2	177	185,000	280,000	1,940
1-5/8	9-3/4	5-7/8	42	42-1/4	42-7/8	165	216,000	325,000	2,240
1-3/4	10-1/2	6-5/16	45-1/4	45-1/2	46-1/8	153	249,000	380,000	2,590
1-7/8	11-1/4	6-3/4	48-1/2	48-3/4	49-1/2	143	285,000	432,000	2,980
2	12	7-3/16	51-11/16	52	52-3/4	135	318,800	454,000	3,360
2-1/8	12-3/4	7-5/8	54-15/16	55-1/4	56-1/8	125	357,000	510,000	3,790
2-1/4	13-1/2	8-1/8	58-3/16	58-1/2	59-3/8	119	396,000	570,000	4,250
2-3/8	14-1/4	8-9/16	61-7/16	61-3/4	62-3/4	113	440,000	628,000	4,730
2-1/2	15	9	64-11/16	65	66	107	484,000	692,000	5,270
2-5/8	15-3/4	9-7/16	67-7/8	68-1/4	69-1/4	101	530,000	758,000	5,820
2-3/4	16-1/2	9-7/8	71-1/8	71-1/2	72-9/16	97	578,000	826,000	6,410
2-7/8	17-1/4	10-3/8	74-3/8	74-3/4	75-7/8	93	628,000	897,000	7,020
3	18	10-13/16	77-5/8	78	79-3/16	89	679,000	970,000	7,650
3-1/8	18-3/4	11-1/4	80-13/16	81-1/4	82-1/2	87	732,000	1,046,000	8,320
3-1/4	19-1/2	11-11/16	84-1/16	84-1/2	85-3/4	83	787,000	1,124,000	9,010
3-3/8	20-1/4	12-1/8	87-5/16	87-3/4	89	79	843,000	1,204,000	9,730
3-1/2	21	12-5/8	90-9/16	91	92-5/16	77	900,000	1,285,000	10,500
3-5/8	21-3/4	12-15/16	93-13/16	94-1/4	95-5/8	73	958,000	1,369,000	11,300
3-3/4	22-1/2	13-3/8	97-1/16	97-1/2	98-7/8	71	1,019,000	1,455,000	12,000
3-7/8	23-1/4	14	100-1/4	100-3/4	102-3/16	69	1,080,000	1,543,000	12,900
4	24	14-3/8	103-1/2	104	105-1/2	67	1,143,000	1,632,000	13,700

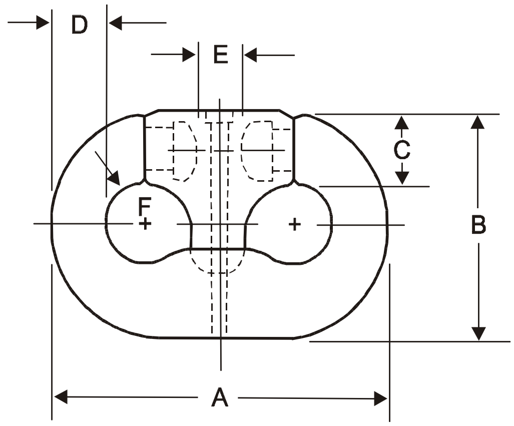
* Not mandatory, for information only.

Table D-3. Commercial Stud Link Anchor Chain.



Chain Size		Link Length (Inches) (A)	Link Width (Inches) (B)	Length Over Five Links (Inches) (C)	Grip Radius (Inches) (D)	Approx. Weight per 15-Fathom Shot (lbs)	No. of Links per 15-Fathom Shot	ABS Grade 1		ABS Grade 2		ABS Grade 3	
Inches	mm							Proof Test (lb)	Break Test (lb)	Proof Test (lb)	Break Test (lb)	Proof Test (lb)	Break Test (lb)
3/4	19	4-1/2	2-5/8	16-1/2	1/2	480	357	23,800	34,000	34,000	47,600	47,600	68,000
13/16	20	4-7/8	2-7/8	17-7/8	17/32	570	329	27,800	39,800	39,800	55,700	55,700	79,500
7/8	22	5-1/4	3-1/8	19-1/4	37/64	660	305	32,200	46,000	46,000	64,400	64,400	91,800
15/16	24	5-5/8	3-5/16	20-5/8	5/8	760	285	36,800	52,600	52,600	73,700	73,700	105,000
1	25	6	3-9/16	22	21/32	860	267	41,800	59,700	59,700	83,600	83,600	119,500
1-1/16	27	6-3/8	3-3/4	23-3/8	11/16	970	251	47,000	67,200	67,200	94,100	94,100	135,000
1-1/8	28	6-3/4	4	24-3/4	25/32	1,080	237	52,600	75,000	75,000	105,000	105,000	150,000
1-3/16	30	7-1/8	4-1/4	26-1/8	25/32	1,220	225	58,400	83,400	83,400	116,500	116,500	167,000
1-1/4	32	7-1/2	4-1/2	27-1/2	25/32	1,350	213	64,500	92,200	92,200	129,000	129,000	184,000
1-5/16	33	7-7/8	4-3/4	28-7/8	7/8	1,490	203	70,900	101,500	101,500	142,000	142,000	203,000
1-3/8	34	8-1/4	4-15/16	30-1/4	7/8	1,630	195	77,500	111,000	111,000	155,000	155,000	222,000
1-7/16	36	8-5/8	5-3/16	31-5/8	15/16	1,780	187	84,500	120,500	120,500	169,000	169,000	241,000
1-1/2	38	9	5-3/8	33	63/64	1,940	179	91,700	131,000	131,000	183,500	183,500	262,000
1-9/16	40	9-3/8	5-5/8	34-3/8	1-1/32	2,090	171	99,200	142,000	142,000	198,500	198,500	284,000
1-5/8	42	9-3/4	5-7/8	35-3/4	1-1/16	2,240	165	108,000	153,000	153,000	214,000	214,000	306,000
1-11/16	43	10-1/8	6-1/16	37-1/8	1-3/32	2,410	159	115,000	166,500	166,500	229,000	229,000	327,000
1-3/4	44	10-1/2	6-5/16	38-1/2	1-5/32	2,590	153	123,500	176,000	176,000	247,000	247,000	352,000
1-13/16	46	10-7/8	6-1/2	39-7/8	1-3/16	2,790	147	132,000	188,500	188,500	264,000	264,000	377,000
1-7/8	48	11-1/4	6-3/4	41-1/4	1-1/4	2,980	143	140,500	201,000	201,000	281,000	281,000	402,000
1-15/16	50	11-5/8	7	42-5/8	1-9/32	3,180	139	149,500	214,000	214,000	299,000	299,000	427,000
2	51	12	7-3/16	44	1-5/16	3,360	133	159,000	227,000	227,000	318,000	318,000	454,000
2-1/16	52	12-3/8	7-7/16	45-3/8	1-3/8	3,570	129	168,500	241,000	241,000	337,000	337,000	482,000
2-1/8	54	12-3/4	7-5/8	46-3/4	1-27/64	3,790	125	178,500	255,000	255,000	357,000	357,000	510,000
2-3/16	56	13-1/8	7-7/8	48-1/8	1-15/32	4,020	123	188,500	269,000	269,000	377,000	377,000	538,000
2-1/4	58	13-1/2	8-1/8	49-1/2	1-1/2	4,250	119	198,500	284,000	284,000	396,000	396,000	570,000
2-5/16	59	13-7/8	8-5/16	50-7/8	1-17/32	4,490	117	209,000	299,000	299,000	418,000	418,000	598,000
2-3/8	60	14-1/4	8-9/16	52-1/4	1-9/16	4,730	113	212,000	314,000	314,000	440,000	440,000	628,000
2-7/16	62	14-5/8	8-3/4	53-5/8	1-5/8	4,960	111	231,000	330,000	330,000	462,000	462,000	660,000
2-1/2	64	15	9	55	1-5/8	5,270	107	242,000	346,000	346,000	484,000	484,000	692,000
2-9/16	66	15-3/8	9-1/4	56-3/8	1-11/16	5,540	105	254,000	363,000	363,000	507,000	507,000	726,000
2-5/8	67	15-3/4	9-7/16	57-3/4	1-11/16	5,820	103	265,000	379,000	379,000	530,000	530,000	758,000
2-11/16	68	16-1/8	9-11/16	59-1/8	1-3/4	6,110	99	277,000	396,000	396,000	554,000	554,000	792,000
2-3/4	70	16-1/2	9-7/8	60-1/2	1-13/16	6,410	97	289,000	413,000	413,000	578,000	578,000	826,000
2-13/16	71	16-7/8	10-1/8	61-7/8	1-27/32	6,710	95	301,000	431,000	431,000	603,000	603,000	861,000
2-7/8	73	17-1/4	10-3/8	63-1/4	1-7/8	7,020	93	314,000	449,000	449,000	628,000	628,000	897,000
2-15/16	75	17-5/8	10-9/16	64-5/8	1-7/8	7,330	91	327,000	467,000	467,000	654,000	654,000	934,000
3	76	18	10-13/16	66	2	7,650	89	340,000	485,000	485,000	679,000	679,000	970,000
3-1/16	78	18-3/8	11	67-3/8	2	7,980	87	353,000	504,000	504,000	705,000	705,000	1,008,000
3-1/8	79	18-3/4	11-1/4	68-3/4	2-1/16	8,320	85	366,000	523,000	523,000	732,000	732,000	1,046,000
3-3/16	81	19-1/8	11-1/2	70-1/8	2-1/16	8,660	85	380,000	542,000	542,000	759,000	759,000	1,084,000
3-1/4	83	19-1/2	11-11/16	71-1/2	2-1/8	9,010	83	393,000	562,000	562,000	787,000	787,000	1,124,000
3-5/16	84	19-7/8	11-15/16	72-7/8	2-1/8	9,360	81	407,000	582,000	582,000	814,000	814,000	1,163,000
3-3/8	86	20-1/4	12-1/8	74-1/4	2-3/16	9,730	79	421,000	602,000	602,000	843,000	843,000	1,204,000
3-7/16	87	20-5/8	12-3/8	75-5/8	2-3/16	10,100	77	435,000	622,000	622,000	871,000	871,000	1,244,000
3-1/2	90	21	12-5/8	77	2-5/16	10,500	77	450,000	643,000	643,000	900,000	900,000	1,285,000
3-5/8	92	21-3/4	12-15/16	79-3/4	2-5/16	11,300	73	479,000	685,000	685,000	958,000	958,000	1,369,000
3-3/4	95	22-1/2	13-3/8	82-1/2	2-15/32	12,000	71	509,000	728,000	728,000	1,019,000	1,019,000	1,455,000
3-7/8	98	23-1/4	14	85-1/4	2-15/32	12,900	69	540,000	772,000	772,000	1,080,000	1,080,000	1,543,000
4	102	24	14-3/8	88	2-5/8	13,700	67	571,000	816,000	816,000	1,143,000	1,143,000	1,632,000
4-1/8	105	24-3/4	14-7/8	90-3/4	2-11/16	14,600	65	603,000	862,000	862,000	1,207,000	1,207,000	1,724,000
4-1/4	108	25-1/2	15-5/16	93-1/2	2-3/4	15,400	63	636,000	908,000	908,000	1,272,000	1,272,000	1,817,000
4-3/8	111	26-1/4	15-3/4	96-1/4	2-7/8	16,200	61	669,000	956,000	956,000	1,338,000	1,338,000	1,911,000
4-1/2	114	27	16-3/16	99	2-15/16	17,100	59	703,000	1,000,400	1,000,400	1,405,000	1,405,000	2,008,000

Table D-4. Commercial Detachable Chain Connecting Link.

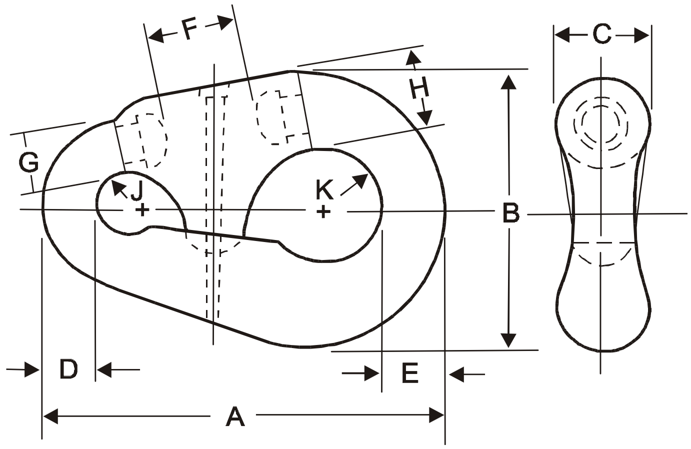


Chain Size Inches	Chain Size mm	A	B	C	D	E	F	Proof Test	Break Test	Weight per Link (lbs.)
3/4	19	4-1/2	3	1-3/64	3/4	27/32	1/2	67,500	91,100	2.1
13/16 - 7/8	21-22	5-1/4	3-1/2	1-7/32	7/8	63/64	19/32	88,200	119,000	3.4
15/16 - 1	24-25	5	4	1-25/64	1	1-1/8	21/32	116,110	156,700	5.1
1-1/16 - 1-1/8	27-28	6-3/4	4-1/2	1-9/16	1-1/8	1-17/64	47/64	145,000	195,000	7.2
1-3/16 - 1-1/4	30-32	7-1/2	5	1-47/64	1-1/4	1-13/32	13/16	178,200	240,600	9.9
1-5/16 - 1-3/8	33-34	8-1/4	5-1/2	1-29/32	1-3/8	1-35/64	29/32	211,500	285,500	13.3
1-7/16 - 1-1/2	36-38	9	6	2-5/64	1-1/2	1-11/16	83/84	252,000	340,200	17.3
1-9/16 - 1-5/8	40-42	9-3/4	6-1/2	2-1/4	1-5/8	1-63/64	1-1/16	292,500	395,000	22.0
1-11/16 - 1-3/4	43-44	10-1/2	7-1/2	2-7/16	1-3/4	2	1-3/16	352,000	476,000	27.5
1-13/16 - 1-7/8	46-48	11-1/4	7-1/4	2-1/2	1-7/8	2-5/32	1-1/4	285,000	432,000	32
1-15/16 - 2	50-51	12	7-3/4	2-1/2	2	2-5/16	1-5/16	322,000	488,000	36
2-1/16 - 2-1/8	52-54	12-3/4	8-1/4	2-21/32	2-1/8	2-1/2	1-13/32	362,000	548,000	44
2-3/16 - 2-1/4	56-58	13-1/2	8-23/32	2-13/16	2-1/4	2-5/8	1-1/2	403,000	610,000	52
2-5/16 - 2-3/8	59-60	14-1/4	9-7/32	3-1/16	2-3/8	2-3/4	1-9/16	447,000	675,000	61
2-9/16 - 2-5/8	66-67	15-3/4	10-3/16	3-1/4	2-5/8	3-1/16	1-3/4	540,000	813,000	82
2-11/16 - 2-3/4	68-70	16-1/2	10-13/16	3-11/16	2-7/8	3-1/4	1-13/16	649,000	981,000	100
2-13/16 - 2-7/8	71-73	17-1/4	11-1/8	3-19/32	2-7/8	3-11/32	1-29/32	640,000	965,000	107
2-15/16 - 3	75-76	18	11-5/8	3-3/4	3	3-17/72	1-31/32	693,000	1,045,000	120
3-1/16 - 3-1/8	78-79	18-3/4	12-1/8	4	3-1/8	3-5/8	2-3/64	748,000	1,128,000	138
3-3/16 - 3-1/4	81-83	19-1/2	12-5/8	4-1/16	3-1/4	3-5/8	2-5/32	804,100	1,210,000	161
3-5/16 - 3-3/8	84-86	20-1/4	13-3/32	4-7/32	3-3/8	3-15/16	2-1/4	862,200	1,296,000	177
3-7/16 - 3-1/2	87-89	21-1/8	13-25/32	4-13/16	3-3/4	4-1/8	2-13/32	1,080,000	1,700,000	205
3-9/16 - 3-5/8	90-92	21-3/4	14	4-9/16	3-5/8	4-3/16	2-5/16	1,021,100	1,566,000	215
3-11/16 - 3-3/4	94-95	22-1/2	14-1/2	4-11/16	3-3/4	4-11/16	2-7/16	1,120,000	1,750,000	256
3-11/16 - 3-7/8	97-98	23-1/4	15	5	3-7/8	4-1/2	2-5/8	1,205,000	1,863,400	271
3-17/16 - 4	100-102	24	15-1/2	5-3/16	4	4-5/8	2-11/16	1,298,000	1,966,000	288
4-1/8	105	24-3/4	16-1/2	5-7/8	4-1/8	5	2-25/32	1,347,000	2,062,500	384
4-1/4	108	25-1/2	17-3/8	6-1/2	4-3/8	5-1/4	2-7/8	1,393,700	2,134,000	422
4-3/8	111	26-1/4	18-3/8	7-1/4	4-1/2	5-5/8	2-15/16	1,569,700	2,398,000	460
4-1/2	114	27	19-3/8	8	4-5/8	6	3	1,672,000	2,508,000	500

All specifications in pounds and inches, unless otherwise stated.

See Figures D-2 and D-3 for hairpin locking details.

Table D-5. Commercial Detachable Anchor Connecting Link.

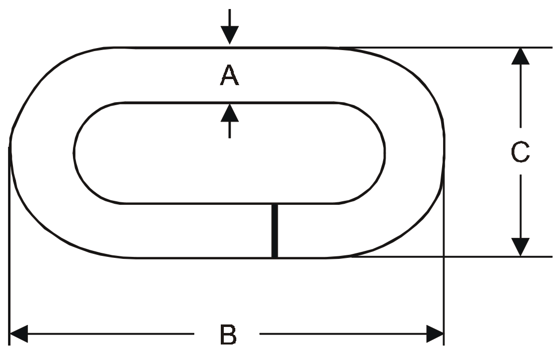


Small End Chain Size			A	B	C	D	E	F	G
No.	Inches	mm							
2	3/4 - 15/16	19-24	7-5/8	5-3/16	1-1/2	15/16	1-1/4	2-1/4	15/16
3	1 - 1-3/16	25-30	9-3/8	6-9/16	1-13/16	1-3/16	1-1/2	2-19/32	1-5/16
4	1-1/4 - 1-9/16	32-40	11-3/4	8-1/8	2-5/16	1-9/16	1-7/8	3-1/4	1-9/16 x 1-3/4
5	1-5/8 - 2	42-51	14-7/8	10-1/4	3	2	2-1/2	3-15/16	2-15/16 x 2-3/8
6	2-1/16 - 2-3/8	52-60	17-7/8	12-5/16	3-5/8	2-3/8	3	4-3/4	2-7/16 x 2-7/8
7	2-7/16 - 3-1/8	62-79	22-1/8	14-13/16	4-5/8	3-1/8	3-3/4	5-7/8	3-3/8 x 3-1/8
8	3-3/16 - 3-5/8	81-92	25-3/4	16-1/2	5-1/4	3-5/8	4-7/8	5-7/8	4-3/8 x 4
9	3-11/16 - 3-3/4	94-95	27-1/4	17-1/8	5-3/4	3-7/8	5-1/8	6-1/4	4-7/8 x 5-3/8
10	3-13/16 - 4	97-102	35	22-1/2	7-1/2	4-3/4	6-1/2	7-1/2	5-1/8
11	4-1/16 - 4-1/4	103-108	37	24	8	5	6-7/8	8	6-1/8

Small End Chain Size			H	J	K	Proof Test	Break Test	Weight per Link (lbs)
No.	Inches	mm						
2	3/4 - 15/16	19-24	1-3/8	21/32	1-3/16	74,000	113,500	7
3	1 - 1-3/16	25-30	1-3/4	3/4	1-3/8	118,000	179,500	14
4	1-1/4 - 1-9/16	32-40	2-7/32	1-1/32	1-11/16	200,500	302,500	28
5	1-5/8 - 2	42-51	2-29/32	1-1/4	2-1/16	322,000	488,000	60
6	2-1/16 - 2-3/8	52-60	3-15/32	1-15/32	2-17/32	447,000	675,000	107
7	2-7/16 - 3-1/8	62-79	4-3/8	1-29/32	3	748,000	1,128,000	208
8	3-3/16 - 3-5/8	81-92	5-1/8 x 5-1/4	2-1/8	3-1/8	1,021,000	1,566,000	328
9	3-11/16 - 3-3/4	94-95	5-9/16	2-1/4	3-1/4	1,120,000	1,750,000	520
10	3-13/16 - 4	97-102	7-1/8	2-7/8	4-1/4	1,298,000	1,996,500	850
11	4-1/16 - 4-1/4	103-108	7-7/8	3	4-3/8	1,440,000	2,220,000	920

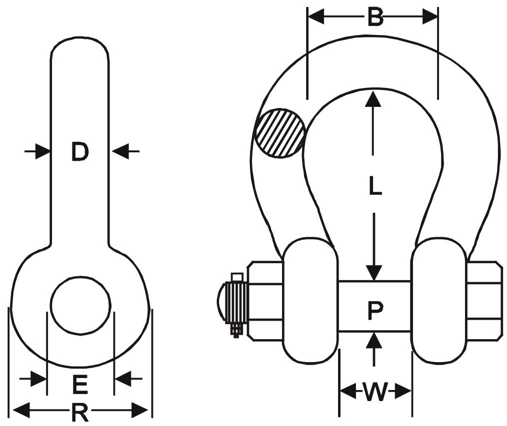
All specifications in pounds and inches, unless otherwise stated.
See Figures D-2 and D-3 for hairpin locking details.

Table D-6. Commercial End Link.



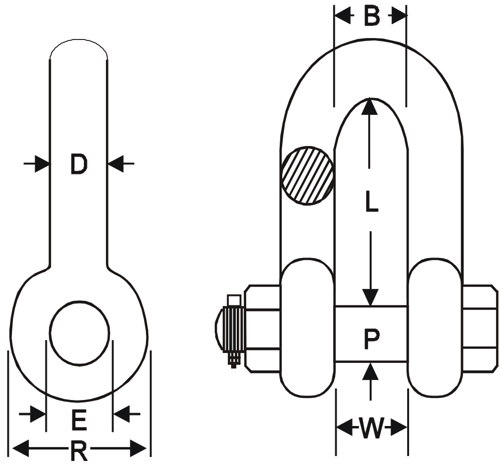
Chain Size Inches	Chain Size mm	Link Diameter (Inches) A	Link Length (Inches) B	Link Width (inches) C	Weight per Link (lbs)	Proof Test (lbs)
11/16 - 3/4	17-19	13/16	5-5/8	2-7/8	1.8	48,000
13/16 - 1	21-25	1-1/16	7-1/2	3-3/4	4.0	84,000
1-1/16 - 1-1/4	27-32	1-3/8	9-3/8	4-7/8	8.0	130,000
1-5/16 - 1-1/2	33-38	1-5/8	11-1/4	5-3/4	14.2	185,000
1-9/16 - 1-3/4	40-44	1-7/8	13	6-5/8	21.6	249,000
1-13/16 - 2	46-51	2-1/8	15	7-5/8	34.2	322,000
2-1/16 - 2-1/4	52-58	2-1/2	16-7/8	8-3/4	45.4	403,000
2-5/16 - 2-1/2	59-64	2-3/4	18-3/4	9-3/4	62.0	492,000
2-9/16 - 2-3/4	66-70	3	20-1/2	10-3/4	81.0	590,000
2-13/16 - 3	71-76	3-1/4	22-1/2	11-5/8	105.0	693,000
3-1/16 - 3-3/8	78-86	3-5/8	25-1/4	13	148.0	862,000
3-7/16 - 3-3/4	87-95	4	28	14-1/2	202.0	1,120,000
3-13/16 - 4	97-102	4-1/4	30	15-1/4	258.0	1,298,000

Table D-7. Type I, Class 3 Safety Anchor Shackle (MIL-S-24214A (SHIPS)).



Size (D) Minimum	Diameter Bolt (P) Minimum	Diameter Inside Eye (E) Maximum	Width between eyes (W)		Length inside (L)		Width Minimum (B)	Diameter Outside Eye (R) Maximum	Approx. Weight per 100 Shackles
			Nominal	Tolerance (+)	Nominal	Tolerance (+)			
Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Pounds
1/2	5/8	23/32	13/16	1/16	1-7/8	1/8	1-3/16	1-3/8	82
5/8	3/4	27/32	1-1/16	1/16	2-13/32	1/8	1-1/2	1-7/8	158
3/4	7/8	31/32	1-1/4	1/16	2-27/32	1/4	1-3/4	2-1/8	280
7/8	1	1-3/32	1-7/16	1/16	3-5/16	1/4	2	2-3/8	395
1	1-1/8	1-7/32	1-11/16	1/16	3-3/4	1/4	2-5/16	2-5/8	560
1-1/8	1-1/4	1-11/32	1-13/16	1/16	4-1/4	1/4	2-5/8	2-7/8	785
1-1/4	1-3/8	1-15/32	2-1/32	1/16	4-11/16	1/4	2-7/8	3-1/4	1,120
1-3/8	1-1/2	1-5/8	2-1/4	1/8	5-1/4	1/4	3-1/4	3-1/2	1,520
1-1/2	1-5/8	1-3/4	2-3/8	1/8	5-3/4	1/4	3-3/8	3-3/4	1,950
1-5/8	1-3/4	1-7/8	2-5/8	1/8	6-1/4	1/4	4	4-1/8	2,410
1-3/4	2	2-5/32	2-7/8	1/8	7	1/4	4-1/2	4-1/2	3,130
2	2-1/4	2-13/32	3-1/4	1/8	7-3/4	1/2	5-1/4	5-1/4	4,630
2-1/4	2-1/2	2-21/32	3-7/8	1/8	9-1/4	1/2	5-1/2	5-3/4	5,650
2-1/2	2-3/4	2-29/32	4-1/8	1/8	10-1/2	1/2	6-3/4	6-1/4	9,400
3	3-1/4	3-13/32	5	1/8	13	3/4	7-3/8	6-3/4	14,500
3-1/2	3-3/4	3-29/32	5-3/4	1/4	15	3/4	9	8-1/2	25,000
4	4-1/4	4-13/32	6-1/2	1/4	17	3/4	10-1/2	9-1/2	35,800

Table D-8. Type II, Class 3 Safety Chain Shackle (MIL-S-24214A(SHIPS)).

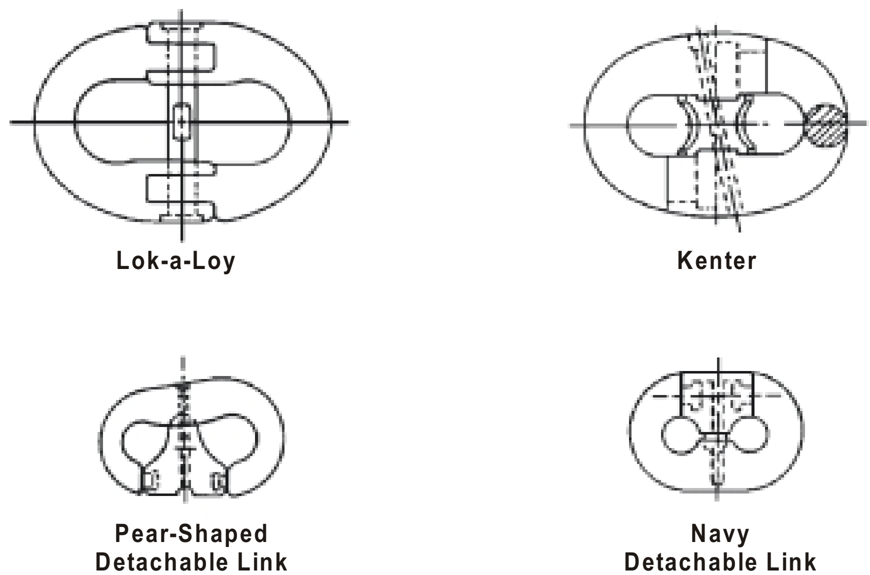


Size (D) Minimum	Diameter Bolt (P) Minimum	Diameter Inside Eye (E) Maximum	Width between eyes (W) Nominal	Width between eyes (W) Tolerance (+)	Length inside (L) Nominal	Length inside (L) Tolerance (+)	Diameter Outside Eye (R) Maximum	Approx. Weight per 100 Shackles
Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Pounds
1/2	5/8	23/32	13/16	1/16	1-5/8	1/8	1-3/8	76
5/8	3/4	27/32	1-1/16	1/16	2	1/8	1-7/8	156
3/4	7/8	31/32	1-1/4	1/16	2-3/8	1/4	2-1/8	262
7/8	1	1-3/32	1-7/16	1/16	2-13/16	1/4	2-3/8	365
1	1-1/8	1-7/32	1-11/16	1/16	3-3/16	1/4	2-5/8	535
1-1/8	1-1/4	1-11/32	1-13/16	1/16	3-9/16	1/4	2-7/8	727
1-1/4	1-3/8	1-15/32	2-1/32	1/16	3-15/16	1/4	3-1/4	1,020
1-3/8	1-1/2	1-5/8	2-1/4	1/8	4-7/16	1/4	3-1/2	1,335
1-1/2	1-5/8	1-3/4	2-3/8	1/8	4-7/8	1/4	3-3/4	1,850
1-5/8	1-3/4	1-7/8	2-5/8	1/8	5-1/4	1/4	4-1/8	2,310
1-3/4	2	2-5/32	2-7/8	1/8	5-3/4	1/4	4-1/2	2,850
2	2-1/4	2-13/32	3-1/4	1/8	6-3/4	1/2	5-1/4	4,110
2-1/2	2-3/4	2-29/32	4-1/8	1/8	8	1/2	6-1/4	8,450
3	3-1/4	3-13/32	5	1/8	9	3/4	6-3/4	12,300
3-1/2	3-3/4	3-29/32	5-3/4	1/4	10-1/2	3/4	8-1/2	21,800
4	4-1/4	4-13/32	6-1/2	1/4	12	3/4	9-1/2	31,000

See Table D-9 for shackle strengths.

Table D-9. Mechanical Properties of Shackles (FED SPEC RR-C-271D).

Size (D)	Working Load Limit		Proof Load (Minimum)		Breaking Load (Minimum)	
	Pounds		Pounds		Pounds	
Inches	Grade A	Grade B	Grade A	Grade B	Grade A	Grade B
3/16	650	1,000	1,430	2,200	3,250	5,000
1/4	1,000	1,500	2,200	3,300	5,000	7,500
5/16	1,500	2,500	3,300	5,500	7,500	12,500
3/8	2,000	4,000	4,400	8,800	10,000	20,000
7/16	3,000	5,200	6,600	11,440	15,000	26,000
1/2	4,000	6,600	8,800	14,520	20,000	33,000
9/16	5,000	8,000	11,000	17,600	25,000	40,000
5/8	6,500	10,000	14,300	22,000	32,500	50,000
3/4	9,500	14,000	20,900	30,800	47,500	70,000
7/8	13,000	19,000	28,600	41,00	65,000	95,000
1	17,000	25,000	37,400	55,000	85,000	125,000
1-1/8	19,000	30,000	41,800	66,000	95,000	150,000
1-1/4	24,000	36,000	52,800	79,200	120,000	180,000
1-3/8	27,000	42,000	59,400	92,400	135,000	210,000
1-1/2	34,000	60,000	74,800	132,000	170,000	300,000
1-5/8	40,000	70,000	88,000	154,000	200,000	350,000
1-3/4	50,000	80,000	110,000	176,000	250,000	400,000
2	70,000	100,000	154,000	220,000	350,000	500,000
2-1/4	80,000	120,000	176,000	264,000	400,000	600,000
2-1/2	110,000	160,000	242,000	352,000	550,000	800,000
2-3/4	120,000	180,000	264,000	396,000	600,000	900,000
3	170,000	220,000	374,000	484,000	850,000	1,100,000
3-1/2	240,000	280,000	528,000	616,000	1,200,000	1,400,000
4	300,000	350,000	660,000	770,000	1,500,000	1,750,000



NOTE

See Figures D-2 and D-3 for Navy detachable locking hairpin details.

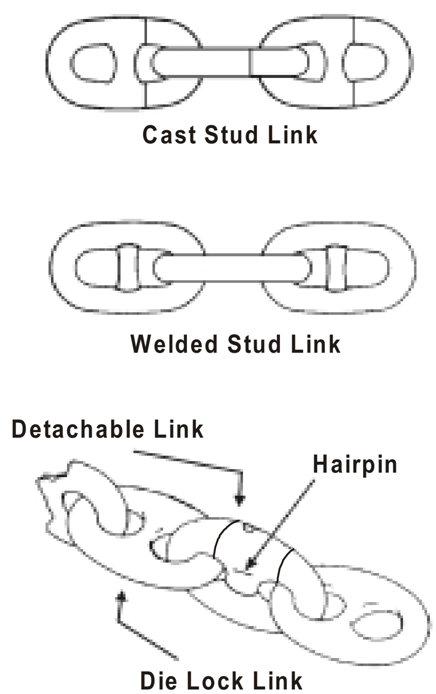
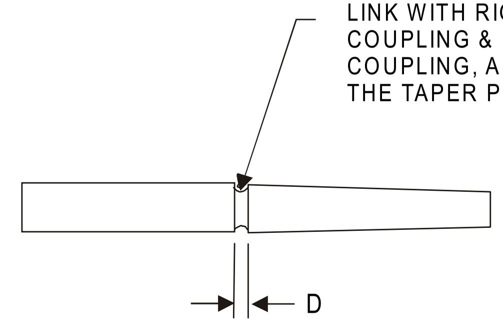


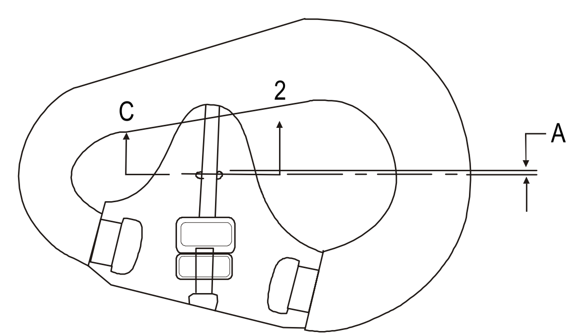
Figure D-1. Types of Chains and Connecting Links.

NOTES

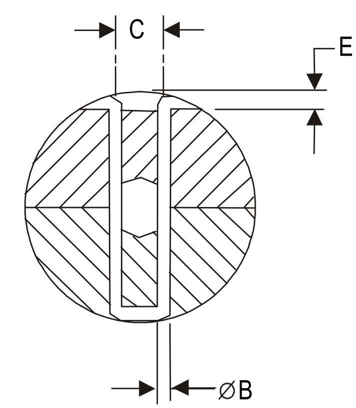
1. INSTRUCTIONS FOR GROOVING
   A. REPLACEMENT TAPER PIN:
      A. AFTER INSPECTING AND CLEANING DETACHABLE LINK, INSTALL TAPER PIN WHICH HAS BEEN WIPED WITH OIL.
      B. DRIVE TAPER PIN DOWN TIGHT USING A HAMMER & ASSEMBLING PUNCH.
      C. USING A DRILL 1/32-INCH LESS IN SIZE THAN THE HAIR-PIN DIAMETER, DRILL MARK THE TAPER PIN THROUGH ONE OF THE HAIRPIN HOLES IN THE DETACHABLE LINK.
      D. DRIVE OUT TAPER PIN USING HAMMER & DISASSEMBLNG PUNCH. MACHINE THE GROOVE AT DRILL MARK TO THE DIMENSIONS SPECIFIED IN CHART BELOW.



TAPER PIN



DETACHABLE LINK



SECTION C-2
SECTION VIEW SHOWN WITH LINK FULLY ASSEMBLED

LINK SIZE	"A"	"ØB"	"C"	"D"	"E"
3/4 HS 7/8 HRS	.12	.09	.366	.109	.12
1 HS 1 1/8 HS	.15	.12	.438	.140	.15
1 1/4 HS 1 1/2 HS	.18	.15	.630	.171	.18
1 5/8 HS 1 3/4 HS 2	.28	.25	.768	.265	.28
2 1/8 - 2 2 3/8	.28	.25	1.082	.265	.28
2 1/2 - 3 1/8 2 3/4 HD 3HD	.34	.31	1.076	.327	.34
3 1/4 - 3 1/2 3 1/2 HD	.34	.31	1.346	.327	.34

Figure D-2. Detachable Link with Identifying Marks for Assembly.

NOTES

1. INSTRUCTIONS FOR GROOVING
   A. REPLACEMENT TAPER PIN:
      A. AFTER INSPECTING AND CLEANING DETACHABLE LINK, INSTALL TAPER PIN WHICH HAS BEEN WIPED WITH OIL.
      B. DRIVE TAPER PIN DOWN TIGHT USING A HAMMER & ASSEMBLING PUNCH.
      C. USING A DRILL 1/32-INCH LESS IN SIZE THAN THE HAIR-PIN DIAMETER, DRILL MARK THE TAPER PIN THROUGH ONE OF THE HAIRPIN HOLES IN THE DETACHABLE LINK.
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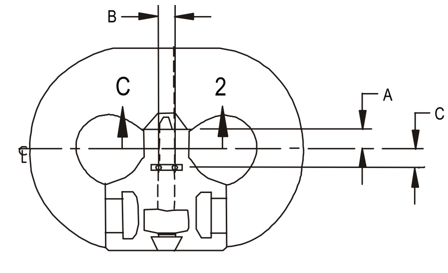
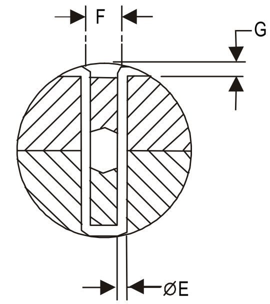
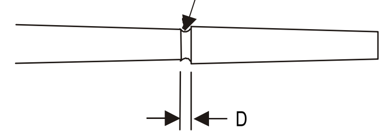


DETACHABLE LINK



SECTION C-2
SECTION VIEW SHOWN WITH LINK FULLY ASSEMBLED

GROOVE FOR HAIRPIN TO BE LOCATED AFTER ASSEMBLING LINK WITH RIGHT-HAND COUPLING & LEFT-HAND COUPLING, AND DRIVING THE TAPER PIN DOWN TIGHT.



TAPER PIN

LINK SIZE	“A”	“B”	“C”	“D”	“ØE”	“F”	“G”
3/4	1/4	19/64	9/32	3/32	1/16	15/64	3/32
7/8	19/64	5/16	5/16	1/8	3/32	7/32	1/8
1	11/32	3/8	3/8	1/8	3/32	9/32	1/8
1 1/8	3/8	7/16	11/32	1/8	3/32	11/32	1/8
1 1/4	27/64	15/32	15/32	5/32	1/8	11/32	5/32
1 3/8	15/32	33/64	33/64	5/32	1/8	25/64	5/32
1 1/2	1/2	37/64	9/16	5/32	1/8	29/64	5/32
1 5/8	35/64	39/64	39/64	5/32	1/8	31/64	5/32
1 3/4	19/32	41/64	5/8	7/32	3/16	29/64	7/32
1 7/8	11/16	45/64	11/16	3/16	5/32	35/64	3/16
2	3/4	49/64	3/4	7/32	3/16	37/64	7/32
2 1/8	13/16	13/16	13/16	1/4	7/32	19/32	1/4
2 1/4	7/8	7/8	7/8	1/4	7/32	21/32	1/4
2 3/8	29/32	7/8	7/8	9/32	1/4	5/8	9/32
2 1/2	15/16	7/8	7/8	9/32	1/4	5/8	9/32
2 5/8	1	1	1	5/16	9/32	23/32	5/16
2 3/4	27/32	1 1/16	1 1/32	11/32	5/16	3/4	11/32
2 3/4 HD	1	1 3/64	1 3/32	11/32	5/16	47/64	11/32
2 7/8	1 1/16	1 3/32	1 3/32	11/32	5/16	25/32	11/32
3	1 1/8	1 9/64	1 1/8	11/32	5/16	53/64	11/32
3 HD	1 1/8	1 1/8	1 1/8	11/32	5/16	13/16	11/32
3 1/8	1 5/32	1 11/64	1 3/16	3/8	11/32	53/64	3/8
3 1/4	1 7/32	1 7/32	1 7/32	13/32	3/8	27/32	13/32
3 3/8	1 5/16	1 11/32	1 5/16	13/32	3/8	31/32	13/32
3 1/2	1 11/32	1 13/32	1 5/16	13/32	3/8	1 1/32	13/32
3 1/2 HD	1 1/2	1 13/32	1 3/8	13/32	3/8	1 1/32	13/32
3 5/8							
3 3/4	1 13/32	1 15/32	1 3/8	13/32	3/8	1 3/32	13/32
3 7/8							
4							
4 3/4	1 13/16	1 7/8	1 13/16	17/32	1/2	1 3/8	17/32

Figure D-3. Typical Method for Modifying Detachable Chain Connecting Links for Hairpin Installation.

Appendix E

STOPPERS

E-1 Introduction

The term "stopper," as used in seamanship, describes a device or rigging arrangement that is used to temporarily hold a part of running rigging or ground tackle that may come under tension. The stopper is an indispensable tool in a towing operation.

WARNING

Never pass a stopper on a tension member that is under a strain greater than the safe working load of the stopper, or on a tension member that might be subjected to a heavier loading condition while the stopper is in place.

E-2 Types of Stoppers

There are many types of stoppers and methods of attaching them to the tension members. There is no single "best" type of stopper for all situations. For the three basic types of tension members—chain, fiber line, and wire rope—the following stoppers are recommended:

- **Chain.** The attachment to the tension member should be made by means of a suitably sized, jaw-type chain stopper (see Figure 4-18).
- **Fiber Line.** Fiber line always should be stopped off with fiber stoppers.
- **Wire Rope.** Wire rope should be stopped off with a carpenter stopper See Figure 4-19), Klein grip, chain, or fiber stopper using Kevlar.

Most stoppers cannot be released under load and require the held line to be heaved in to slack the stopper and allow its removal. Some stoppers, however, such as the pelican hook and carpenter stopper, can be released when under load. In some cases, it may be possible to use a combination of two stoppers to achieve this capability, for example, attaching a pelican hook to a fiber stopper (the fiber stopper holds the line and the pelican hook holds the stopper, allowing a quick release.)

E-3 Prevention of Damage

When passing a stopper, prevention of damage to the tension member is a major consideration, second only to safety of personnel. If the hawser is damaged, the towing ship is essentially out of action. Properly using a stopper on a towing hawser entails considerably more than merely passing the stopper. It requires very close coordination between the Conning Officer on the bridge and the Boatswain's Mate in charge of passing the stopper on the fantail.

During the period when the stopper is in use on the towing hawser or pendant, the Conning Officer should not increase speed or radically change course without first notifying the afterdeck and reaching concurrence with the Afterdeck Supervisor that it is safe to do so. Direct communication between the deck work area and the bridge is mandatory. The Conning Officer should also be well versed in the use of stoppers, especially concerning their applications and limitations.

E-4 Stopping Off a Wire Towing Hawser

If possible, a properly fitted carpenter stopper should always be used when stopping off a wire rope towing hawser. See NAVSHIPS 0994-004-8010 *Carpenter Stopper, Operation and Maintenance Instruction* (Ref. AD).

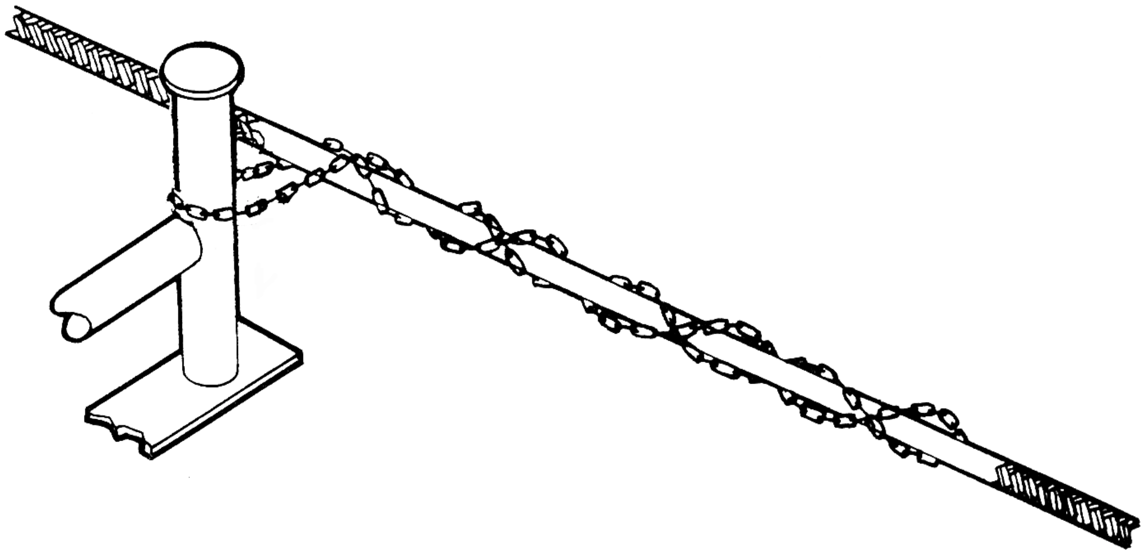


Figure E-1. Crisscross Chain Stopper.

In a situation where a carpenter stopper is not readily available, the hawser can be stopped off with a chain. If using a chain stopper, be very careful not to damage the hawser (see Figure E-1).

E-5 Synthetic Line

In recent years, synthetic fiber line has replaced virtually all large natural fiber line in the Navy. Synthetic fiber has many good qualities, such as its superior strength and elasticity. Its prime weakness, however, is its susceptibility to physical damage. It is very easily cut by sharp objects, melted by friction, and abraded by rough surfaces. All three types of damage can occur from the action of a poorly passed stopper.

When stopping off a synthetic towing hawser, a synthetic fiber stopper should always be used.

E-6 Stopper Breaking Strength

Ideally, the strength of the passed stopper would be equal to or greater than the strength of the tension member, thus eliminating the stopper as the weak

link in the system. This condition is easy to achieve when stopping off relatively small lines such as fiber boat falls.

The prime factor limiting breaking strength of a large stopper is the physical size that can be handled manually by the deck seaman. A stopper of ½-inch chain can be passed fairly easily and one of ¾-inch chain can be passed with some difficulty. If, however, one were to try to match the breaking strength of a large towing hawser of 2- to 2½-inch wire, a stopper of 1½-inch or 2-inch chain would be required. From an engineering point of view the numbers would match up, but the seaman would be faced with an impossible task.

In cases of heavy rigging, the stopper often becomes the weak link. Thus, all personnel

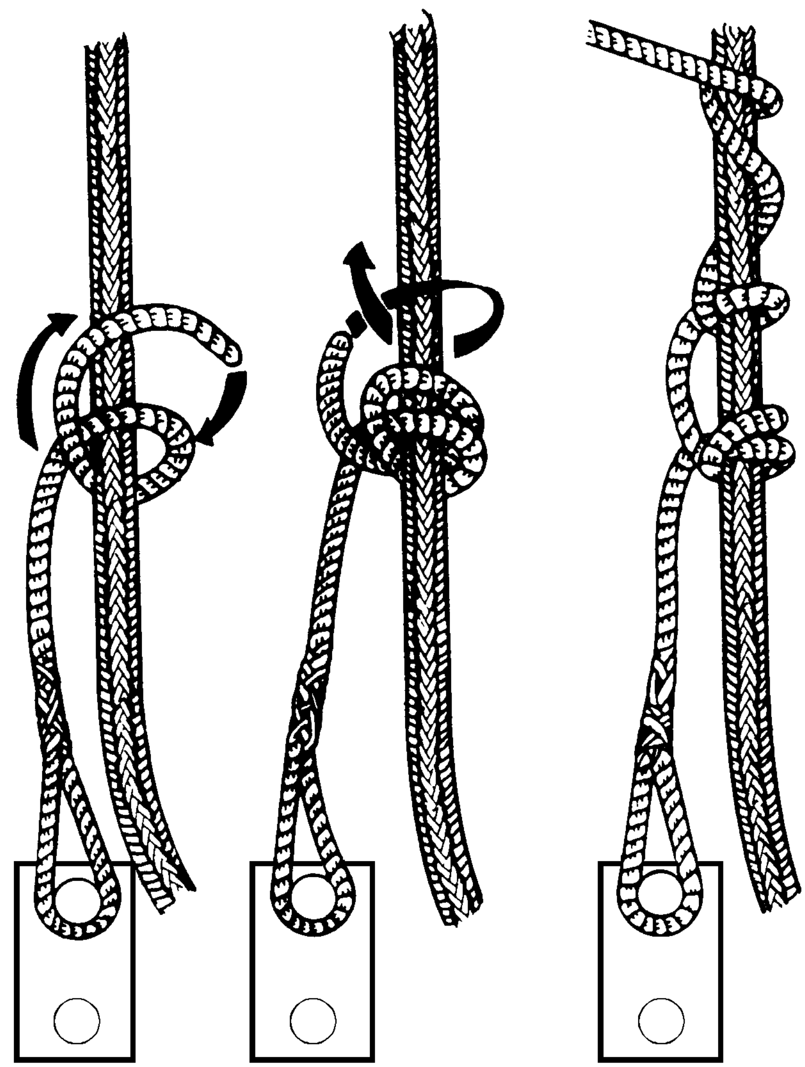


Figure E-2. Typical Stopper.

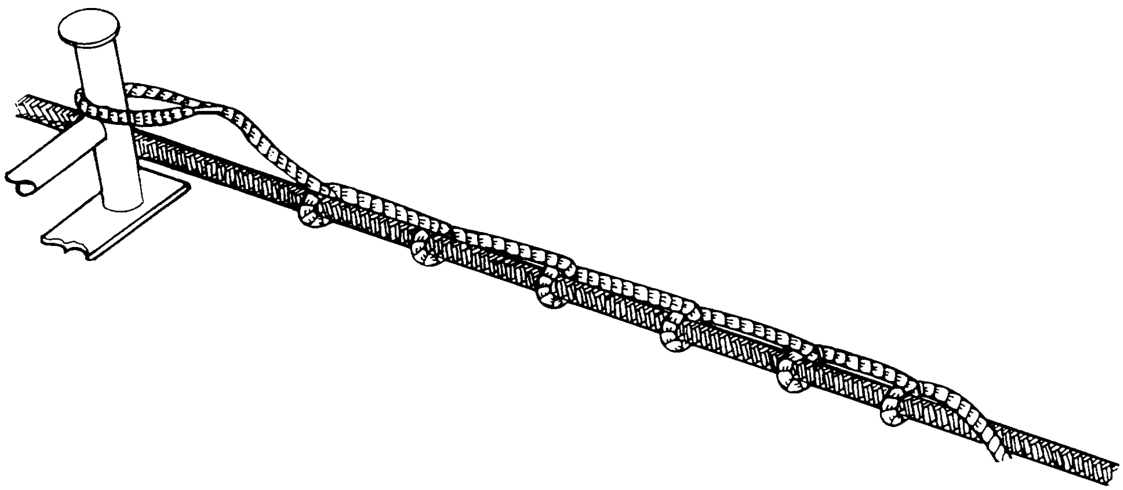


Figure E-3. Half Hitches.

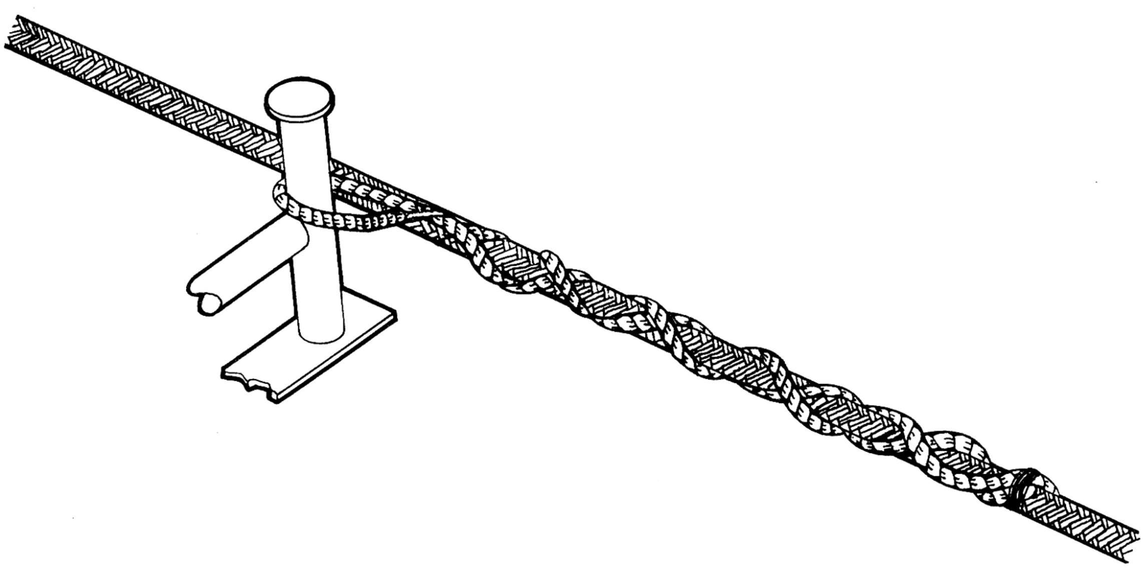


Figure E-4. Crisscross Fiber Stopper.

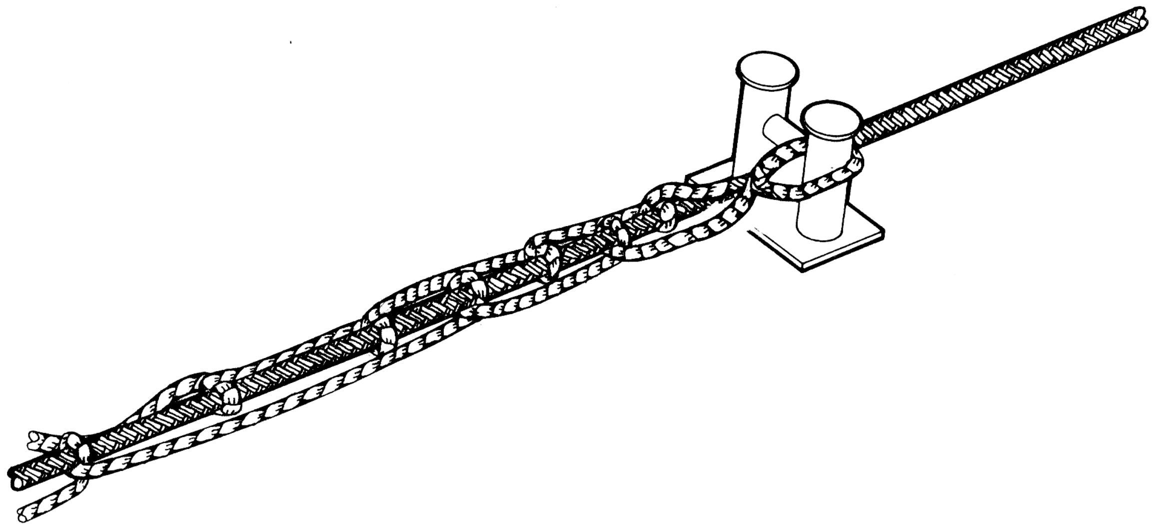


Figure E-5. Double Half-Hitch Stopper.

who are involved in the towing hawser/stopper passing procedure must be aware of inherent dangers.

E-7 Fiber Stoppers

Fiber stoppers are the simplest and most commonly used type of stopper (see Figures E-2 through E-5). One version, called a rat tail stopper, is merely a length of fiber line with an eye in one end and the section of the stopper that makes contact with the tension member flattened. When using a three-strand line, a section is flattened by passing a seizing, unlaying the line, and then weaving the line back together in a three-strand braid. In the case of double-braided line, slip the cover back and remove a section of the core to flatten the stopper.

Stoppers made of Kevlar are now available and are acceptable for use on fiber line.

E-8 Stopper Hitches

A number of methods can be used to attach the stopper to the tension member:

- A rolling hitch backed up with half hitches (see Figure E-2)
- A long series of half hitches, known as a crossover or Chinese stopper (see Figure E-3)
- A series of crisscrosses formed by weaving the stoppers over and under the tension member—this is the most preferred method (see Figures E-1 and E-4)
- Two long series of half hitches formed by half hitching a double stopper to the hawser (see Figure E-5)
- Any desired number or combination of the above.

Again, there is no universal "best" stopper hitch. The decision about which hitch arrangement to use depends on the size and composition of the line to be stopped, the size and composition of the stoppers available, and the judgment of the Boatswain's Mate in charge.

E-9 Securing the Passed Stopper

When securing a passed stopper to a part of relatively small, low-tension rigging, such as a boat fall, the end of the stopper is usually held in place by hand. To secure a passed stopper to a large tension member, such as a towing hawser, the ends of the stopper should be securely seized to the hawser with small stuff.

E-10 Setting the Stopper

Once the stopper is in place and all personnel are safely out of the way, the tension member should be very slowly and carefully eased out.

This should continue until a determination can be made as to whether the stopper is holding or not. This critical determination is normally made by the Boatswain's Mate.

If the stopper is slipping, or shows any indication that it might slip, the stopper should be removed and reattached.

- The Conning Officer must be made aware of any overloading of a towing hawser stopper so that corrective action is taken, such as easing the tension by slowing or stopping the ship.

E-11 Releasing the Stopper

WARNING
Releasing a stopper under load can cause shock loading in the stopped line. Personnel should be kept clear of any potential snapback.

WARNING
Carpenter stoppers, once set, may retain tension even after wire is slacked. These stoppers should always be opened carefully.

Some stoppers, such as the carpenter stopper, chain stopper, and pelican hook, are designed to be released under tension. These devices all have hinge-type grabs that can be released by striking a pin with a sledge. This pin does not see full line tension and can be removed under load.

Fiber stoppers and stopper hitches cannot be released under load except by cutting. This is not recommended except in an emergency. (It may be prudent to rig a block of wood as a striking surface so the stopper may be cut with a fire axe instead of a knife. This should be done prior to setting the stopper.)

- Normal release of stoppers should be under no tension. The stopped line should be heaved in to allow the stopper to be slacked. The stopper can then be removed safely by personnel. This method is recommended for all stoppers, including quick release types.

Appendix F

TOWING HAWSER LOG

F-1 Introduction

The purpose of this appendix is to establish the requirement for towing ships to keep a Towing Hawser Log. Entries in this log are critical when evaluating past hawser usage, evaluating the present condition of the hawser, and making decisions concerning replacement. The log provides the Commanding Officer with a documented reference to use when determining the readiness of the hawser. Since the condition of the hawser may not be apparent, even to the experienced operator, the record of usage can be a decisive factor in evaluating operational readiness and overall system safety. This appendix replaces the NAVSEAINST 4740 series regarding hawser logs.

F-2 Background

Historically, fewer towline component failures have occurred on ships where close attention has been paid to the condition and history of the hawser and other tensile components of the towline. Life of towline components depends less on age than on care and use. Fiber lines of all types, including natural and synthetic fiber, deteriorate with age, exposure, and usage. The fiber core in wire ropes, particularly if it is natural fiber, also deteriorates with age. Old wires with no documentation should be treated with suspicion.

F-3 Discussion

In some instances when hawsers and other components have failed, it was impossible to ascertain usage, manufacture, and installation data because a log had not been kept. This lack of data precluded a meaningful analysis of the failure.

NSTM CH-613 (Ref. F) describes the fabrication, conditions of use, care, and preservation of wire rope, fiber rope, and cordage. In addition, the *Wire Rope Users' Manual* (Ref. C) and handbooks and catalogs published by major wire and rope manufacturers are useful.

Keeping a hawser log is mandatory for all towing ships. Selection and identification of other components that should be similarly logged and administered is left to the discretion of the Commanding Officer. Ships may also find it beneficial to keep a similar log on mooring lines. Salvage ships may also find it prudent to keep logs on beach gear components, chain, and connecting hardware.

F-4 Log

Salvage ships, fleet tugs, and surface ships carrying emergency towing hawsers and engaging in tow-and-betowed operations shall maintain a Towing Hawser Log in the format of Attachment A to this appendix. Ships may also keep similar logs on other towline components.

The log shall record a comprehensive history of all towing hawsers on the ship, including the main wire rope hawser, all synthetic hawsers, and target towing hawsers.

It is the responsibility of the command to maintain the log. Periodic review is mandatory. Type Commanders should include the requirement for keeping hawser logs as a check-off item in their Operational Readiness and Administrative Inspection Lists.

F-5 Failures

Ships experiencing failure of hawsers and other logged towline components should advise NAVSEA (Attention SEA 00C and SEA 03P8) and provide details that can be used for technical evaluation.

Whenever a hawser or other logged component breaks under suspicious conditions, save the broken ends and at least twelve feet of good rope (or three links in the case of chain) on each side of the break. Serve the broken ends to prevent unlaying of fiber line or oil them to prevent corrosion of wire rope. Log and describe details of the break. Save fragments and pieces for analysis. Also record names of any witnesses to the failure. If the break occurs in the vicinity of an end fitting, the end fitting also should be sent for test and evaluation, with the broken end wrapped in plastic.

Attachment A to Appendix F

Towing Hawser Log

1. The Towing Hawser Log is used to record data about both wire rope and fiber line hawsers. It may be used to record data about other towline components as well. The Towing Hawser Log should be kept in a standard record book. A separate book or separate section of the same book should be kept for each component.

2. The log for any towing hawser or other component consists of three parts: New Rope Entry, Operations Entry, and Post-Operations Entry.

NOTE
When measuring any rope length and identifying (mapping) a spot along the hawser, always measure back from the original outboard end. Do the same if hawser is end-for-ended, but carefully measure the entire length when end-for-ending and precisely log the conversion technique to be used in subsequent mapping. If the hawser is shortened to install a new end fitting, use the original measuring system; that is, measure as if it were still all there, but make a note in the comments section that the hawser has been shortened for installation of a new end fitting.

PART A: New Rope (Hawser or Component) Entry

Record data as follows:

1. Date and place of installation.

2. Identification of installer (ship's force, yard, etc.).

3. Method of installation. For example, was the line put on drum under back tension? If so, what was tension? How was tension applied? If not applied, what was done to ensure a tight spool?

4. Comprehensive description of new item. For wire rope and fiber line, include material (such as IPS, EIPS, or stainless for wire; nylon or polyester for fiber); size (rope diameter for wire; circumference for fiber line), and breaking strength. Ensure that the Federal Stock Number and any other specifications are included.

5. Details of line construction as found on tag attached or tacked onto shipping reel. Include the actual tag in log if possible, or attach a photocopy.

6. Manufacturer of rope or line (obtain from tag or shipping reel).

7. Date of manufacture of basic rope/line/chain. Also include dates of any rigging loft work.

8. Source of rope (such as NSC or private supplier).

9. Details of end fittings at both ends. Provide details of splices and servings for synthetic hawsers and springs. Include photos.
10. Record any other observations of the hawser or component, such as degree of lubrication, level of rust, discoloration, or other damage. Include observations from internal inspection of rope or line.

PART B: Operations Entry

Record for every employment of the hawser or component:

1. Description of the basic employment, for example, towing an FFG or hauling on a wreck.
2. Duration of use (days/hours).
3. Scope of tow hawser used (if varied, cite maximum and minimum scopes).
4. Maximum strains experienced by hawser or component. This may come from towing machine or other strain measuring instrumentation. Include notations of weather on trip.
5. A map and complete description of all chafe, bearing or nip points and any chafing gear used. Include photos when practical.
6. Description of use of carpenter stopper, chain stopper or other hardware on rope. For example, where was stopper placed on rope (lengthwise)?
7. For fiber line hawsers, include a description of how it was secured on towing vessel: for example, wrapped around main traction sheave/drum, stopped on the H-bitts, etc.
8. Minimum depth of water traversed. For example, did hawser drag bottom?
9. If hawser was passed to a wreck, include a description of how it was passed. Was the hawser floated or dragged across the bottom? If the hawser was dragged, how far was it dragged, and across what type of bottom was it dragged?
10. Other experiences of note, for example surging against hawser/components or fouling on rocks or ship's appendages.
11. Between-use maintenance: type of lubricant applied, how applied, and by whom applied.
12. Respooling method (as listed in Part A-3).

PART C: Post-Operations Entry

Record after every use:

1. Specific inspection of hawser for wear points such as carpenter or chain stopper wear points, caprail/nipping chafe area, shock bearing points, sheaves and fairleads, and so forth. Include photographs.
2. Quantification of wear:
    a. *General and wire rope.* Include count of "fish hooks" and record and identify (map) spots. Count fish hooks per strand lay. Count all broken wires, not just those that protrude from

the rope. Record maximum number of broken wires per lay (total) and maximum number of broken wires per strand lay. Include information on any "birdcaging," kinking, broken surface wires, and surface wire flattening. Indicate surface corrosion. Include photographs. Record and map any instance of burying. Periodic inspection/maintenance of hawser or components, which includes opening the lays and internal inspection, need not be performed after every employment, but when undertaken, it should be logged. When lubrication is performed, carefully log stock number and manufacturer's data on lubricant as well as who performed the maintenance and inspection.

b. *Fiber line.* Include information on surface chafing and abrasion wear, kinking, or any other visible damage. Include photographs.

c. *Chain.* Pay particular attention to the link bearing points (the "grip" area). Pay special attention to places along the chain where it passed through or bore against chocks or fairleads. In these latter places a straight edge should be laid against the flat face of the link to ensure that the link is not bent in this plane. Any bending is to be reported as failure and requires replacement.

d. *Joining links and shackles of all kinds.* Inspect the mechanical joints and screw threads. In the case of safety shackles, measure the mortise to ensure that the bow is not sprung. If sprung, dispose of the shackle. Ensure that all detachable link pieces have serial numbers and are matched in sets. Ensure also that the hairpins fit snugly.

3. General comments. Include as a minimum a general post-f observation of hawser, component, and end fitting.

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Appendix G

CALCULATING STEADY STATE TOWLINE TENSION

This appendix provides a method for calculating the towing resistance of various ships and craft. The data required to calculate resistance for self-propelled ships, dry docks, and barges come from different sources; therefore, each category is discussed separately.

Calculating tow resistance is often an iterative process. Starting with the ship or craft to be towed, resistance is usually computed for several assumed towing speeds and for different wind and sea conditions. The resulting values are then compared to the capabilities of available tugs.

Next, the towing connection elements (bridles, chain pendants, etc.) are selected, towing hawser length determined, catenary checked, and towline hydrodynamic resistance estimated. This process may result in a towing ship pull requirement or total hawser tension that will require an adjustment to the assumed tow speed.

G-1 Self-Propelled Surface Ships

The following method combines hull, propeller, wind, and sea state resistances into one calculation for determination of the total tow resistance of a ship. Methods for calculating the resistance of the towline are discussed in Chapter 3 (see Section 3-4.1.2 and Table 3-1). Use Table G-1 as a worksheet for determining tow resistance, following the step-by-step procedures below.

NOTE

The coefficients used to calculate resistance account for unit conversion. If recommended units are used, these equations will yield resistance in pounds.

Use Table G-2 for Items 4 Through 9

Item 1

Identify the ship class under consideration, or select a class as close as possible.

Item 2

Select tow speed (V_{TOW}), in knots.

Item 3

Select tow course, in degrees.

Item 4

List the displacement in long tons (Δ). If the ship is known to be lighter than full load, adjust the full load figures from the table accordingly.

Item 5

List frontal windage area (A_T) in square feet. Estimate this number for ships not listed. Ships at lighter than full load condition will have increased windage area than that listed in Table G-2.

Item 6

List wind drag coefficient (C_W).

Item 7

List projected area of all propellers (A_P) in square feet. This value assumes that propellers are locked. If propellers are trailing, reduce this value by one-half. If propellers have been removed, use a value of zero.

Item 8

List the curve number for hull resistance. (See Section G-1.1.)

Item 9

List curve number for sea state resistance. (See Section G-1.2.)

Item 10

The expected sustained wind speed should be used when calculating towline tensions. The estimate should be conservative and should account for anticipated changes in weather.

Item 11

With the aid of Table , determine the Beaufort wind force number. This number is based on expected or measured wind velocity or observation of the sea state (Item 10).

Item 12

List relative wind speed (V_R) in knots. (If unknown, assume worst condition, that is, tow speed plus true wind speed.)

Item 13

Select a heading coefficient (K). If the relative wind is dead ahead, use 1.0. If the relative wind is 15 to 45 degrees off the bow, use 1.2. For 45 to 90 degrees relative wind, use 0.4. There is higher wind resistance to ahead movement when the wind is slightly off the bow than when directly ahead, because of the larger ship area presented to the wind. As the wind veers farther aft, however, the wind effect on the ahead direction falls off faster than the increase of the area presented to the wind. (See Section G-1.3 for additional guidance.)

Item 14

Calculate the wind resistance (R_W) by multiplying 0.00506 by the frontal windage area (item 5) by the wind drag coefficient (item 6) by the relative wind speed (item 12) squared by the heading coefficient (item 13). (See Section G-1.3).

$R_W = 0.00506 \text{ x } (A_T) \text{ x } (C_W) \text{ x } (V_R)^2 \text{ x } (K)$

Item 15

In Figure G-6, locate the curve identified in item 8 and compare it to the tow speed (item 2). The point where these two values intersect is the value for $R_{H/\Delta}$. (See Section G-1.1.)

Item 16

Calculate the hull resistance (R_H) by multiplying 1.25 by $R_{H/\Delta}$ (item 15) by the displacement (item 4). (The factor 1.25 accounts for hull roughness and other variables).

$R_H = 1.25 \text{ x } (R_{H/\Delta}) \text{ x } (\Delta)$

Item 17

In Figure G-7, locate the curve identified in item 9 and compare it to the Beaufort wind force number identified in item 11. The point where these two values intersect is the sea state resistance (R_S). (See Section G-1.2.)

Item 18

Calculate the propeller resistance (R_P) by multiplying 3.737 by the projected area of the propellers (item 7) by the tow speed (item 2) squared. (See Section G-1.4.)

$R_P = 3.737 \text{ x } (A_P) \text{ x } (V_{TOW})^2$

Item 19

Calculate the total steady-state tow resistance (R_T) by adding the four resistance values (items 14, 16, 17, and 18).

$R_T = R_W + R_H + R_S + R_P$

Item 20

Using Table 3-1, estimate the hydrodynamic resistance of the towline (R_{WIRE}). If the size of the tow hawser is not yet determined, estimate the towline resistance to be 10 percent of the tow resistance (item 19).

Item 21

To calculate horizontal tow hawser tension, add the tow resistance (item 19) to the tow hawser resistance (item 20).

$R = R_T + R_{WIRE}$

Figures G-1 through G-4 contain sample calculations.

G-1.1 Hull Resistance Curves

Hull resistance curves are plotted on a per-ton-displacement basis. Thus they are applicable to similar hull shapes. Hull shapes are largely influenced by speed/length ratio:

$$\frac{V}{\sqrt{L}}$$

Assume that it is necessary to estimate the towing resistance of a large tanker with the following design characteristics:

Displacement:	110,000 long tons
Length:	850 feet
Speed:	15 knots
Speed/length ratio	0.51

NAVSEA 00C can provide assistance in locating a hull of similar dimensions. In this case, the T-AGM 20 is similar; with a speed of 14 knots, a length of 595 feet and, therefore, a speed/length ratio of 0.57. This is close enough for the purpose intended. In Figure G-6, use curve 5 (from Table G-2) for the T-AGM 20 at the assumed tow speed and read resistance *per ton*. For instance, at 6 knots, read 0.75 lbs. resistance per ton. If the tanker is at full load, its hull resistance is 1.25 x 0.75 x 110,000 = 103,125 lbs. Even without estimating propeller, wind, or sea state resistance, it is apparent from Figure 6-1 that towing this ship at this speed is impractical for Navy tow ships except the T-ATF. While working on curve 5, it will save time to also compute the smooth hull resistances for 5, 4, and 3 knots as well, for future use. The resulting smooth hull resistance values are 66,000, 42,600 and 20,600 pounds, respectively.

G-1.2 Additional Resistance Due to Waves

Note that there is no method provided for estimating the effect of other than head seas. Under the more usual sea conditions where the tug has total freedom in course-setting, the effect of the waves on the tow and tug is modest. Under the more strenuous cases, the tug will have to set a course into the seas to maintain stability as well as to relieve dynamic effects on the hawser. It is unlikely that the tug will be able to take advantage of following seas under the more strenuous cases.

For the larger ships (represented by curves 2 and 3 in Figure G-6), the added resistance is significant at the higher sea states. Under these conditions, however, the tug itself may experience difficulty and may simply have to reduce power to maintain steerageway. Speed over the ground of the tug and tow may well be sternward in this case, and is perfectly appropriate.

Note 1: The method of estimating the added resistance from waves at certain tow speeds is not well developed. The data presented here are developed from stationary (anchored) theory and include no correction for tow course or speed. From the shape of the curves, it can be seen that there is little effect in seas up to State 4 or 5. The added resistance increases rapidly in heavier seas, which usually require the tow to head into the seas. Furthermore, the effect of the additional speed of the tow is small compared to the speed of the seas in this case and can be ignored. Therefore, the amount of error introduced by assuming head seas and neglecting tow speed is small, and, in any event, provides a conservative answer for most tow courses.

Following wind and seas will reduce the tow resistance. However, the dynamic effects of ship motions on the tow hawser may preclude towing downwind under strenuous sea conditions (see Appendix M). Likewise, stability of

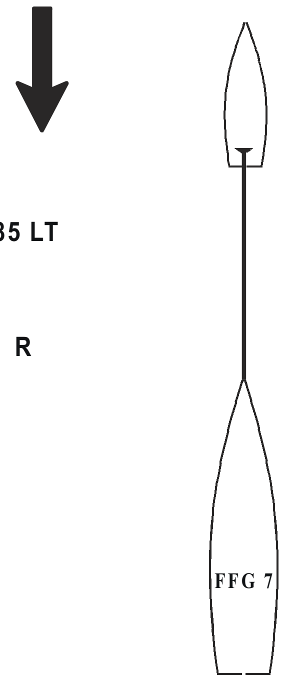
Table G-1. Calculation of Steady State Towing Resistance.

SHIP: ______________________ CALCS BY: ______________________

Item	Description	Symbol	Units	Source			
1	Ship Class (AE, CV, etc.)						
2	Tow Speed	V_{TOW}	Knots				
3	Tow Course	γ	Degrees				
4	Tow Displacement	Δ	Long tons	Table G-2			
5	Frontal Windage Area	A_T	Sq. feet	Table G-2			
6	Wind Drag Coefficient	C_W		Table G-2			
7	Total Projected Area of Propellers	A_P	Sq. feet	Table G-2			
8	Curve Number for Hull Resistance			Table G-2			
9	Curve Number for Sea State Resistance			Table G-2			
10	True Wind Speed	V_{wind}	Knots				
11	Beaufort Number			Table G-3			
12	Relative Wind Speed	V_R	Knots				
13	Heading Coefficient	K		Section G-1			
14	Wind Resistance	R_W	Pounds	$R_W = 0.00506(A_T)(C_W)(V_R)^2(K)$			
15	Resistance Factor	$R_{H/\Delta}$		Figure G-6			
16	Hull Resistance	R_H	Pounds	$R_H = 1.25(R_{H/\Delta})(\Delta)$			
17	Sea State Resistance	R_S	Pounds	Figure G-7			
18	Propeller Resistance	R_P	Pounds	$R_P = 3.737(A_P)(V_{TOW})^2$			
19	Total Steady State Tow Resistance	R_T	Pounds	$R_T = R_W + R_H + R_S + R_P$			
20	Tow Hawser Resistance	R_{WIRE}	Pounds	Table 3-1 or 10% of R_T			
21	Total Tow Hawser Tension	R	Pounds	$R = R_T + R_{WIRE}$			

Example 1. Scenario

Wind @ 20 knots



Towed ship: FFG 7
Full load displacement - 3585 LT
Desired speed - 8 kts
Course - 000 T
Relative wind: 28 kts @ 000 R

The predicted tow resistance is 74486 lbs. Assuming an 2000-ft 2 1/4-inch hawser with 90 feet of 2 1/4-inch chain pendant, the tow hawser resistance will be approximately 2700 lbs. The total tug requirement is 77186 lbs. Inspection of Figure 3-3 shows that the T-ATF 166, and ARS 50 Classes can perform this tow. The other tugs can tow at a slower speed.

Figure G-1. Example 1 - Scenario.

SHIP: ____________________ CALCS BY: LT. MARK FIVE

Item	Description	Symbol	Units	Source			
1	Ship Class (AE, CV, etc.)				FFG-7		
2	Tow Speed	V_{TOW}	Knots		8	6	4
3	Tow Course	γ	Degrees				
4	Tow Displacement	Δ	Long tons	Table G-2	3585	3585	3585
5	Frontal Windage Area	A_T	Sq. feet	Table G-2	2200	2200	2200
6	Wind Drag Coefficient	C_W		Table G-2	0.7	0.7	0.7
7	Total Projected Area of Propellers	A_P	Sq. feet	Table G-2	170	170	170
8	Curve Number for Hull Resistance			Table G-2	2	2	2
9	Curve Number for Sea State Resistance			Table G-2	1	1	1
10	True Wind Speed	V_{wind}	Knots		20	20	20
11	Beaufort Number			Table G-3	5	5	5
12	Relative Wind Speed	V_R	Knots		28	26	24
13	Heading Coefficient	K		Section G-1	1.0	1.0	1.0
14	Wind Resistance	R_W	Pounds	$R_W=0.00506(A_T)(C_W)(V_R)^2(K)$	6109	5268	4488
15	Resistance Factor	$R_{H/\Delta}$		Figure G-6	4.4	2.9	1.7
16	Hull Resistance	R_H	Pounds	$R_H=1.25(R_{H/\Delta})(\Delta)$	19718	12996	7618
17	Sea State Resistance	R_S	Pounds	Figure G-7	8000	8000	8000
18	Propeller Resistance	R_P	Pounds	$R_P=3.737(A_P)(V_{TOW})^2$	40659	22870	10165
19	Total Steady State Tow Resistance	R_T	Pounds	$R_T=R_W + R_H + R_S + R_P$	74486	49134	30271
20	Tow Hawser Resistance	R_{WIRE}	Pounds	Table 3-1 or 10% of R_T	2700	2200	1250
21	Total Tow Hawser Tension	R	Pounds	$R=R_T + R_{WIRE}$	77186	51334	31521

Figure G-2. Example 1 - Worksheet.

Table G-2. Characteristics of Naval Vessels (sheet 1 of 3).

CLASS	DESCRIPTION	Δ FULL LOAD DISPLACEMENT (L. TONS)	A_T LIGHT SHIP FRONTAL WINDAGE AREA (Ft)	C_W WIND COEFFICIENT	A_P TOTAL PROJECTED AREA OF ALL PROPELLERS (Ft)	CURVE FOR HULL RESISTANCE SEE FIGURE G-6	CURVE FOR WAVE RESISTANCE SEE FIGURE G-7
BB 61-64	BATTLESHIPS	59,000	8,500	.70	664	5	3
CVN 74-77	AIRCRAFT CARRIERS	104,000					
CVN 68-73,65	AIRCRAFT CARRIERS	91,000	16,600	.45	895	5	3
CVN 59-64, 66, 67	AIRCRAFT CARRIERS	81,000	15,000e	.45	1028	5	3
CV 41-43	AIRCRAFT CARRIERS	65,000	9,500	.45	615	5	3
CV 14-34	AIRCRAFT CARRIERS	42,000	9,000	.45	300	5	3
CVS 9-39	ASW AIRCRAFT CARRIERS	40,600	9,000	.45	300	5	3
CA 68-124	GUN CRUISERS	17,500	5,300	.70	308	5	2
CA 134-148	GUN CRUISERS	20,950	4,500	.70	324	5	2
CGN 38-41 (DLGN)	GUIDED MISSILE CRUISERS	11,000	4,000	.70	207	4e	1
CGN 36-37 (DLGN)	GUIDED MISSILE CRUISERS	10,450	4,000	.70	238	4e	1
CGN 35 (DLGN)	GUIDED MISSILE CRUISER	9,127	2,960	.70	239	3	1
CGN 25 (DLGN)	GUIDED MISSILE CRUISER	8,592	3,040	.70	239	3	1
CGN 9	GUIDED MISSILE CRUISER	17,525	7,900	.70	312	4	2
CG 47-56	GUIDED MISSILE CRUISERS	10,100	7,000e	.70	254	4e	1
CG 26-34 (DLG)	GUIDED MISSILE CRUISERS	8,250	3,675	.70	296	4	1
CG 16-24 (DLG)	GUIDED MISSILE CRUISERS	8,250	3,000e	.70	243	3	1
CG 10-12	GUIDED MISSILE CRUISERS	19,500	5,300	.70	308	5e	2
DDG 51-53	GUIDED MISSILE DESTROYERS	8,300	6,900	.70	254	4e	1
DDG 993-996	GUIDED MISSILE DESTROYERS	10,000	5,000e	.70	254	4e	1
DDG 37-46 (EX-DLG 6/9)	GUIDED MISSILE DESTROYERS	6,150	3,000e	.70	228	3	1
DDG 2-24	GUIDED MISSILE DESTROYERS	4,500	2,256	.70	176	2	1
DDG 31-34	GUIDED MISSILE DESTROYERS	4,150	2,100	.70	194	3	1
DD 963-992, 997	DESTROYERS	9,400	4,400	.70	254	3	1
DD 931-951	DESTROYERS	4,200	2,100	.70	194	2	1
DD 445 CLASS	DESTROYERS	3,040	1,400	.70	134	3	1
DD 692 CLASS	DESTROYERS	3,400	1,400	.70	158	3	1
DD 710 CLASS	DESTROYERS	3,540	1,450	.70	158	3	1
DE 1006 CLASS	DESTROYER ESCORT	1,914	1,342	.70	79	1	1
FFG 7-61	GUIDED MISSILE FRIGATES	4,100	2,200	.70	170e	2e	1
FFG 1-6 (DEG)	GUIDED MISSILE FRIGATES	3,426	1,715	.70	131	2	1
FF 1052-1097 (DE)	FRIGATES	3,900	2,020	.70	131	2	1
FF 1040-FF 1051 (DE)	FRIGATES	3,400	1,715	.70	131	2	1
LCC 19-20	AMPHIBIOUS COMMAND SHIPS	18,650	7,360	.70	220e	5	2
LHA 1-5	AMPHIBIOUS ASSAULT SHIPS	39,300	11,500	.70	262	5	3
LPH 2-12	AMPHIBIOUS ASSAULT SHIPS	18,800	6,700	.75	155	5	2
LPD 4-15	AMPHIBIOUS TRANSPORT DOCKS	17,000	8,350	.75	175	5	2
LPD 1-2	AMPHIBIOUS TRANSPORT DOCKS	14,665	8,300	.75	175	5e	2
LSD 41-48	DOCK LANDING SHIPS	15,730	8,000e	.75	360e	5e	2
LSD 36-40	DOCK LANDING SHIPS	13,700	7,450e	.75	348	5	2
LSD 28-35	DOCK LANDING SHIPS	12,000	6,150	.75	174	5	2
LST 1179-1194	TANK LANDING SHIP	8,450	5,200	.75	108	4	2
LST 1171-1178	TANK LANDING SHIP	7,100	3,400	.75	82	4	2
LST 47-1088	TANK LANDING SHIP (WWII)	4,000	2,000	.75	30	4	1
LKA 113-117	AMPHIBIOUS CARGO SHIPS	20,700	7,650	.75	312	5e	2
MCM 1-14	MINE COUNTERMEASURE VESSELS	1,040	1,500	.75	40	2e	1
MHC 51		970					
MSO 427-511	OCEAN MINESWEEPERS	735	1,340	.75	40	2	1
T-ACS 1-12	AUXILIARY CRANE SHIPS	31,500	5,300e	.75	300e	5e	3

“e” represents best estimate

Table G-2. Characteristics of Naval Vessels (sheet 2 of 3).

CLASS	DESCRIPTION	Δ FULL LOAD DISPLACEMENT (L. TONS)	A_T LIGHT SHIP FRONTAL WINDAGE AREA (Ft)	C_W WIND COEFFICIENT	A_P TOTAL PROJECTED AREA OF ALL PROPELLERS (Ft)	CURVE FOR HULL RESISTANCE SEE FIGURE G-6	CURVE FOR WAVE RESISTANCE SEE FIGURE G-7
AD 15-19	DESTROYER TENDERS	18,400	6,200	.75	136	5	2
AD 37-44	DESTROYER TENDERS	20,500	8,000	.75	136	5	2
AE 21-25	AMMUNITION SHIP	16,000	6,490	.75	187	5	2
AE 26-35	AMMUNITION SHIP	18,000	7,800	.75	216	5	2
T-AF 58	STORE SHIP	15,540	5,400	.75	198	4	2
AFS 1-7	COMBAT STORE SHIPS	18,000	6,350	.70	216	5	2
T-AFS 8-10 (ex RN/RFA)	COMBAT STORES SHIPS	16,792	4,00Oe	.75	156e	4e	2
T-AG 194 (ex AGM-19)	MISC.	21,626	5,020	.70	150e	4	2
AGF 11 (ex LPD-11)	MISC. COMMAND SHIP	16,912	8,350	.75	175	5	2
AGF 3 (ex LPD-1)	MISC. COMMAND SHIP	15,000	8,300	.75	175	4	2
T-AGM 10 (ex AP 145)	MISSILE RANGE INST.	17,120	5,000e	1.00	200e	5e	2
T-AGM 20 (ex AO-114)	MISSILE RANGE INST.(T2-SE-A2)	24,710	5,020	.70	150e	5e	2
T-AGM 23 (ex AG 154)	MISSILE RANGE INST. (C4-S-A1)	17,015	5,550	1.00	200e	5	2
AGOR 14-15	OCEANOGRAPHIC RESRCH SHIPS	1,915	1,800e	.75	30e	4e	1
AGOR 21-22	OCEANOGRAPHIC RESRCH SHIPS	1,437	1,080e	.75	40e	4e	1
AGOR 23	OCEANOGRAPHIC RESRCH SHIPS	2,433	1,500e	.75	45e	4e	1
AGOR 3, 9-10	OCEANOGRAPHIC RESRCH SHIPS	1,370	1,100	.75	35e	4e	1
T-AGOR 16	OCEANOGRAPHIC RESRCH SHIPS	3,860	4,500e	.75	100	4e	1
T-AGOR 7, 12-13	OCEANOGRAPHIC RESRCH SHIPS	1,370	1,100	.75	35e	4e	1
T-AGOR 8, 11	OCEANOGRAPHIC RESRCH SHIPS	3,886	2,400e	1.00	50e	4e	1
T-AGOS 1-26	OCEAN SURVEILLANCE SHIPS	2,285	2,800e	.75	55e	4e	1
T-AGS 21-22	SURVEYING SHIPS (VC2-S-AP3)	13,050	2,900e	.75	120	5e	2
T-AGS 26-27, 33-34	SURVEYING SHIPS	2,800	2,000e	.75	55e	4e	1
T-AGS 29, 32	SURVEYING SHIPS	4,330	2,500e	.75	90e	4	1
T-AGS 38	SURVEYING SHIP	21,235	4,050	.75	200e	4e	2
T-AGS 39-40	SURVEYING SHIPS	15,800	3,500e	.75	150e	4e	2
AH 17	HOSPITAL SHIP	15,500	4,900	.75	115	5	2
T-AH 19-20	HOSPITAL SHIPS	44,875	8,400e	1.00	330e	5e	3
AK 283	CARGO SHIPS (C2-S-B1)	11,000	4,375	.75	106	5	2
T-AK 1010	MPS-CARGO SHIP	22,600e	5,600e	.75	220e	5e	2
T-AK 2043	MPS-CARGO SHIP (CR-S-66a)	24,300e	5,000e	.75	210e	5e	2
T-AK 2046	MPS-CARGO SHIP (LASH TYPE)	49,000e	9,000e	1.00	320e	5e	3
T-AK 267	CARGO SHIPS (C4-S-B1)	22,056	4,200	.75	150e	5e	2
T-AK 271	CARGO SHIPS (C1-ME2-13a)	3,886	1,600	.75	50e	5	1
T-AK 280-282	CARGO SHIPS (VC2-S-AP3)	11,300	4,100	.75	119	5	2
T-AK 284-286, 295	CARGO SHIPS (C3-S-33a)	15,404	3,800e	.75	130e	5e	2
T-AKB 1015, 2049	MPS-CARGO SHIPS (BARGE CARRIER)	53,000e	9,000e	1.00	300e	5e	3
T-AKR 287-294	MPS-VEHICLE CARGO SHIPS (SL-7)	55,000e	10,000	1.00	500e	5e	3
T-AKR 7	VEHICLE CARGO SHIP (C3-ST-14A)	18,286	4,000e	.75	180e	5	2
T-AKR 9	VEHICLE CARGO SHIP (C4-ST-67A)	21,700	4,100e	.75	200e	5	2
T-AKR (new)	VEHICLE CARGO SHIP	24,500	6,200e	.75	400e	5e	2
T-AKX 3000-3004	MPS-VEHICLE CARGO SHIPS	44,086	9,800	1.00	280e	5e	3
T-AKX 3005-3007	MPS-VEHICLE CARGO SHIPS	51,612	10,000	1.00	380e	5e	3
T-AKX 3008-3012	MPS-VEHICLE CARGO SHIPS	46,111	9,800	1.00	350e	5e	3
AO 177-186	OILERS	26,110	6,300	1.00	220	5e	3
AO 51, 98-99	OILERS	34,040	5,480	1.00	346	5	3
T-AO 105-109	OILERS	35,000	5,480	1.00	346	5e	3

"e" represents best estimate

Table G-2. Characteristics of Naval Vessels (sheet 3 of 3).

CLASS	DESCRIPTION	Δ FULL LOAD DISPLACEMENT (L. TONS)	A_T LIGHT SHIP FRONTAL WINDAGE AREA (Ft)	C_W WIND COEFFICIENT	A_P TOTAL PROJECTED AREA OF ALL PROPELLERS (Ft)	CURVE FOR HULL RESISTANCE SEE FIGURE G-6	CURVE FOR WAVE RESISTANCE SEE FIGURE G-7
T-AO 143-148	OILERS	36,000	5,000e	1.00	400e	5e	3
T-AO 187-204	OILERS	40,000	6,750e	1.00	420e	5e	3
T-AO 57, 62	OILERS	25,500	5,480	1.00	346	5e	3
AOE 1-6	FAST COMBAT SUPPORT SHIPS	51,000	9,750	1.00	456	5	3
T-AOG 78	GASOLINE TANKERS (T1-M-BT2)	6,047	2,500e	1.00	70e	4e	1
T-AOG 81-82	GASOLINE TANKERS (T1-MET-24a)	7,000	2,500e	1.00	67	4e	1
AOR 1-7	REPLENISHMENT OILERS	37,700	7,590	1.00	274	5	3
T-AOT	TRANSPORT OILERS (T5 type)	39,000	5,000e	.75	180e	5e	3
T-AOT 1203-1205	MPS-TRANSPORT OILERS	44,000e	4,500e	1.00	270e	5e	3
T-AOT 134	TRANSPORT OILERS (T2-SE-A2)	22,380	3,600e	1.00	135e	5e	2
T-AOT 149-152	TRANSPORT OILERS (T5-S-12A)	32,953	4,000e	1.00	200e	5e	3
T-AOT 165	TRANSPORT OILERS (T5-S-RM2A)	31,300	4,600e	1.00	210e	5e	3
T-AOT 168-176	TRANSPORT OILERS	34,100	4,600e	.75	200e	5e	3
T-AOT 181	TRANSPORT OILERS	35,000	4,700e	.75	270e	5e	3
T-AOT 50-76	TRANSPORT OILERS (T2-SE-A1)	21,880	3,600e	1.00	120e	5e	2
AP 110	TRANSPORTS	20,175	6,800	.75	200	5e	2
AP 121-127	TRANSPORTS	22,574	6,300e	.75	216	4e	2
AR 5-8	REPAIR SHIPS	16,300	5,460	.75	136	5	2
T-ARC 2, 6	CABLE REPAIR SHIP (S3-S2-BP1)	8,500	2,250e	.75	72e	5	1
T-ARC 7	CABLE REPAIRING SHIP	14,157	4,700e	1.00	300e	5e	2
ARL 24	SMALL REPAIR SHIP	4,325	2,320	.75	30	4	1
ARS 38-43	SALVAGE SHIP	2,045	1,500	.75	56	5	1
ARS 50-53	SALVAGE SHIP	2,880	2,000e	.75	80	5e	1
AS 11, 17, 18	SUBMARINE TENDERS	17,000	6,200	.75	136	4	2
AS 19	SUBMARINE TENDERS	19,200	6,200	.75	136	4	2
AS 31-32	SUBMARINE TENDERS	19,000	6,440	.75	140	4	2
AS 33-34	SUBMARINE TENDERS	21,089	7,550	.75	136	5e	2
AS 36-41	SUBMARINE TENDERS	23,000	7,550	.75	136	5	2
ASR 21-22	SUBMARINE RESCUE SHIPS	3,411	4,500e	.75	100	3e	1
ASR 9, 13-15	SUBMARINE RESCUE SHIPS	2,320	1,200	.75	50	5	1
ATF 91-160	FLEET TUGS	1,640	1,100	.75	43	2	1
T-ATF 166-172	FLEET OCEAN TUGS	2,260	1,700e	.75	120e	4e	1
ATS 1-3	SALVAGE & RESCUE SHIPS	2,929	2,500	.75	110	5e	1
T-AVB 3-4	MPS-AVIATION MAINTENANCE SUP.	23,800	6,000e	1.00	370e	5e	2
AVM 1	GUIDED MISSILE SHIP	15,170	5,300	.75	136	4	2
WAGB 10-11	(CG) ICEBREAKERS	12,087	4,500	.75	280e	4e	3
WAGB 281-282	(CG) ICEBREAKERS	6,515	3,150	.75	182	5e	2
WAGB 4	(CG) ICEBREAKERS	8,449	3,400	.75	300e	5e	2
WHEC 35, 37	(CG) HIGH ENDURANCE CUTTERS	2,656	1,600	.70	50e	1e	1
WHEC 379	(CG) HIGH ENDURANCE CUTTERS	2,800	1,600	.70	47e	1e	1
WHEC 715-726	(CG) HIGH ENDURANCE CUTTERS	3,050	2,000	.70	154e	2e	1
WMEC 165-166	(CG) MED. ENDUR. CUTTERS (ATF)	1,731	1,200	.75	43	2e	1
WMEC 615-623	(CG) MEDIUM ENDUR. CUTTERS	1,000	1,400	.70	40e	2e	1
WMEC 76, 85, 153	(CG) MED. ENDUR. CUTTERS (ATF)	1,731	1,500	.75	56	2e	1
WMEC 901-913	(CG) MEDIUM ENDUR. CUTTERS	1,780	1,300	.70	55e	1e	1
WMEC 6, 167, 168	(CG) MED. ENDUR. CUTTERS (ARS)	1,745	1,500	.75	56	5e	1
YTB 752-836	LARGE HARBOR TUGS	350	560	.75	22e	2e	1

“e” represents best estimate

Table G-3. Beaufort Scale.

Beau-fort No.	Knots	Description	Avg. Ht. (ft)	Significant 1/3 Highest (ft)	Avg. Wave Length (ft)	Minimum Duration (Hours)	Avg. Wave Height (ft)*
0	< 1	Calm	---	---	---	---	---
1	1-3	Light air	< 1	< 1	10 in	18 min	---
2	4-6	Light breeze	< 1	< 1	6.7 (ft)	39 min	---
3	7-10	Gentle breeze	< 1	< 1	20-27	1.7-2.4 (hr)	2 (3)
4	11-16	Moderate breeze	1.8-2.9	2.9-4.6	52-71	4.8-6.6	3½ (5)
5	17-21	Fresh breeze	3.8-5.0	6.1-8.0	90-111	8.3-10.0	6 (8½)
6	22-27	Strong breeze	6.4-9.6	10-15	134-188	12-17	9½ (13)
7	28-33	Moderate gale (high wind)	11-16	18-26	212-285	20-27	13½ (19)
8	34-40	Fresh gale	19-28	30-45	322-444	30-42	18 (25)
9	41-47	Strong gale	31-40	50-64	492-590	47-57	23 (32)
10	48-55	Storm	44-59	71-95	650-810	63-81	29 (41)
11	56-63	Violent storm	64-73	103-116	910-985	88-101	37 (52)
12	> 63	Hurricane	> 80	> 128	---	---	45 (-)

1. Figures shown are associated with the low and high wind speed within each force range.
2. Except for the far right-hand column, figures are for fully developed seas. Note that the more strenuous seas require a progressively longer duration to develop. The fully developed seas associated with 50-kt or stronger winds rarely occur. Average heights listed in the right-hand column are more representative of waves actually encountered under the stated wind conditions.

* For tow planning purposes, use “average height” column in computing added resistance due to waves. These are the more usual wave heights encountered, due to the long duration required to achieve the "fully developed sea" for the stated wind conditions. Figures in parentheses represent the occasional highest wave in the average spectrum. These occasional highest waves have little long-term impact on the towing resistance.

DD 963 @ 7500 LT displacement

What is the maximum speed each Navy tug can achieve?

Solution: Compute hawser tension at 10, 8, 6, 4 knots and plot in Figure 3-3

Tow Speed	Tow Resistance	Hawser Resistance	Total Pull Required
10 kts	173,449 lbs.	negligible	173,449 lbs.
8 kts.	122,159 lbs.	1,500 lbs.	124,059 lbs.
6 kts.	82,336 lbs.	1,850 lbs.	84186 lbs.
4 kts.	53,044 lbs.	1,100 lbs.	54,144 lbs.

The attached Figure G-4 work-up shows hawser tensions for the 6- and 8-knot cases.

Figure G-5 is a replica of Figure 3-3, with this resistance curve plotted on it. This provides the following likely maximum tow speeds for each of the tug types listed, with total hawser average tension.

	Max. Tow Speeds	Average Tension
T-ATF 166	7.6 kts	117,000
ARS 50	6.9 kts	98,000

Figure G-3. Example 2 - Scenario.

SHIP: ____________________ CALCS BY: LT. MARK FIVE

Item	Description	Symbol	Units	Source			
1	Ship Class (AE, CV, etc.)				DD 963	DD 963	
2	Tow Speed	V_{TOW}	Knots		8	6	
3	Tow Course	γ	Degrees				
4	Tow Displacement	D	Long tons	Table G-2	7500	7500	
5	Frontal Windage Area	A_T	Sq. feet	Table G-2	4400	4400	
6	Wind Drag Coefficient	C_W		Table G-2	0.70	0.70	
7	Total Projected Area of Propellers	A_P	Sq. feet	Table G-2	254	254	
8	Curve Number for Hull Resistance			Table G-2	3	3	
9	Curve Number for Sea State Resistance			Table G-2	1	1	
10	True Wind Speed	V_{wind}	Knots		25	25	
11	Beaufort Number			Table	6	6	
12	Relative Wind Speed	V_R	Knots		33	31	
13	Heading Coefficient	K		Section G-1	1.0	1.0	
14	Wind Resistance	R_W	Pounds	$R_W=0.00506(A_T)(C_W)(V_R)^2(K)$	16972	14977	
15	Resistance Factor	$R_{H/D}$		Figure G-6	3.3	2.1	
16	Hull Resistance	R_H	Pounds	$R_H=1.25(R_{H/D})(D)$	30938	19688	
17	Sea State Resistance	R_S	Pounds	Figure G-7	13500	13500	
18	Propeller Resistance	R_P	Pounds	$R_P=3.737(A_P)(V_{TOW})^2$	60749	34171	
19	Total Steady State Tow Resistance	R_T	Pounds	$R_T=R_W + R_H + R_S + R_P$	122159	82336	
20	Tow Hawser Resistance	R_{WIRE}	Pounds	Table 3-1 or 10% of R_T	1900	1850	
21	Total Tow Hawser Tension	R	Pounds	$R=R_T + R_{WIRE}$	124059	84186	

Figure G-4. Example 2 - Worksheet.

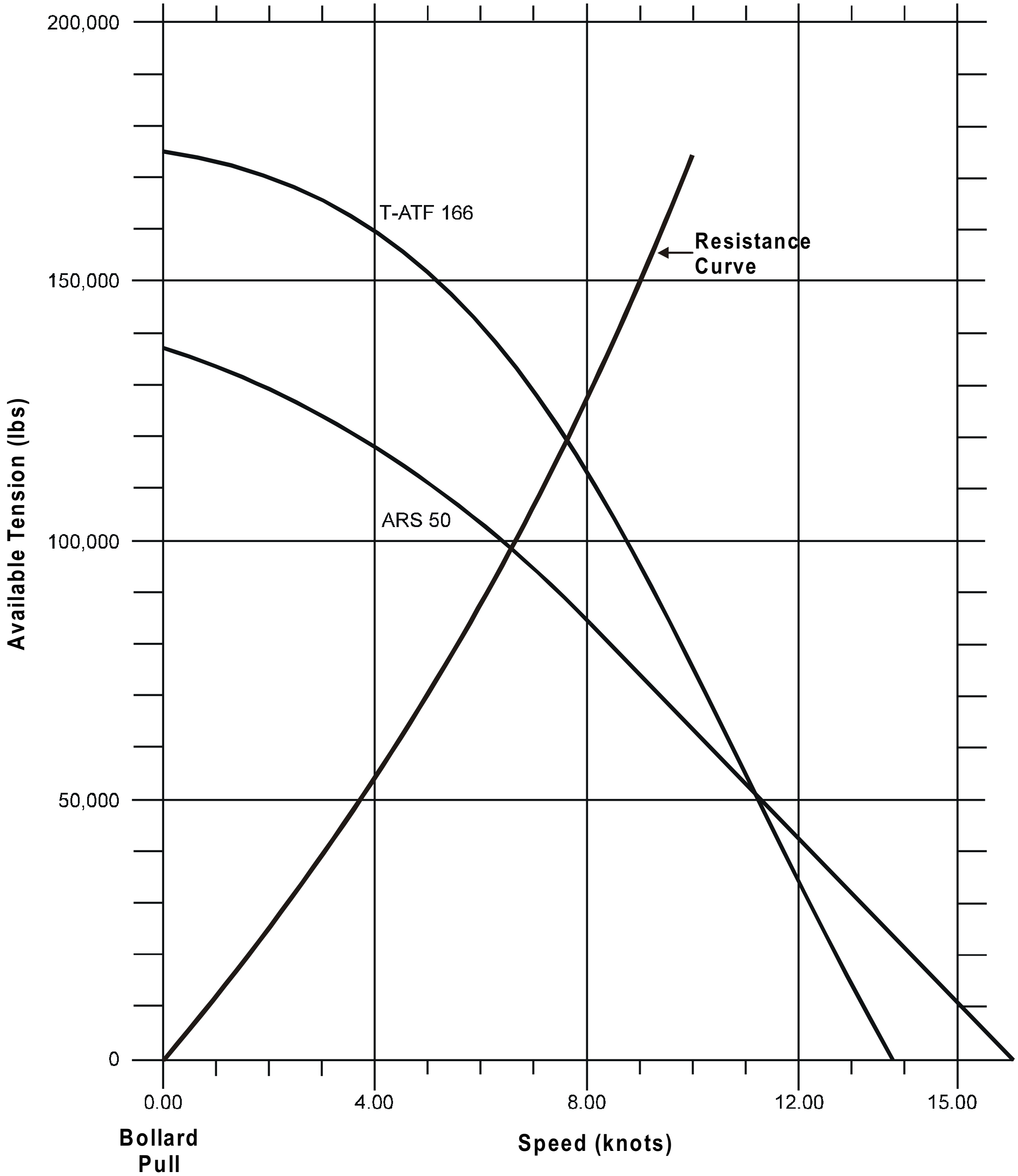


Figure G-5. Available Tension vs. Ship's Speed for U.S. Navy Towing and Resistance Curve.

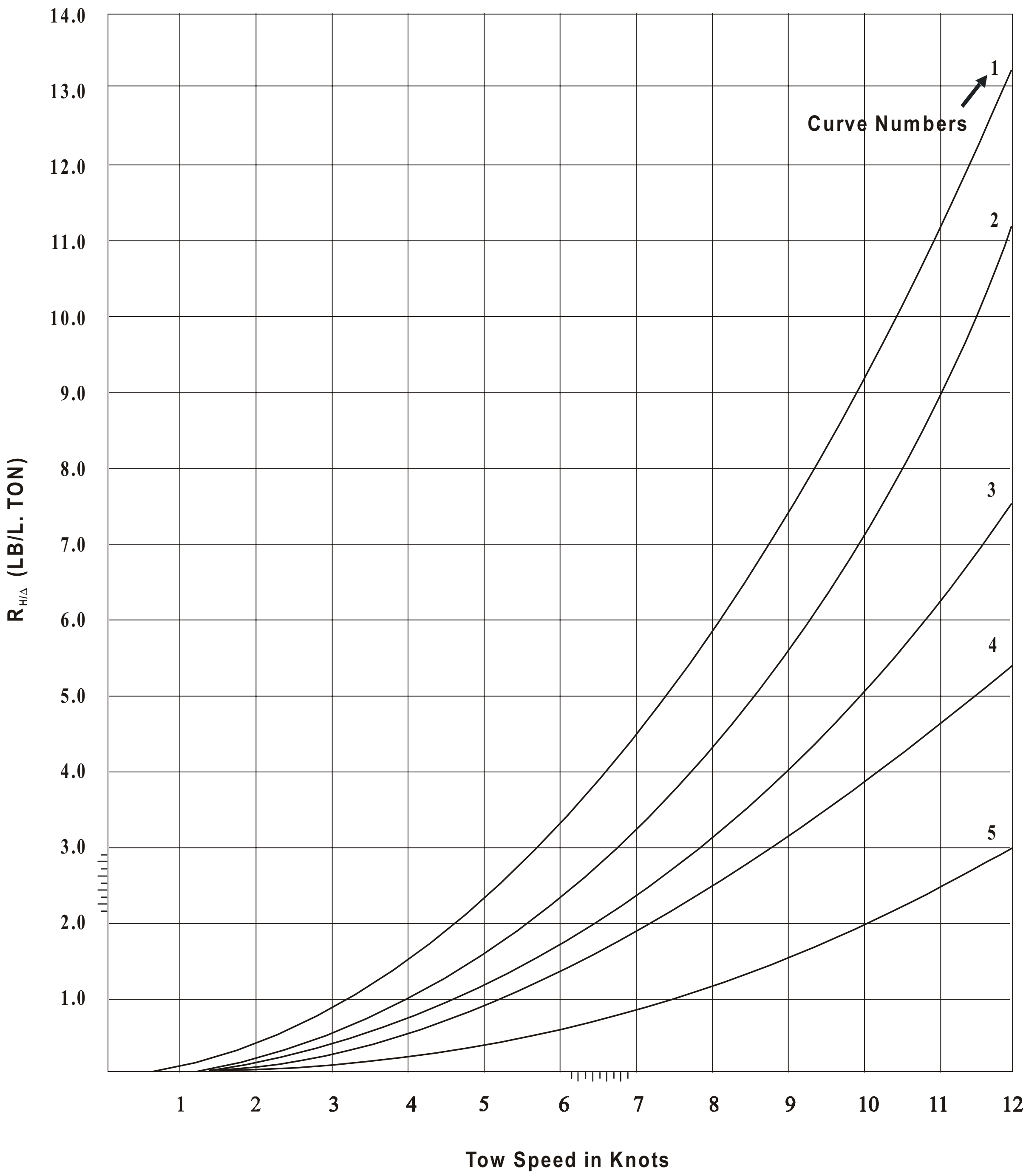


Figure G-6. Hull Resistance Curve, $R_{H/\Delta}$ vs. Tow Speed.

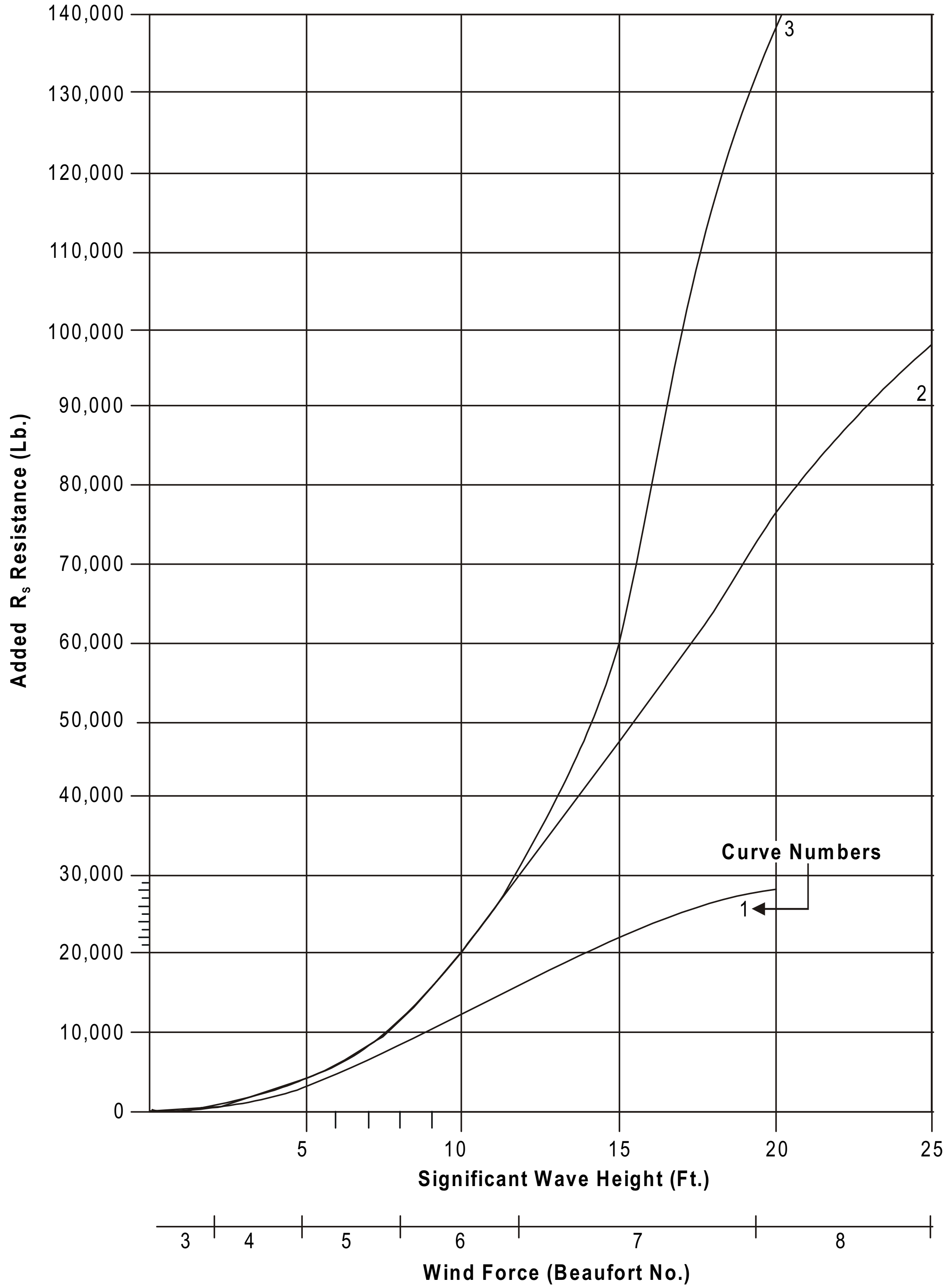


Figure G-7. Wave Resistance Curve R_S vs. Wave Height and Wind Force.

the tug and tow may preclude towing across the wind and seas under strenuous conditions.

G-1.3 Wind Resistance

The prediction of wind resistance is also simplified in the manual. The sea conditions associated with the most significant winds generally dictate towing into or close to the wind. The ability to precisely predict the reduction of tow resistance from a Force 10 wind off the quarter is not too important. Furthermore, in those cases where there is insufficient pitch or duration of the strong winds to raise fully-developed waves, the tug will base operational decisions on actual observations of the towline, not on the predicted assistance from strong stern winds.

Note 2: At higher wind strengths, Force 5 to 7, (the latter with winds of 28 to 33 knots), the tow will be forced to head into the wind because of the sea conditions. Therefore, the most severe weather expected should be checked for head wind and seas to confirm tug and especially tow hawser selection.

G-1.4 Propeller Resistance

Ships of comparable size (displacement) *and* speed have comparable propeller size. For ships not listed in Table G-2, select a comparable listed ship for propeller projected area. In the case above, there is no comparable ship listed in Table G-2. The T-AGM 20 is assumed to have a similar hull shape as the tanker, since it has a similar speed/length ratio. The propeller projected area for the T-AGM 20 is 150 square feet. The displacement of the ship in question is 4.4 times as large as the T-AGM 20, so it will require roughly 4.4 times the power for the same speed. Therefore, estimate the propeller projected area as 4.4 x 150 square feet, which equals 660 square feet.

G-2 Floating Dry Docks

The following method for determining the total tow resistance of non self-propelled floating dry docks is based on the now out-of-circulation *Towing Non Self-Propelled Floating Structures* (Technical Publication NAVDOCKS TP-DM-26, 1 October 1953). This procedure, which has been successfully used for many years, is recommended for estimating tow resistance for these types of craft. Table contains the various constants used in the following formulas.

G-2.1 Frictional Resistance

The data used for determining frictional resistance are based upon a series of experiments on model and actual conditions. The resistance caused by the friction of water on the vessel's wetted surface depends upon:

- Area of surface below the waterline
- Nature of surface
- Speed of tow.

Thus the formula for frictional resistance of a vessel passing through water is:

$$R = f_1 \times S \times (V/6)^2$$

where:

R	=	Resistance in pounds
f_1	=	A coefficient depending on the shape of the ship's hull (from Table G-4)
S	=	Area of the vessel's wetted surface below the waterline, in square feet (from Table G-4)
V	=	Speed of tow in knots relative to still water.

G-2.2 Wave-Forming Resistance

Data for wave-forming resistance are based on model tests and depend on:

Table G-4. Drydock Towing Coefficients.

Ship Class			f1	S	f2	B	f3	C
AFDB-1	Section	256′ x 80′	.45 to .8	23,000	.3	720	.7	3,800
AFDB-4	Section	240′ x 101′	.45 to .8	26,000	.3	900	.7	4,500
AFDM-1	3-Piece	496′ x 116′	.45 to .8	50,000	.6	750	.67	7,000
AFDM-3	3-Piece	488′ x 124′	.45 to .8	52,000	.6	800	.67	7,800
ARD-1	1-Piece	390′ x 60′	.45 to .8	20,000	.2	250	.61	2,000
ARD-2	1-Piece	486′ x 71′	.45 to .8	34,000	.2	370	.61	3,700
ARD-12	1-Piece	492′ x 81′	.45 to .8	40,000	.2	480	.61	4,400
AFDL-1	1-Piece	200′ x 64′	.45 to .8	13,000	.4	220	.7	1,400
AFDL-7	1-Piece	288′ x 64′	.45 to .8	19,000	.4	210	.7	1,500
AFDL-35	1-Piece	389′ x 84′	.45 to .8	38,000	.3	780	.67	1,900
AFDL-47	1-Piece	488′ x 97′	.45 to .8	46,000	.5	420	.7	2,500
AFDL-48	1-Piece	400′ x 96′	.45 to .8	48,000	.4	1,350	.7	2,540
YFD-7	3-Piece	488′ x 124′	.45 to .8	52,000	.6	800	.67	7,800
YFD-68 to 71	3-Piece	474′ x 118′	.45 to .8	48,000	.6	750	.67	7,300

- Area below water line (maximum cross section)
- Form of bow and stern
- Speed of tow.

Thus the formula for wave-forming resistance of a body passing through water is:

$$G = 2.85 \times B \times f_2 \times V^2 \times K$$

where:

G = Resistance in pounds

B = Cross-sectional area of vessel below waterline in square feet (from Table G-4)

f_2 = A coefficient depending upon the configuration of the vessel's bow and stern (from Table G-4)

V = Speed of tow in knots relative to still water

K = 1.2 (multiplying by this number adds 20 percent for additional resistance from rough water and eddies)

G-2.3 Wind Resistance

Data used for determining wind resistance are based on a series of experiments on models. The resistance caused by wind blowing against a vessel depends upon:

- Cross-sectional area of vessel above waterline subjected to wind
- Speed of wind
- Speed of tow
- Shape of vessel subjected to wind.

Thus the formula for frictional resistance caused by wind is:

$$W = C \times .004\,(V_w + V)^2 \times f_3$$

where:

W = Resistance in pounds

C = Cross-sectional area of vessel above waterline in square feet (from Table G-4)

V_w = Speed of wind in knots

V = Speed of tow in knots, relative to still water

f_3 = A coefficient depending on the shape of vessel subjected to wind (from Table G-4).

G-2.4 Total Tow Resistance for Dry Docks

The total tow resistance for docks (R_{TOT}) is the sum of the frictional resistance, wave-forming resistance, and wind resistance. This total tow resistance is then used in selecting the tow ship and designing the tow connection as described in Chapter 3. This does not include towline resistance when figuring total towline tension.

$$R_{TOT} = R + G + W$$

G-2.5 Example

The following example is given to show the use of the four resistance formulas already outlined.

The problem is to determine the extreme requirements for towing AFDL 1 Class floating dry dock under all weather conditions. To illustrate this design, the following known factors have been selected:

- Hurricane wind speed: 64 knots
- Towing speed during hurricane: 6 knots
- Bottom condition of dry dock — moderately rough and in need of cleaning: use f_1 coefficient of 0.65

Substitute into resistance formulas, using above factors and coefficients from Table G-4.

$$R = f_1 \text{ x } S\ (V/6)^2$$
$$= 0.65 \text{ x } 13{,}000 \text{ x } (6/6)^2$$
$$= 8{,}450 \text{ lbs.}$$

$$G = 2.85 \text{ x } B \text{ x } f_2 \text{ x } V^2 \text{ x } K$$
$$= 2.85 \text{ x } 220 \text{ x } 0.4 \text{ x } 6^2 \text{ x } 1.2$$
$$= 10{,}835 \text{ lbs.}$$

$$W = C \text{ x } 0.004 \text{ x } (V_w + V)^2 \text{ x } f_3$$
$$= 1{,}400 \text{ x } 0.004 \text{ x } (64 + 6)^2 \text{ x } 0.7$$
$$= 19{,}208 \text{ lbs.}$$

Total resistance

$$R_{TOT} = R + G + W$$
$$= 8{,}450 + 10{,}835 + 19{,}208$$
$$= 38{,}493 \text{ lbs.}$$

G-3 Barges

The previous section on towing resistance of dry docks can be adapted for computing the total resistance of barges.

G-3.1 Frictional Resistance

The method is identical to the one used in Section G-2.1. The wetted surface (S), is simply the barge's length times beam (for bottom) *plus* perimeter times draft (for sides, bow, and stern).

G-3.2 Wave-Forming Resistance

The cross section area (B) equals beam times draft. For the typical rake-ended barge, use $f_2 = 0.2$. This also is applicable to the comparatively blunt ship-shaped bow of some barges such as YFBNs and APLs. For square-ended barges, use $f_2 = 0.5$.

G-3.3 Wind Resistance

Use the formula contained in Section G-2.3. The cross sectional area (C), is the freeboard times beam *plus* height times width of the deck house or any deck cargo. Use $f_3 = 0.60$ as an average barge figure in the formula.

G-3.4 Total Barge Resistance

To calculate total tow resistance (R_{TOT}), add the frictional resistance, wave-forming resistance, and wind resistance from the previous three sections.

$$R_{TOT} = R + G + W$$

G-3.5 Example

Assume a berthing barge (YRBM) is to be towed. Dimensions are:

Length: 265 feet

Width:	65 feet
Draft:	7 feet
Hull Depth:	12 feet
Deck House:	220 ft. x 55 ft. x 25 ft.

Desired tow speed is 10 knots, maximum head wind is 20 knots. Bottom conditions are average. The hull has rake-shaped ends.

G-3.5.1 Frictional Resistance

Estimate average length below the waterline as 250 feet, with the bottom being 245 feet.

S = Wetted surface

= 7 x 2 (250 + 65) + (245 x 65)

= 20,335 square feet

Therefore:

$R = .65 \times 20{,}335 \times (10/6)^2$

= 36,716 lbs.

G-3.5.2 Wave Forming Resistance

B = Cross sectional area

= 65 x 7

= 455

Therefore:

$G = 2.85 \times 455 \times 0.2 \times 10^2 \times 1.2$

= 31,122 lbs.

G-3.5.3 Wind Resistance

C = Frontal area

= 65 x (12 - 7) + (25 x 55)

= 1,700 square feet

Therefore:

$W = 1{,}700 \times .004\ (20 + 10)^2 \times .6$

= 3,672 lbs.

G-3.5.4 Total Resistance

$R_{TOT} = R + G + W$

= 36,716 + 31,122 + 3,672

= 71,510 lbs.

Inspecting Figure 3-1 shows that this tow is within the capability of the T-ATF and ATS 1 Classes, at the assumed towing speed of 10 knots. Clearly, other towing ships would be adequate for this tow at lower speeds.

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Appendix H

CHECKLIST FOR PREPARING AND RIGGING A TOW

The following checklist is designed to help the preparing activity ready a tow for sea. It lists pre-tow preparations and general requirements which must be completed before the towing unit will accept the tow for sea. If the preparing activity has questions concerning this checklist or preparations required to ready the tow, it should communicate these concerns to the towing unit or its Immediate Superior in Command (ISIC). The preparing activity is responsible for completing this checklist. Items that are not applicable or cannot be accomplished must be cleared through the towing unit or its ISIC. All not applicable or not accomplished items shall be documented. Rationale for accepting the tow with not accomplished items shall be documented as a part of the completed Towing Inspection Checklist.

The command conducting the tow should conduct a preliminary pre-tow inspection as soon as possible to preclude misunderstandings and rework. In special situations, the standards reflected in this checklist can be relaxed and an “acceptable risk” tow accepted. The Commanding Officer of the towing ship and the ISIC must agree to all acceptable risk tows, as such tows do not relieve them of responsibility or safe practice. Acceptable risk tows are not routine.

The Commanding Officer of the towing ship conducts a final inspection of the tow, accompanied by a representative of the preparing command. Upon satisfactory completion of this inspection, the preparing activity sets condition ZEBRA on the tow and the towing ship’s Commanding Officer accepts and signs for the tow.

Note: For more information on preparing a tow for sea, refer to Chapter 3 and 4.

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TOWING INSPECTION CHECKLIST

Vessel Name ______________________ Hull Number ______________________

Owner ______________________ P.O.C. and 24 Hour # ______________________

Departure Port ______________________ Arrival Port ______________________

Receiving Activity Port ______________________ P.O.C. and 24 Hour # ______________________

Vessel Characteristics

Length:	Beam:		Displacement:
Draft fwd:	Draft aft:		Mean draft:
Freeboard fwd:	Freeboard aft:		Freeboard mid:
MTI:	TPI:		KG:
GM:		Maximum Ht above WL:	
Maximum Navigational Draft (include sonar domes, propellers, etc.):			

Is craft designed and authorized to be ocean-towed in accordance with requirements set forth in this manual? ________

Provide rationale for accepting the tow with items not accomplished. ______________________

____

____

____

____

____

Use separate sheet if additional space is needed.

The tow described above is seaworthy in all respects. The material condition is noted. Copies of the master inventory and storage keys are receipted for.

Representative of command having prepared the tow for sea ***Date***

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1. SHIP INFORMATION

		Reference	N/A	Yes	No
a.	Is the booklet of general plans available? Location of booklet:				
b.	Is damage control book, curves of forms, or other stability data available? If yes, provide location:				
c.	Are liquid load diagrams and damage control flooding plates available on board? If the answer is Satisfactory, provide location:				
d.	Are instructions posted in after steering for lining up hydraulic steering systems to hand pump?				
e.	Are plans and date of the last drydocking available? Date of last drydocking: Location of plans:				
f.	Were hull thickness recordings taken during last drydocking:	*5-7.5*			
g.	Is record of sonic drill test satisfactory? If not, has a satisfactory report of ultrasonic testing been provided?				
h.	Has a list of equipage been provided to the towing activity? ***Note:*** *The preparing activity is responsible for providing a list of equipage assigned to the craft that is pilferable and must be on board at destination. Preparing and towing representatives' signatures are required. Provide list on separate sheet.*				
i.	List remaining HAZMAT on board:				
j.	If craft is a floating drydock, has it been inspected by a representative of NAVSEA? If satisfactory, provide name of inspector and date of inspection:				
k.	Do you hold a signed copy of the inspection?				

2. RIDING CREW

		Reference	N/A	Yes	No
a.	Will a riding crew be employed? If so, attach a copy of the directive (message, letter, etc.) and proceed with the following checks. ***Note***: *Riding crews are not ordinary practice for open ocean tows.*	*5-6*			
b.	Authority that authorized a riding crew.				
c.	Is a copy of the authorizing message attached? Number of crew members:__________________				
d.	Has a list of the riding crews been provided to the towing activity? ***Note***: *A list of the riding crew is entered in towing ship's diary (name, rate, SSN, and NOK; address and phone number of rider and NOK for civilians).*				
e.	Are enough life rafts on board with emergency rations and water for the riding crew in the event that they have to abandon ship? Location of life rafts:				
f.	Date life rafts were last tested/inspected:	*5-9.2*			
g.	Are a sufficient quantity of life jackets and life rings on board? Number, type, and location				
h.	Means of communication with the towing ship: ***Note***: *Both visual and radio are recommended.*				
i.	Has the riding crew been trained in damage control and support systems? ***Note:*** *The preparing activity is normally responsible for such training*.	*5-9.2*			
j.	Is habitability and sustenance sufficient from on-board assets?	*5-9.2*			

3. *SEAWORTHINESS*

		Reference	N/A	Yes	No
a.	Does craft have a fixed rudder or a skeg?				
b.	Is craft ballasted? Type and location of ballast:	*5-7.3* *5-7.2*			
c.	If not, will craft require additional ballst?				
d.	Types of ballast required:	*5-2.9*			
e.	Describe where ballast will be placed and how much:				
f.	Draft after craft is in proper trim: Forward:________________ Aft:_________________________ Max. navigational draft:	*5-7.2*			
g.	GM after craft is in proper trim:				
h.	KG after craft is in proper trim:				
i.	If GM is not known, "sally ship" to establish period of roll: Normally $T = 2\sqrt{\text{Beam(ft)}}$ T (observed): ***Note:*** *This method to assess the adequacy of ship's stability is fully explained in Section 5-7.3.*	*5-7.3*			

		Reference	N/A	Yes	No
j.	Are all sea valves closed and wired shut?	*5-7.4*			
k.	Is there a two-valve protection from the sea for all sea openings? ***Note:*** *Two-valve protection consists of either two valves wired shut or one valve and a blank flange. A list of all valves should be attached.*	*5-7.4*			
l.	Is a list of sea valves attached?				
m.	Closely inspect, below decks, all drain piping which originates above the water-line and terminates within 20 feet of the waterline. Are there any loose connections or badly deteriorated spots in the piping?	*5-7.4*			
n.	Are all sounding tubes capped?				
o.	Is there a list of all sounding tubes attached? (Required)				
p.	Are all between-tank sluice valves closed?				
q.	Are all normally dry compartments dry?				
r.	Are all bilges free of oil and water?				
s.	Are there any broken, cracked or weak frames, longitudinals, plates, welds, or rivets?	*5-7.5.1*			
t.	Have repairs been made?	*5-7.5.1*			
u.	Has the hull structure been inspected to the best of your ability?				
v.	Type(s) of hull inspection conducted, including location: (e.g., ultrasonic interior, exterior, voids) ***Note:*** *All compartments should be entered and inspected.*				
w.	Have all compartments been inspected?				
x.	Has steel wire or cable been used to secure all equipment to prevent any movement in heavy weather? ***Note:*** *All moveable equipment must be secured in place with wire or by welding. No fiber rope or line will be accepted.*	*5-7*			
y.	Are all rudders locked? ***Note:*** *The rudders should be locked by using structural steel of acceptable size and quantity. The lock should transfer the rudder load from the yoke to structural members of the tow's hull. Refer to Chapter 4 for typical configurations and sizing.*	*5-7.6*			
z.	Type of locking device used:				
aa.	Are all shafts locked?	*5-7.1.9*			
bb.	Are propellers removed?	*5-7.1.8*			
cc.	Are shafts equipped with extra rings of packing in the gland to allow emergency repair during transit?	*5-7.1.11*			
dd.	Is the gland tightened to its tightest position but not two-blocked?	*5-7.1.11*			
ee.	Ensure that there is no leakoff at the stern tube. Can the stern tube packing gland be tightened at least two more inches before it is two-blocked? ***Note:*** *Leaving two more inches will allow additional sealing room should there be leakage. If this room is not available, it is a good indication that the packing has deteriorated to an unacceptable point.*	*5-7.1.11*			
ff.	Are locking nuts tight on packing glands to prevent their backing off?	*5-7.1.11*			
gg.	Are all portholes sealed and covered with metal to prevent breakage?	*5-7.9*			

		Reference	N/A	Yes	No
hh.	Are all vents that are subject to ***heavy weather flooding*** (e.g., air, fresh water, fuel tank) sealed? ***Note:*** *Wood covers are not considered adequate. The recommended procedure is to remove and blank flange or weld close.)*	*5-7.9*			
ii.	Do vents allow for the escape of air or gas? ***Note:*** *Vents to tanks and other closed spaces should be covered to prevent water entry, but not plugged so as to prevent the escape of air or gas. Plugging a vent allows pressure to build up within the tank if the temperature rises. Barge sides and decks have been known to bulge severely. If necessary, cover compartment vents with canvas socks that prevent water from entering yet allow air to escape.*	*5-7.9*			
jj.	Are all hatches, scuttles, doors, and other watertight closures provided with pliable gaskets?	*5-7.9*			
kk.	Have weather decks and main transverse bulkhead watertight closures been chalk tested?				
ll.	Are all dogs on watertight closures operable and functioning as designed?				
mm.	Is forward one-fifth of craft designed to withstand constant pounding during transit? If the answer is Unsatisfactory, bow should be shored properly.	*5-7.5*			
nn.	If the craft to be towed is a barge, and inspection reveals signs of serious deterioration, or the barge is suspected of being weakened, it may require shoring, particularly in the forward one-fifth of its length. Is shoring required? ***Note:*** *Steel "K" shoring should be installed on all longitudinals in forward and after compartments.*	*5-7.5.1*			
oo.	Has shoring been accomplished?				
pp.	For LST-type tows, all of the following must be answered Satisfactory, or the vessel ***will not be accepted for ocean tow,*** even as a calculated risk:	*7-7*			
	i. Do the bow doors have hydraulic rams connected?				
	ii. Are mud flaps at the bottom of the doors secured?				
	iii. Are all dogs, heavy weather shackles, ratchet-type turnbuckles and strongbacks in place, tight and secure so that they cannot work free?				
	iv. Are bow ramp operating instructions posted in the hydraulic control room?				
qq.	If craft is equipped with a bow or stern ramp, is it secured in accordance with notes listed below? ***Note:*** *YFU/LCUs are inherently unseaworthy due to wide beams and flat bottoms. A lift of opportunity should be used whenever possible. If it is absolutely necessary to tow these craft, the following must be strictly adhered to:*	*7-7*			
	i. The bow ramp will be secured with a minimum of four angle straps on each side, welded on the outside of the ramp. The size of these straps should be at a minimum of 4" by 3/8" and overlap the bow ramp and sides of the craft at a minimum of 10".				
	ii. All normal securing devices (i.e., ramp chains, dogs, and turnbuckles) are in place and in good mechanical order.				
	iii. All hatches, scuttles, and doors have good gaskets and all securing devices are in proper operating condition.				

		Reference	N/A	Yes	No
rr.	Are 1-foot by 3-foot draft marks painted on the sides of the hull forward, aft, and midships at the water's edge to allow visual inspection for proper trim during transit?	*5-7.1.6*			
ss.	Are all lifelines in place and in good condition?				
tt.	Are ladders available for boarding on both port and starboard sides?	*Figure 5-7*			
uu.	Do rungs go all the way to the WL?				
vv.	For unmanned ships with freeboard over 10 feet, are rungs welded to the sides?				
ww.	Is condition ZEBRA set throughout the tow? If the answer is Unsatisfactory, list exceptions on separate sheet.				
xx.	Are damage control inspection routes marked by paint/diagrams and/or reflective tape?	*5-8.4*			
yy.	Is interior access sufficiently marked for DC teams?				
zz.	Shoring may be required to prevent damage to deck fittings, wirings, scuttles, doors, etc. Has this been accomplished?				

4. FLOODING

		Reference	N/A	Yes	No
a.	Are amber (upper) and white (lower) alarms lights installed?	*5-7.1.3*			
b.	Are flooding alarm lights visible for 360º and centered forward on the tow? ***Note:*** *Are additional spares available for long tow?*	*5-7.1.3*			
c.	Are both the low and high water flooding alarm lights rigged with two bulbs each?	*5-7.1*			
d.	Are flooding alarm lights rigged with a separate battery source? ***Note:*** *Flooding alarm lights must not be connected to navigational lights.*	*5-7.1.2*			
e.	Are batteries sufficient to provide continuous operation for the duration of the tow?	*5-7.1.2*			
f.	Total amperage capacity: Sufficient amperage must be calculated and available to cover the following: (1) Wattage of the bulbs serviced (2) Distance of bulbs from battery source (wiring losses) (3) Duration of tow				
g.	Are flooding alarm lights rigged with flasher-type units?	*5-7.1.3*			
h.	Is all wiring connected to sensor indicator lights run below decks insofar as possible?	*5-7.1.1*			
i.	Is all wiring secured and protected from any chafing?	*5-7.1.2*			
j.	Is all topside wiring protected from weather damage?	*5-7.1.2*			
k.	Are flooding alarms rigged in all major compartments closest to the keel?	*5-7.1.1*			
l.	Do all below-waterline areas have alarms? ***Note:*** *If the answer is Unsatisfactory, attach a list of below-waterline areas that do not have alarms. Tanks and voids that can be flooded without sounding an alarm should be identified and the decision not to install alarms justified.*	*5-7.1.1*			

		Reference	N/A	Yes	No
m.	Is this list attached?				
n.	In large craft or in barges where compartments run athwartships, are flooding alarms rigged on both port and starboard sides?	*5-7.1.1*			
o.	Are flooding alarm sensors well-secured to fixed objects such as stanchions, drainage pipes, or ladders?	*5-7.1.1*			
p.	Is the lower indicator light wire rigged to the 1-foot flooding alarm sensors?	*5-7.1.1*			
q.	Is the upper indicator light wire rigged to the 3-foot flooding alarm sensors?	*5-7.1.1*			
r.	Are the batteries secured for heavy weather? ***Note:*** *If topside, batteries must be in a watertight box. The location should be carefully selected and secured from heavy seas. If possible, batteries should be inside the ship.*				
s.	Is battery ventilation adequate?				

5. DEWATERING

		Reference	N/A	Yes	No
a.	Is dewatering equipment required?	*5-8.3.1*			
b.	Are all main spaces accessible for adequate dewatering capability?	*5-8.3.3*			
c.	Is a list of spaces that are unreachable by dewatering equipment attached?				
d.	Location of pumps/generators/eductors:				
e.	Has equipment been tested?				
f.	Amount/location/size of hose:				
g.	Is adequate fuel available for pumps/generators?	*5-8.3.2*			

6. FIRE FIGHTING

		Reference	N/A	Yes	No
a.	Is fire fighting equipment required?	*5-8.2*			
b.	Have pumps been demonstrated to have sufficient suction lift and discharge head?	*5-8.2*			
c.	Are at least two P-100s or operating fire pumps and all other necessary fire fighting equipment on board?				
d.	Is there enough P-100 fuel on board?	*5-8.2*			
e.	Is means for storage of fuel adequate?				

7. NAVIGATION

		Reference	N/A	Yes	No
a.	Are proper navigation lights installed for towed unit?	*5-7.7*			
b.	Is each light rigged with two bulbs, so that if one burns out the craft still complies with COLREGS?	*5-7.7*			
c.	Is all wiring well-secured and protected from damage by the elements?				
d.	Is the tow equipped with a solar switch or time switch?	*5-7.7*			

		Reference	N/A	Yes	No
e.	Are the batteries secured for heavy weather? ***Note:*** *If topside, batteries must be in a watertight box. The location should be carefully selected and secured from heavy seas. If possible, batteries should be inside the ship.*				
f.	Is battery ventilation adequate?				
g.	Are the batteries charged with sufficient amperage available to keep the lights burning brightly for the duration of the trip?	5-7.7			
h.	Total ampere capacity of the bank: Sufficient amperage must be calculated and available to cover the following: (1) Wattage of the bulbs serviced (2) Distance of bulbs from battery source (wiring losses) (3) Duration of tow (taking into consideration the solar/time switch and length of the period of darkness).	*Table 5-4*			
i.	Are day shapes rigged in accordance with COLREGS?				

8. CARGO

		Reference	N/A	Yes	No
a.	Will craft have cargo on board?				
b.	If liquid cargo, give location and type (include any residual liquids):				
c.	Is solid cargo stowed below the main deck secured in position? If so, list location and type:				
d.	Is solid cargo stowed topside secured in position? If so, list location and type: ***Note:*** *All solid cargo on board must be well-secured from heavy weather. All cargo topside must be secured with wire straps and properly secured turn-buckles or equivalent securing devices. In some cases, shoring will be required.*				
e.	Will cargo stowed on board adversely affect the stability of craft? If so, revise stability calculations in Section 4 of this checklist.				
f.	Has a manifest of all cargo been prepared for the towing ship?				

9. MAIN TOWING GEAR

		Reference	N/A	Yes	No
a.	Have towing attachment points and fairleads (including chocks/bullnose) been non-destructively tested? ***Note***: *Dye penetrant recommended.*	*4-5*			

		Reference	N/A	Yes	No
b.	Date of last test:				
c.	Test procedure(s) used (visual, dye, MT): ***Note:*** *If there is any evidence of damage, rust, misalignment, or other damage, visual inspection should not be relied on.*				
d.	Has all chain in the towing bridle been measured in accordance with NSTM 581 and Appendix D? ***Note:*** *The towing bridle is normally chain on ocean tows. On some service craft, especially barges, wire has been successfully used. Wire should be used with extreme caution, however, due to problems with chafing.*	*4-6.6*			
e.	Is the Annual Towing Machine/Towing Winch Certification on hand?	*5-9.2*			
f.	Does the vessel have a copy of its Tow Hawser Certification?	*5-9.3*			
g.	Is the Master's Towing Certificate onboard (Commercial Vessels)?	*5-9.4*			
h.	Is towing bridle of sufficient size and strength, according to the restrictions listed below? The following restrictions apply: (1) For service craft up to 500 tons, no less than 1 1/4" chain. (2) For service craft above 500 tons, no less than 1 5/8" chain. (3) For ships, the bridle must be equal in size to the ship's anchor chain, but not less than 1 1/4". Large ships do not need chain larger than 2 1/4" when towed by U.S. Navy towing ships. More powerful commercial tugs will require larger chain bridles. (4) Non-magnetic chain and attaching hardware will not be used for towing bridles. (5) Single leg bridles of ships must be anchor chain or larger, but not less than 1 5/8". (6) The length of each leg of the bridle from the towing attachment point to the flounder plate after rigging is completed must be equal to or greater than the horizontal distance between the attachment points. (7) A bridle apex should be between 30 and 60 degrees, with 60 degrees the optimal angle. (8) On some ships with high bows (e.g., CV, AD, AOR, AFS), it may be necessary to rig a one or two-shot chain pendant between the bridle flounder plate and the towing hawser. ***Note:*** *Preparing activity should check with the towing activity as to the desired rig.*	*4-6.6*			
i.	Are all detachable links in the bridle legs and chain pendant locked with a hairpin? ***Note:*** *If not, the towing bridle is unsatisfactory.*	*4-6.6*			
j.	Are all bridle legs of the same size chain and equal in length when rigging is complete? Link count: ***Note:*** *To ensure accuracy, counting links prior to rigging and painting bench marks is the only positive method. Total links per bridle should be equal at the attachment point on the tow.*	*4-6.6*			

		Reference	N/A	Yes	No
k.	If a wire bridle is used, and there is a point of chafe on the tow, has sufficient chafing protection been provided? ***Note:*** *Chafing of wire bridles can be severe. Chafing protection must be used to prevent failures.*	*4-6.6*			
l.	If towing pads do not exist and bitts or cleats must be used, are they substantial enough to handle the strain of towing?	*6-2.6.2*			
m.	Are fairlead chocks and/or bullnose substantial enough to handle strain of towing?				
n.	Is the tow bridle fairlead angle sufficiently straight to preclude excessive side loading to fairlead points?				
o.	If mooring bitts are used, state the condition of bitts and surrounding deck areas. If any doubt exists, request that the area be non-destructively tested.	*6-2.6.2*			
p.	Is the towing bridle rigged with a backup system?	*4-6.6*			
q.	If mooring bitts are used a bridle attachment points, has heavy channel iron been welded across the bitts to prevent the wire or chain from jumping out? ***Note:*** *A minimum of 4-inch channel iron is recommended.*	*6-2.6.2*			
r.	Type of backup, cleats, bitts, padeye:	*4-6.6*			
s.	Distance from towing pad or bitts to backup point:				
t.	When using a chain bridle and sets of bitts as the towing point, it is preferable to terminate the chain before reaching the bitts, using wire to make the connection to the bitts. When load-sharing between two sets of bitts, take only one round turn around one barrel of the first set and lead the wire to the second set, where it is terminated with a round turn followed by "figure eights". Has this been done?	*4-6.6*			
u.	Has all slack been taken out of the "figure-eights"?	*4-6.6*			
v.	Has all the slack been removed from the backup wires so that all parts will take an equal strain if the attachment points fail?	*4-6.6*			
w.	In most cases, the bridle legs are run through closed chocks before being connected to the towing pads or bitts. The lead angle from the connecting to the chocks must be fairly straight to prevent bending and failure of the chain where it passes through the chock. Does the towing rig conform to the above?				
x.	Is there sufficient and adequate metal thickness at all potential chafing points to prevent the bridle from cutting into the chocks, gunwale, or hull?				
y.	Is the size of the bridle retrieving pendant adequate (i.e., providing a 4:1 safety factor in lifting bridle weight, but no less than 5/8-inch rope?)	*4-6.8*			
z.	Is there an adequate number of wire clips securing the retrieval pendant?	*Table 4-1*			
aa.	When attached from the bow of the tow to the flounder plate, is there enough slack to allow the retrieval pendant to droop slightly with no strain when the unit is being towed?	*4-6.8*			
bb.	Are flounder plates and plate shackles of approved design, and rigged in accordance with this manual?	*Appendices D and I*			
cc.	Is there a clearance in excess of 1/16" in securing pins in plate shackles, flounder plates and other towing jewelry? ***Note:*** *If not, the rig is unacceptable.*	*Appendix I*			

		Reference	N/A	Yes	No
dd.	All plate and safety shackle pin nuts must be locked with a minimum of a 5/16-inch machine bolt through a drilled hole in the plate shackle nut and pin. Secure the machine bolt in place with jam nuts. It is highly recommended that the bolt be peened over. Has this been done?	*4-6.1* *Appendix I*			
ee.	Lateral movement must be removed from the plate shackle connections by using washers or welding bosses on the plates. Has this been accomplished? ***Note:*** *Welding is not acceptable.*	*Appendix I*			
ff.	Are all safety shackles of the approved types and materials listed in the Appendix D?	*4-6.1* *Appendix D*			
gg.	If a multiple tow is planned (and you are the planning activity), have you checked to ensure that all the necessary equipment is available to rig and stream the tow in accordance with the appropriate towing method? ***Note:*** *Standard U.S. Navy practice allows three possible versions: the Christmas Tree, Honolulu, and Tandem rigs. Any rig selected must be rigged in accordance with this manual.*	*Appendix I*			
hh.	Rig selected:				
ii.	Normally, an open-ocean tow has solid connecting jewelry, but in cases of damaged and some calculated risk tows (such as some SINKEXs), an emergency quick-disconnect method such as a pelican hook is advisable. If this is such a tow, is an emergency quick disconnect provided?	*6-6.2.3* *6-7.6*			
jj.	If so, provide the method used:				
kk.	If an emergency quick disconnect is provided, will all jewelry fit through all fairleads through which it must pass (e.g., the bullnose)?	*6-7.6*			
ll.	Has the system been designed with a safety link?	*4-10*			
mm.	Identify the weakest element in the towing rig: Breaking strength of the weakest element:				

10. ANCHORING

		Reference	N/A	Yes	No
a.	Has an emergency anchoring system been rigged?	*5-8.5*			
b.	Is anchor rig capable of holding the vessel in 60' of water with at least 3:1 ratio of scope of depth?	*5-8.5*			
c.	Is there a need for a deeper anchoring system?				
d.	If so, what is the depth required?				
e.	Is the rig capable of meeting this deeper requirement with at least a 3:1 ratio of scope to depth?				
f.	Is it rigged for quick release?	*5-8.5*			
g.	Is it secured for heavy weather?				
h.	Has the anchor windlass brake been tested?				
i.	If plans have been made to anchor the tow at port of delivery, is power available to raise the anchor?				

11. SECONDARY TOWING GEAR

		Reference	N/A	Yes	No
a.	Are the secondary towing system's attachment and fairlead points adequate to tow the vessel?	*4-5*			
b.	Is adequate chafing protection provided for the vessel's secondary towing systems?				
c.	Is the secondary towing pendant *or the ship's emergency tow pendant* at least 1 5/8" wire rope?	*4-4*			
d.	Is the secondary towing pendant stopped off in bights on one side of the tow?	*4-4*			
e.	Are the stops sufficient to hold in heavy weather, but accessible to allow cutting and light enough to be broken without damaging the towing pendant or tow?	*4-4*			
f.	Will the secondary pendant fall free without turns that will cause kinking as they pull out?	*4-4*			
g.	Is the secondary towing pendant fitted with a synthetic line messenger to facilitate passing it to the tug?	*4-4*			
h.	If the tow is unmanned, is polypropylene floating retrieval line (5"-8" circumference) attached to the end of the messenger with a small buoy secured at its end?	*4-4*			

12. SPECIAL CONSIDERATIONS

Some types of tows require special consideration. For instance, YTBs, YTMs, and other self-propelled service craft were not designed to go to sea and are not very seaworthy. In these craft, the watertight envelope must be absolutely complete; they have low freeboards and water will constantly be breaking over them in moderate seas. Because of the constant pounding of the seas caused by their flat bottoms, submarines are not designed with towing in mind. Generally, a towing padeye is installed near the sail as a single towing point. See Section 7-5 and Appendix J of the *U.S. Navy Towing Manual* for data concerning submarine tows. Extensive information concerning towing of unmanned, defueled, nuclear powered submarines is contained in NAVSEAINST 4740.9 Series. (For unmanned, defueled, nuclear powered cruisers, see NAVSEAINST 4740.10 Series.)

There are many hulls whose design will require special towing rigs. Additional work may be required to rig an applicable bridle to ensure safe delivery of a craft from port to port. This will require additional lead time to prepare the tow(s) for ocean transit. Submarines, wooden-hull mine sweepers, sailing craft, etc., fall into this category.

When towing a sharp "V-shaped" hull that has a bullnose and a bulbous bow/sonar dome, the single leg bridle is the preferred method of rigging. Rig using at least two shots of the tow's anchor chain if that chain is acceptable.

13. REMARKS:

H-2. SAMPLE CERTIFICATE OF SEAWORTHINESS/DELIVERY LETTER

FIRST ENDORSEMENT

1. Upon inspection of the tow described above, the following unsatisfactory conditions were found, which render the tow unseaworthy or not ready for towing (if none, so state).

    a.

    b.

    c.

    d.

2. (Cross out the statement which is not applicable).

a. I find the tow described above in a condition satisfactory for towing, and hereby assume responsibility for delivery to the port of destination prescribed in my sailing orders.

b I will accept the tow as an acceptable risk only upon authorization of my operational commander. I have notified my operational commander of the reasons for this action.

Commanding Officer, USS ______________________ Date ______________

SECOND ENDORSEMENT (To be accomplished only if an acceptable risk tow is acceptable to delivery authority).

1. The following conditions listed in the first endorsement remain uncorrected.

    a.

    b.

2. It is requested that you accept this tow in the above condition as an acceptable risk.

______________________________ ______________________________

Representative of command having cognizance of towed unit. Date

THIRD ENDORSEMENT

1. As authorized by ___________________________________
(DTG reference of operational commander's message)

I accept this tow, with conditions existing as described in the second endorsement, as an acceptable risk for delivery to the port designated in my Sailing Orders.

____

Commanding Officer, USS _____________________________ Date _______________

____

SAMPLE DELIVERY LETTER

From: (Receiving Activity)

To: (Commanding Officer of Towing Vessel)

1. Received custody of (describe tow) this date.

_________________________________ _____________________________________

Representative of Receiving Activity. Date

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Appendix I

TOWING RIGS

I-1 Introduction

This appendix includes towing plans and drawings of towing equipment and rigging associated with towing operations. Towing rigs can be made up in various configurations. Select the tow rig based on its past performance and the needs of the particular tow. Although most Navy tows are simple, single-tug, single-unit operations, some tows are considerably more complex, consisting of a single tug with multiple towed units. Occasionally, the displacement of the towed unit requires using more than one tug.

The enclosed drawings are intended to serve as both guidance and examples of typical tow configurations. Exercise care in selecting compatible components. Keep these important points in mind:

- Each leg of a bridle should be strong enough to assume the entire resistance of the tow.
- When using underiders, using chain bridles and pendants will promote a deeper catenary and minimize interference with intermediate tows.
- Towing flounder plates and plate shackles are designed to be fabricated easily. Flounder plates and cheeks of plate shackles can be fabricated from common steel (that is, ABS Grade A or ASTM A-36). Pins must be machined from 150,000 psi minimum yield material such as AISI 4140. When pins are fabricated, it is recommended that a material certification be required.
- Plate shackles shown in these drawings are not necessarily suitable for beach gear or heavy lifting rig applications. These efforts generally require more robust hardware.

I-2 Single Tug, Single Tow Configurations

Three common variations of the single tug, single tow configuration are a single hawser with pendant, a single hawser with bridle, and towing alongside. A fourth variation, the Liverpool Bridle, is used in special circumstances where extra control is required.

I-2.1 Pendant or Single Leg Rig

The pendant rig is the simplest and most straightforward rig and generally is used for open-ocean towing of ships with fine bows, sonar domes, bulbous bows or when the tow is most stable in this configuration (see Figure I-1). All of the components are linked in a series. A distinguishing element of the pendant rig is the deployment of a single chafing pendant to a single attachment point on the towed vessel. The pendant rig is usually used for emergency towing. Outboard of the tow's fairlead, the chafing pendant usually is connected via a leading chain and/or a towing pendant to the tug's hawser. The advantage of the pendant rig is its ease of connection. There is little, if any, likelihood of the pendant fouling on the cutwater or other outboard structure

I-2.2 Bridle Rig

CAUTION
Each leg of a bridle should be strong enough to assume the entire resistance of the tow.

The bridle rig is characterized by a two-legged bridle instead of the single pendant on the towed vessel (see Figures I-1 through I-3). The length of each bridle leg should be approximately equal to the beam of the towed vessel. The fitting at the apex usually is a

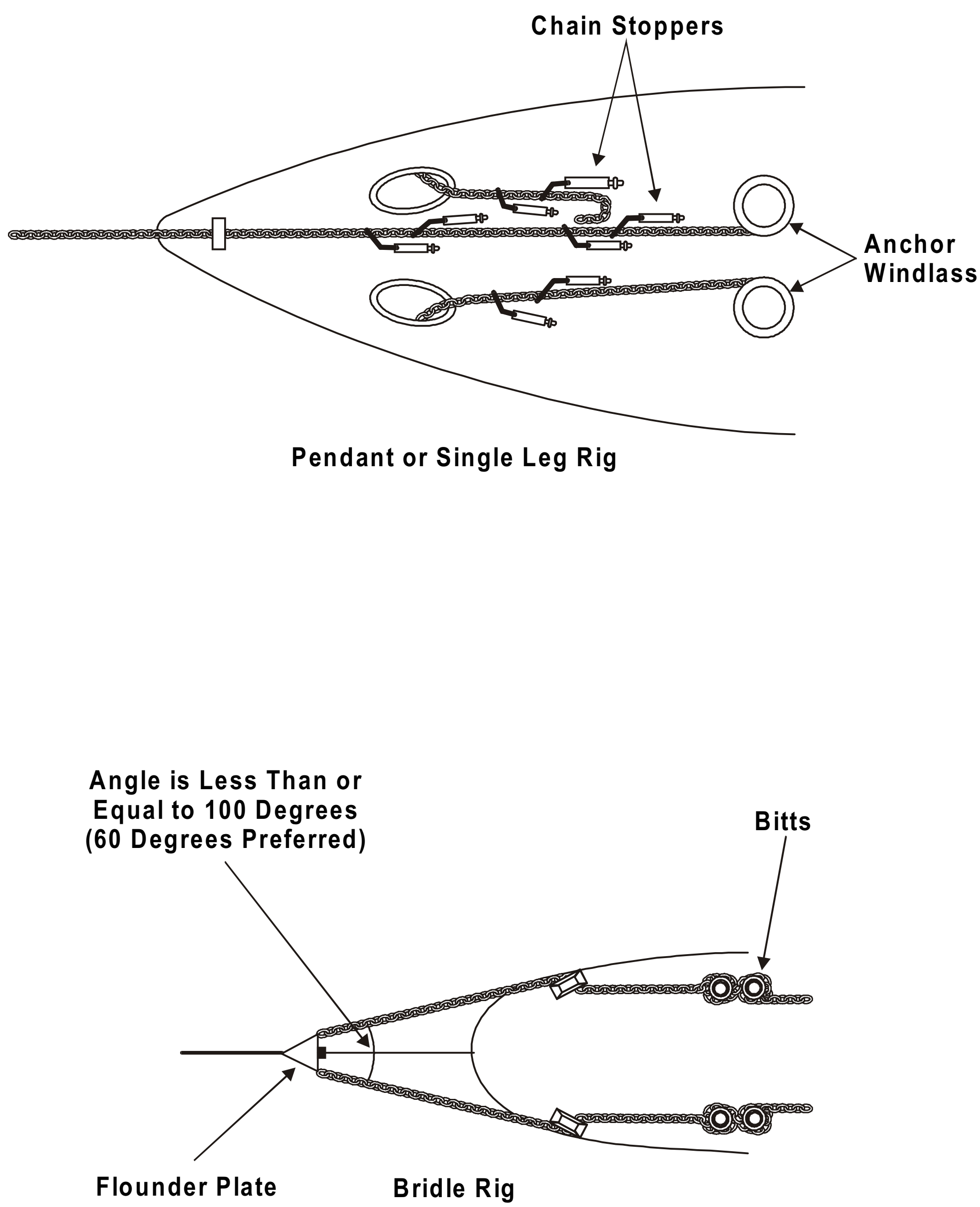


Figure I-1. Towing Rigs (Plan View).

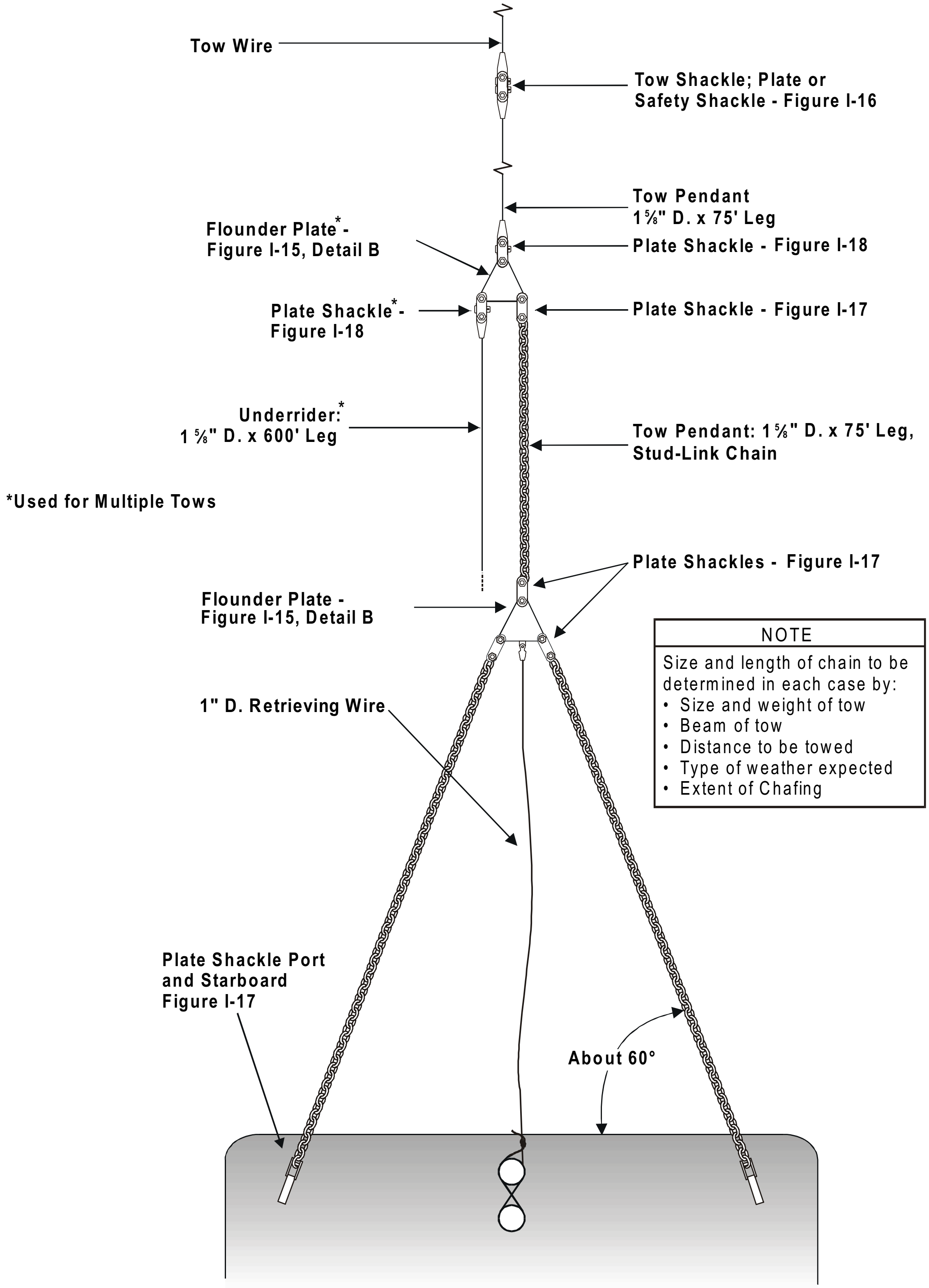


Figure I-2. Example of Chain Bridle with Chain Pendant.

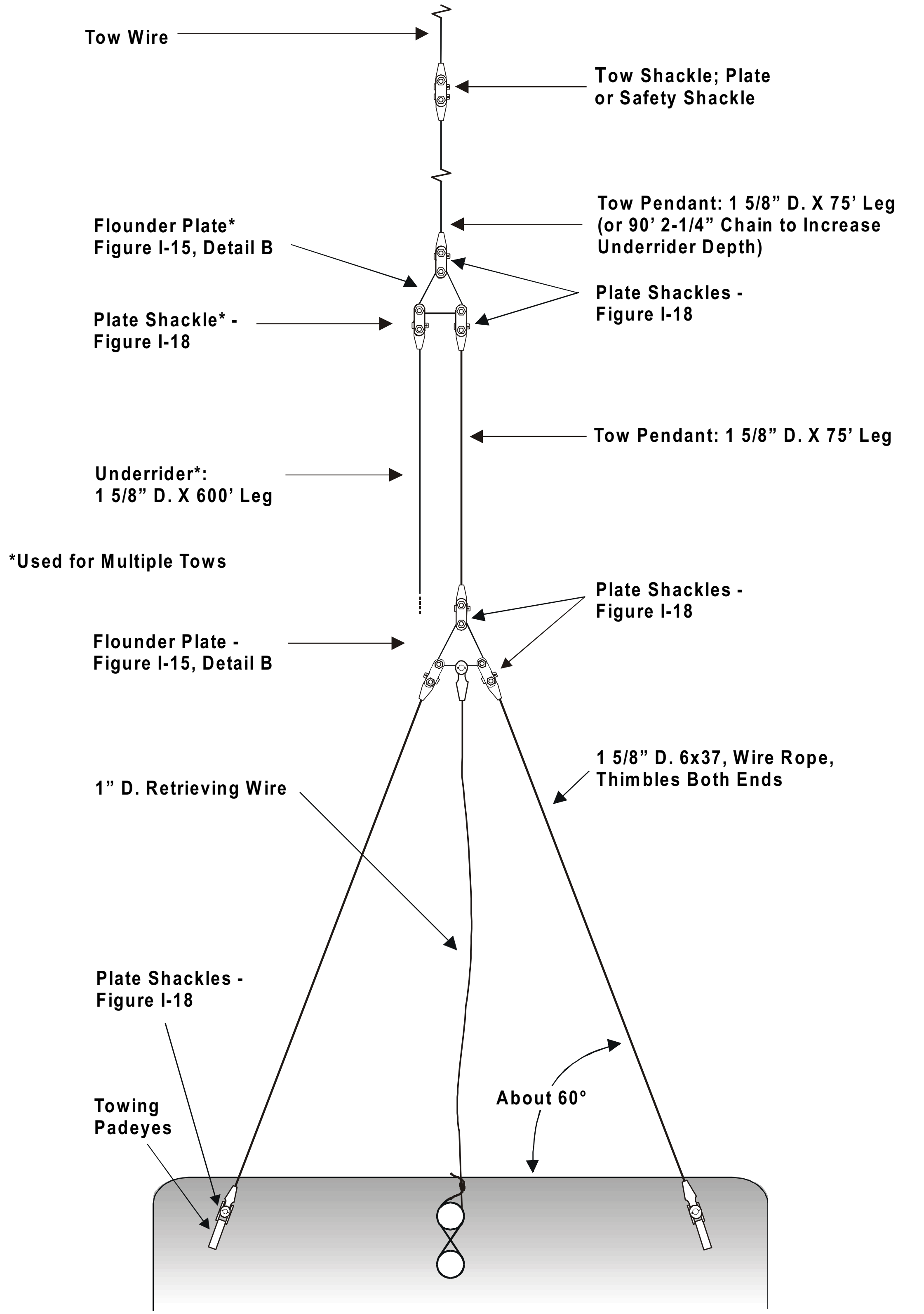


Figure I-3. Example of Wire Bridle with Wire Pendant.

flounder plate with the two bridle legs connected at its base and the apex usually connected to the lead chain and/or towing pendant, which in turn is connected to the tow hawser.

The bridle rig places more and heavier rigging outboard of the towed vessel. This can lead to rigging problems on the deck of the tow. Furthermore, the bridle rig, by definition, uses two off-centerline fairleads. As a consequence, if the tow does not track the tug directly astern, there may be an off-center dynamic load. This load, while tending to be self-correcting, unbalances the loads on each bridle leg. Therefore, each bridle leg must be of full towline strength. Finally a critical problem of the bridle rig occurs when turning, or when the tow sheers off to the side of the tug's track, and the bridle leg on the far side can ride against the cutwater of the tow, causing damage to itself as well as to the tow.

In many cases, the foredeck arrangement, hydrodynamic characteristics or need to tow the vessel backwards does not permit the use of a bridle rig. For example, aircraft carriers and LSTs have forecastle arrangements that require using a pendant rig. Bridle rigs are commonly used on ships with blunt bows and barges.

I-2.3 Towing Alongside

Towing alongside or "towing on the hip" is a configuration often used in congested waters (see Figure I-4). Towing alongside offers excellent control. This configuration is not recommended for the open ocean, however, because of motion between the tug and tow in a seaway. When complex maneuvering is required, consider having harbor tugs to do the job or assist during difficult phases of the maneuvers.

For towing alongside, the tug generally secures to one side of the tow, well aft on the

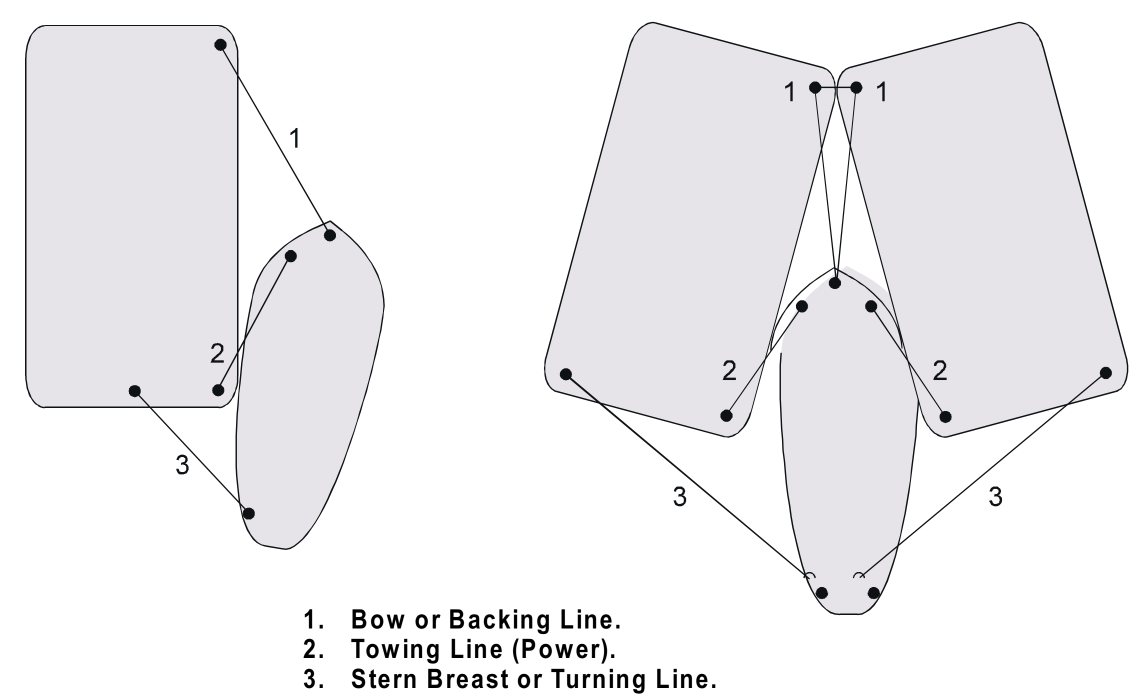


Figure I-4. Towing Alongside.

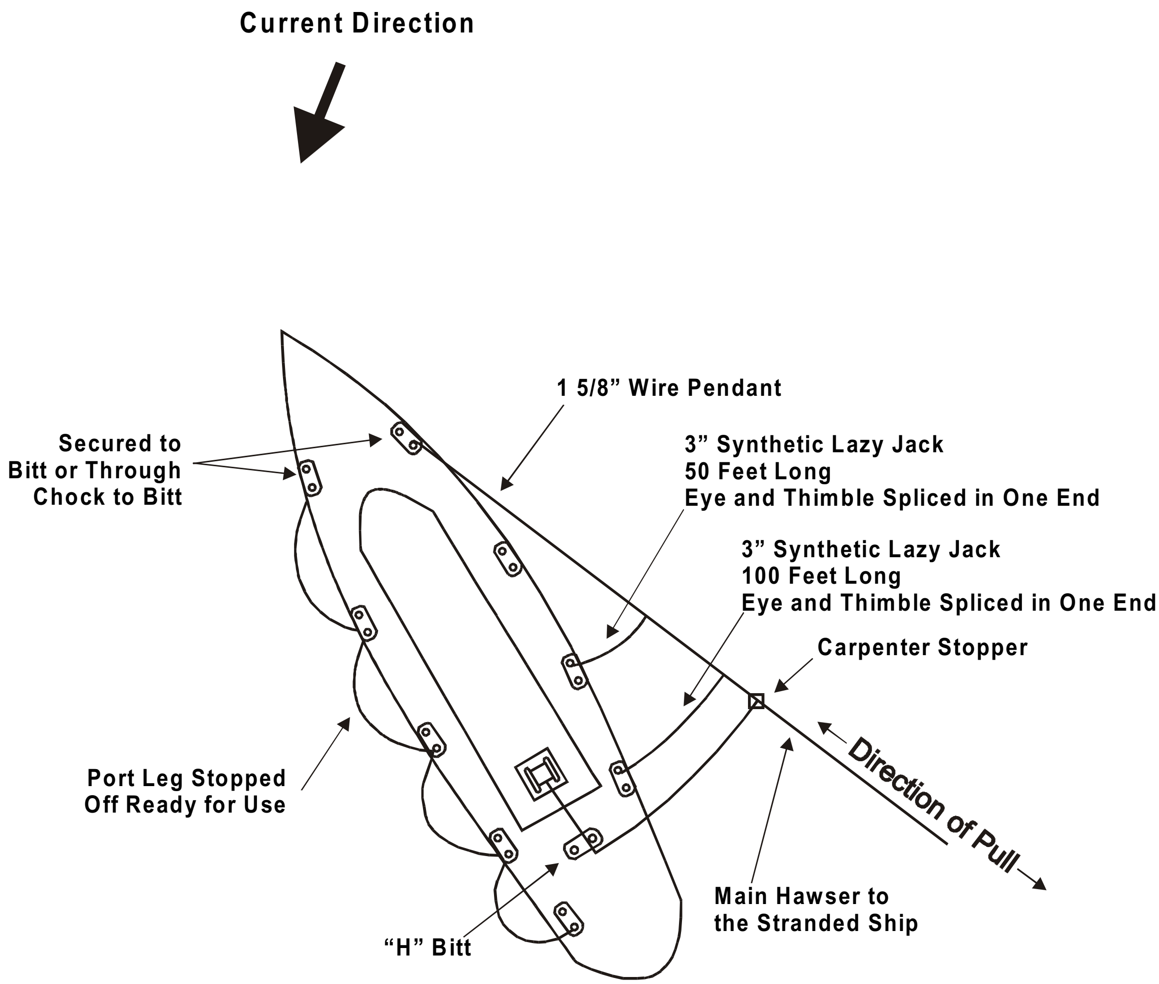


Figure I-5. Liverpool Bridle.

tow to increase the control effectiveness of her propellers and rudder.

CAUTION
When towing alongside, keep all lines taut until ready for streaming the tow. This will prevent the tow from pounding alongside the tug and ensure effective control of the tow.

I-2.4 Liverpool Bridle

CAUTION
In operating the Liverpool Bridle, limit the tension to the safe working load of the bridle's 1 5/8-inch wire rope pendant.

The Liverpool Bridle, as shown in Figure I-5, is a towline harness designed to permit a towing vessel to maintain fine control over heading and position. The Liverpool Bridle is needed in circumstances, typically strandings, where currents and weather make it impossible for a conventionally rigged tug to maintain its station in relation to the tow. The Liverpool bridle is particularly useful when the heading of the tug must be different than the direction of application of towing force.

The Liverpool Bridle requires:

- A towing winch
- One carpenter stopper secured to the towline
- Two pendants of 1 5/8-inch wire rope with a soft eye spliced in one end and an eye with a thimble spliced in the other end.
- Two 3-inch synthetic fiber lazy jacks: one 50 feet long and the other 100 feet long, each with eye and thimble spliced in one end. The lazy jacks are retrieving lines only and take no strain.

One pendant is used on the starboard side, the other on the port side. By rigging a bridle on either side of the tug, the towing point can be shifted from side to side to facilitate ship control. The pendants should be long enough to run slack from the forward rail or shoulder bitts, which are closest to the pivot point of the ship, outboard and in over the quarter to a point on the centerline about 20 feet abaft the towing H-bitts. Thus configured, the point of tow is forward of the vessel's normal pivot point, and the tug is able to maneuver to keep her head in the desired direction.

A typical application of a Liverpool bridle is shown in Figure I-6.

I-3 Single Tug, Multiple Unit Tow Configurations

Single tug, multiple unit tows consist of one tug and several tows; the connection and makeup of the tows can be varied. The U.S. Navy currently uses four versions: the Christmas, Honolulu, Tandem, and Nested rigs.

I-3.1 Christmas Tree Rig

The Christmas Tree rig is used for open-ocean towing (see Figures I-7 through I-10). It requires a review of water depths and bottom conditions prior to use. The catenary of the towline from tug to the first tow and subsequent connecting wires must be deep enough to ensure that the underrider passes safely below the bow of the leading tow(s). It is important to have adequate water depth to prevent grounding the towline. Using chain bridles and pendants will promote a deeper underrider and minimize interference with intermediate tows.

Harbor tug assistance usually is required to break up the Christmas Tree rig before entering port. With the assistance of harbor tugs, it is feasible to break out one of the tows without disrupting the remainder. Although a strong rig, it is difficult to make up and dis-

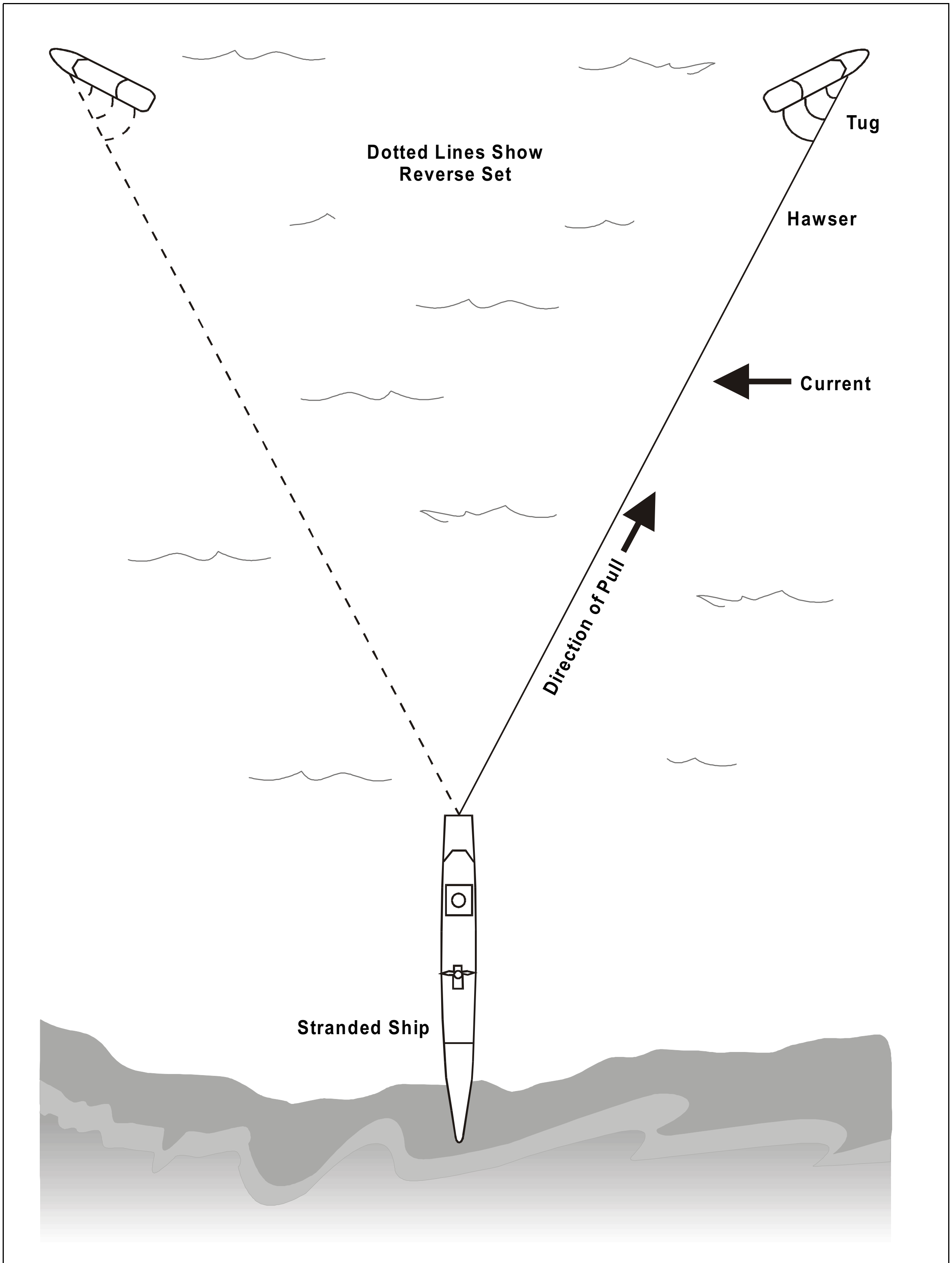


Figure I-6. Use of Liverpool Bridle on Stranding Salvage.

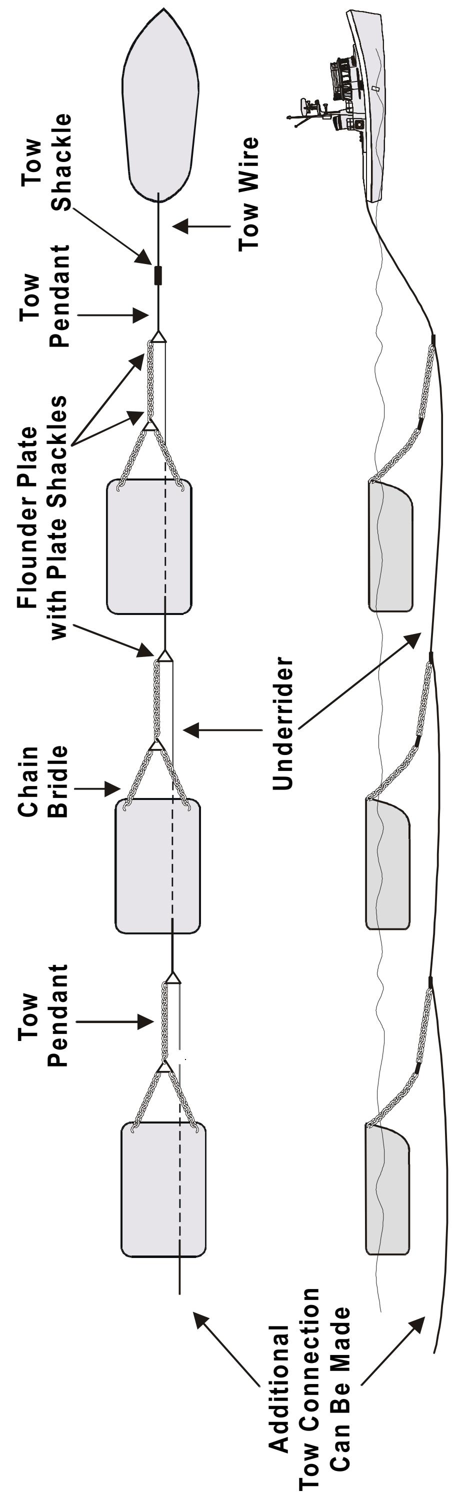
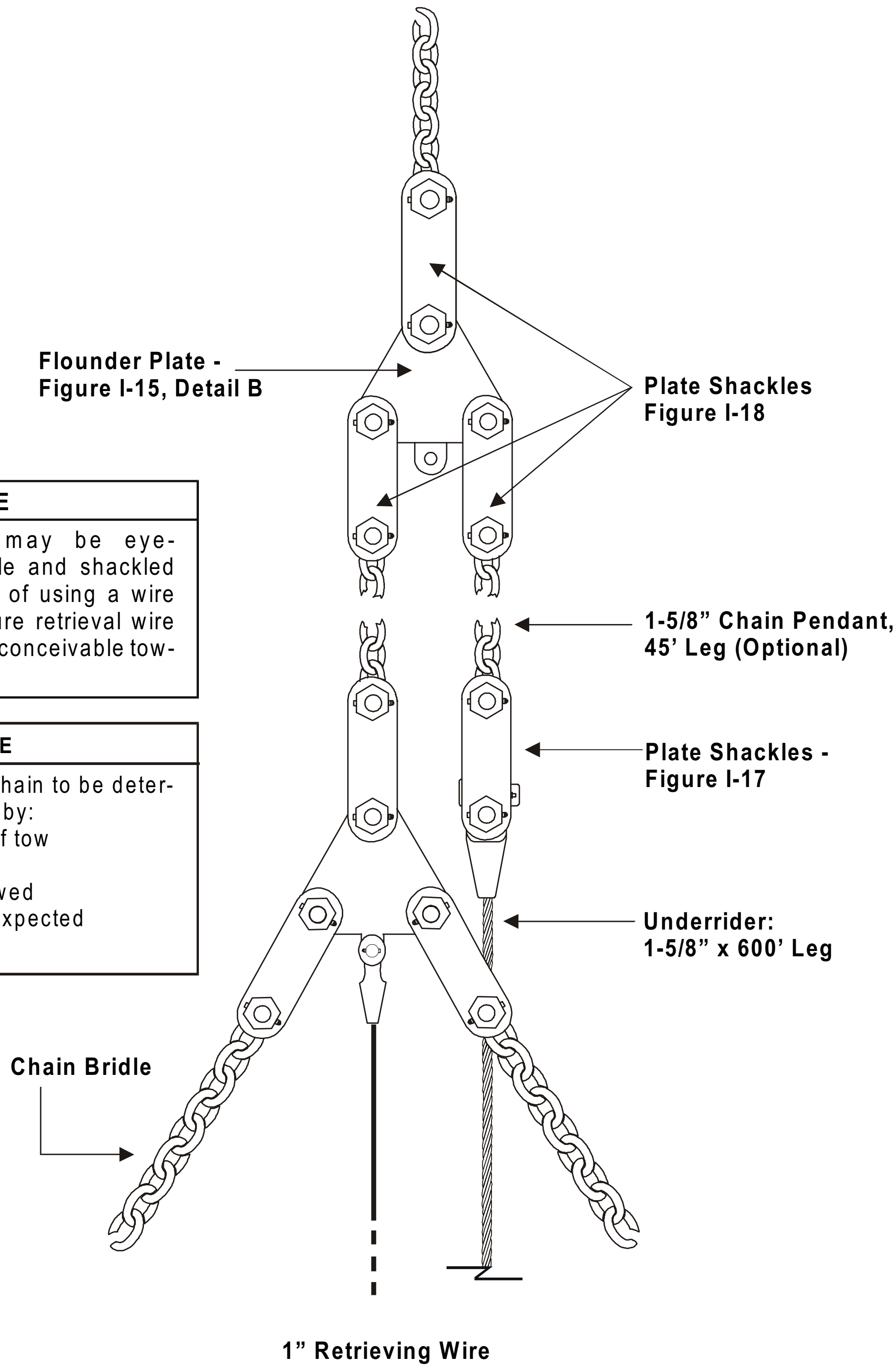


Figure I-7. Christmas Tree Rig.



NOTE

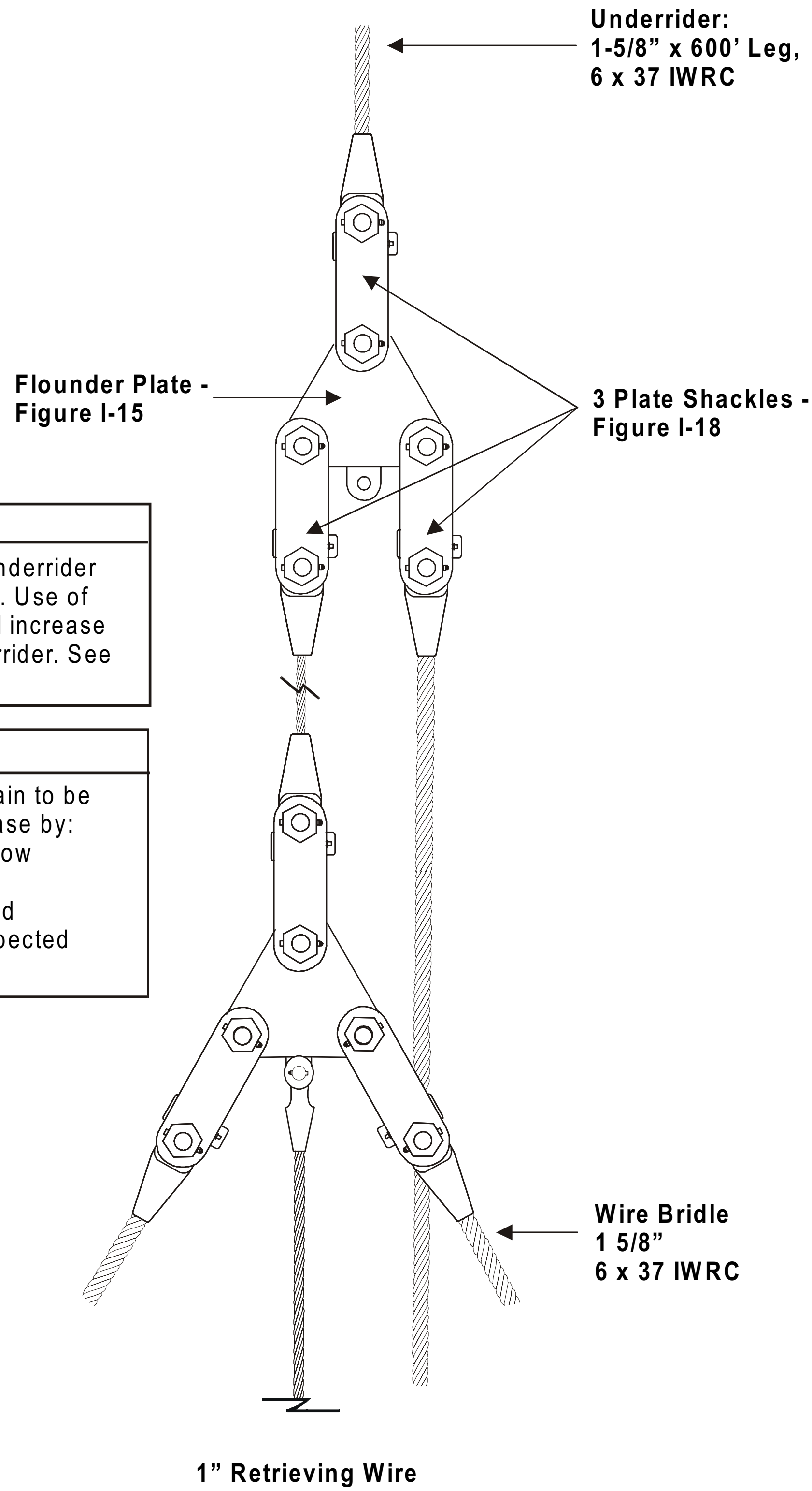
Retrieving wire may be eye-spliced over thimble and shackled into padeye in lieu of using a wire rope socket. Ensure retrieval wire hangs slack at any conceivable towing angle.

NOTE

Size and length of chain to be determined in each case by:

- Size and weight of tow
- Beam of tow
- Distance to be towed
- Type of weather expected
- Extent of Chafing

Figure I-8. Example of a Christmas Tree Rig Configuration with Chain Bridle.



NOTE

Consider the risk of underrider interference with tows. Use of chain components will increase the depth of the underrider. See Figure I-8.

NOTE

Size and length of chain to be determined in each case by:

- Size and weight of tow
- Beam of tow
- Distance to be towed
- Type of weather expected
- Extent of Chafing

Figure I-9. Example of a Christmas Tree Rig Configuration with a Wire Bridle.

connect and does not facilitate getting all elements in step. Figure I-10 shows a series of barges at the pier, ready for streaming.

The forward most tow wire will be subject to the total resistance of all of the attached assets. The strength of this gear must be checked carefully.

I-3.2 Honolulu Rig

The Honolulu rig was developed for inter-island towing, where individual units of multiple tows were delivered to or picked up from different ports (see Figure I-11).

The first tow streamed is connected to the main tow wire and streamed farthest aft. Additional tows are connected with auxiliary tow wires to quarter bitts or auxiliary drums. The Honolulu rig allows independent connection of the two tows, disconnecting and control are readily workable, and it is relatively uncomplicated to get both tows in step with the tug. Additionally, each tow wire is subject to the resistance of only one asset.

I-3.3 Tandem Rig

The Tandem rig, with its close-coupled tows, is generally used only in congested waters where good control is required (see Figure I-12). This is the least desirable of the single tug/multiple tow arrangements, as it lacks the flexibility and control of the other rigs for break-up upon entering port.

The rig connects the tug to the first tow, with subsequent tows connected to the one in front of it. The intermediate towline connects the first tow to the second, and must allow a proper catenary depth to minimize the surging action between the tug and first tow, and between the first and second tows. It is difficult to keep all elements in step with this type of rig. Similar to the Christmas Tree Rig, the forward most tow is subject to the forces of all assets. It may be that the fittings available for tow points on the after end of the first tow are insufficient to withstand the strain of subsequent tows. Remember that these must not only survive the steady tension of the additional tows, but also the dynamic tensions. These attachment points must be inspected using the same criteria for primary attachment points.

I-3.4 Nested Rig

A nested rig tow employs multiple tows secured alongside each other so they may be towed as a single unit. Advantages of using a nested rig include maneuverability, ease of preparation, and ease of retrieval. Because the nested vessels can work against each other and inflict considerable damage, this rig is to be used only in protected waters. A nested rig is generally controlled by a tug tied alongside or by specially designed pusher boats. Rider lines can be used, but a short scope should be maintained to ensure adequate control. Care must be taken to ensure barges do not break free during these operations.

When using any of the above rigs, use one of the flounder plate arrangements shown in Figures I-8 and I-9. Chain should be used as bridles when possible to reduce chafing. Wire bridles can be used if proper care is taken to minimize chafe points and it is calculated that wire provides sufficient strength when using the christmas tree rig or the tandem rig. (Remember that the forward most gear will be subject to the combined tow forces of all of the attached assets. This gear should be sized accordingly.)

I-4 Multiple Tug, Single Tow Configurations

It may be desirable to use more than one tug for a single tow. Greater power, increased towing speed and better control may be obtained in a multiple tug tow. Multiple tugs are generally used to tow large ships, deep-draft large-displacement dry-docks, deep-draft barges, or battle casualties.

I-4.1 Side-By-Side Towing

Figure I-13 shows side-by-side tugs towing a single tow. Each towline should have its own connector and chafing fairlead. There is no universally preferred method of two-tug towline arrangement. Most operators prefer to tow "side-by-side" with equal hawser scopes to avoid sweeping over the other tug's towline. A few operators prefer different scopes to minimize the risk of tug collision. In such cases, the more powerful tug is designated lead tug, with a longer hawser scope. The lead tug may use a longer lead chain to increase the catenary depth. This reduces the chance of interference, should the following tug suffer some untoward event that results in its crossing the lead tug's towline.

I-4.2 Steering Assistance

At times when a tug has a tow at short scope in restricted waters, steering assistance is needed. This assistance can be provided by another tug, normally a harbor tug, astern of the tow. Usually the steering tug's main effect is to restrain the movement of the tow, primarily in yaw. U.S. Navy towing ships rarely perform this function. Use of steering tugs varies widely, depending upon local practice, tug design, and pilot preference. No attempt is made herein to provide information on steering tug connections.

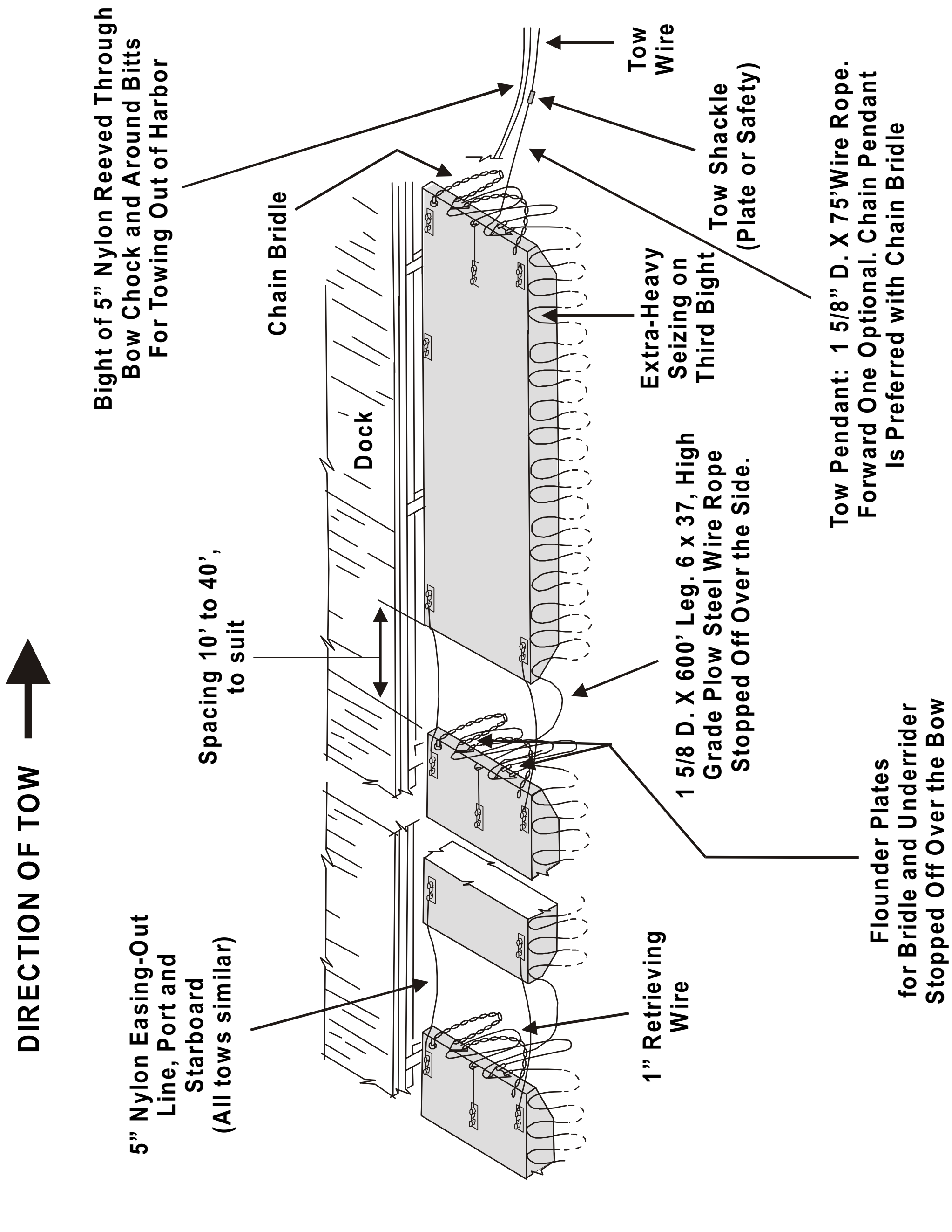


Figure I-10. Three-Barge Tow in Christmas Tree Rig Ready for Streaming.

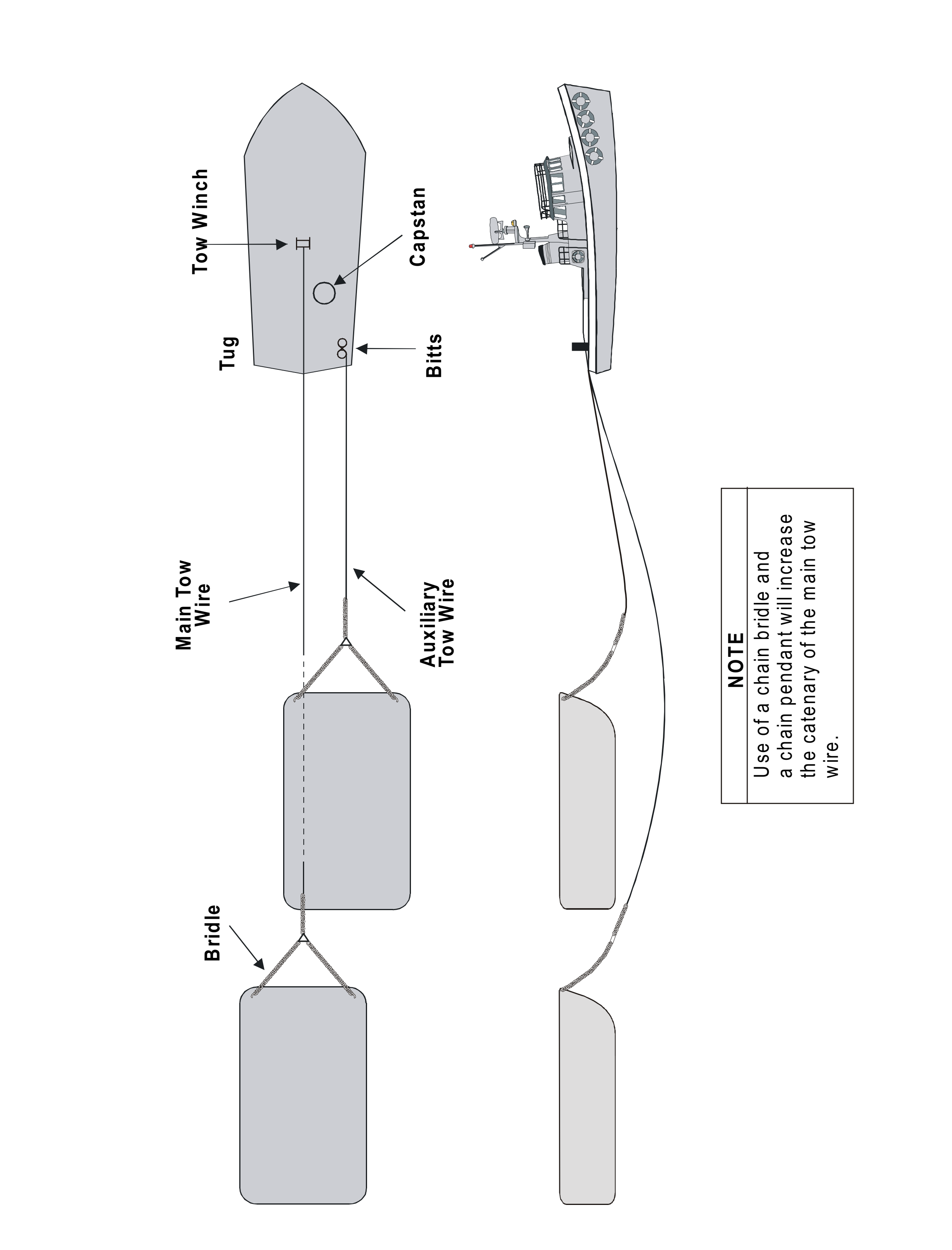


Figure I-11. Honolulu Rig.

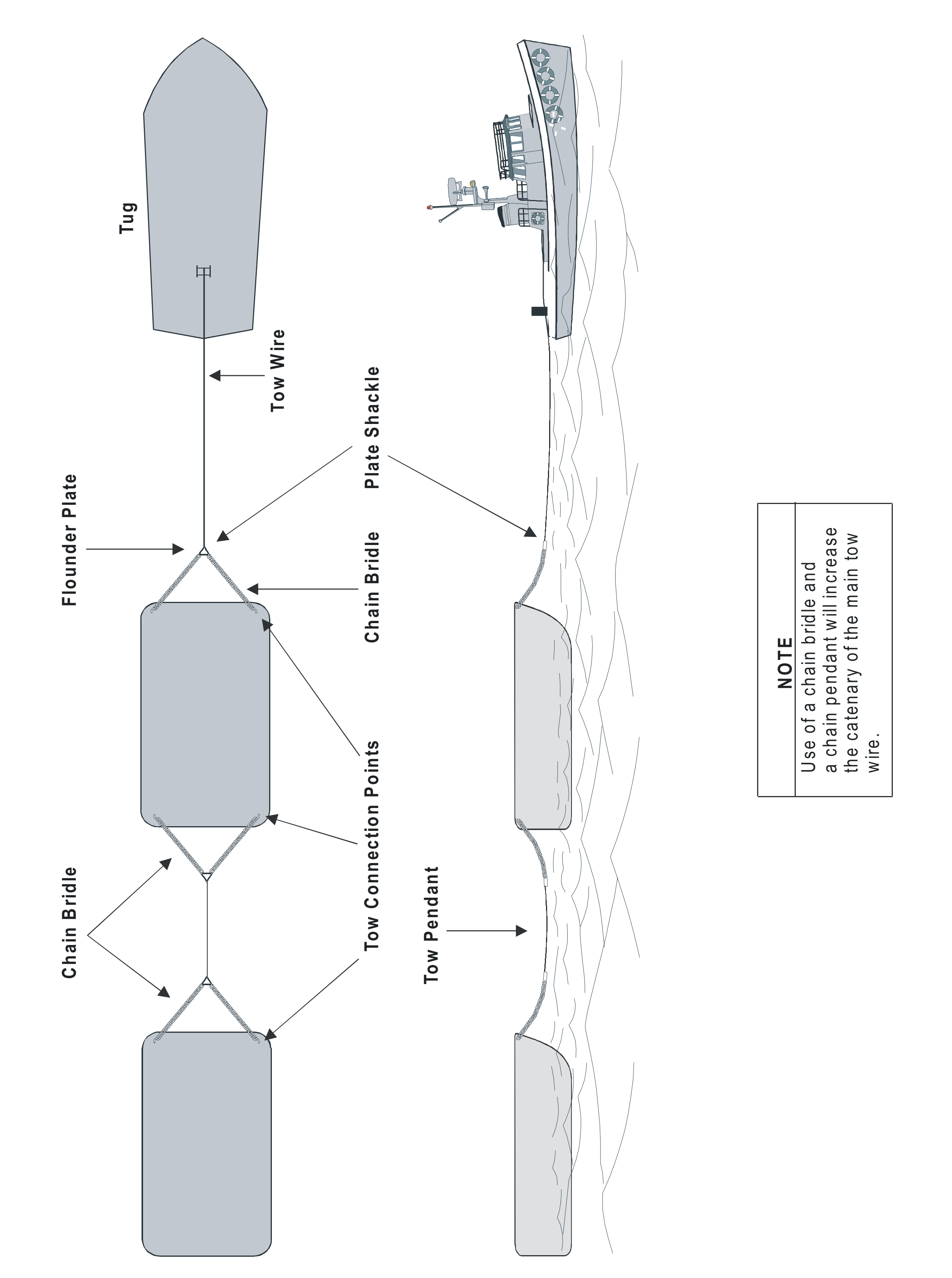
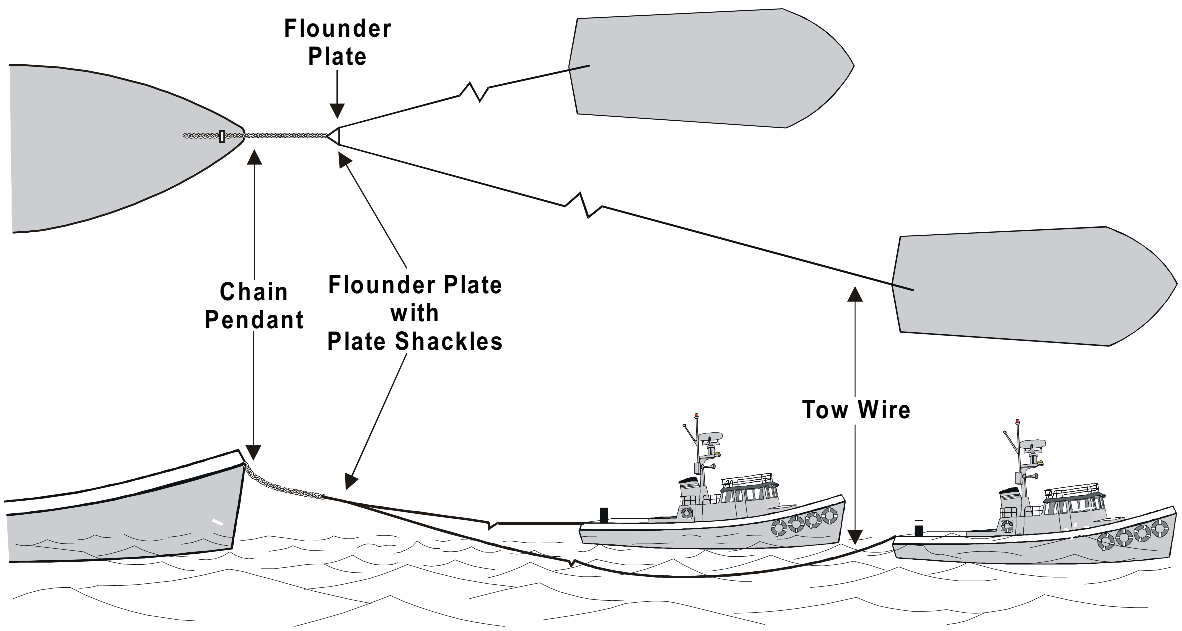


Figure I-12. Tandem Rig.



NOTE
The side-by-side towing arrangement shown here, with the tugs towing on unequal towline scopes, is not necessarily preferred over an arrangement where the tugs use equal towline scopes. See Section I-4.1.

Figure I-13. Two-Tug Tows.

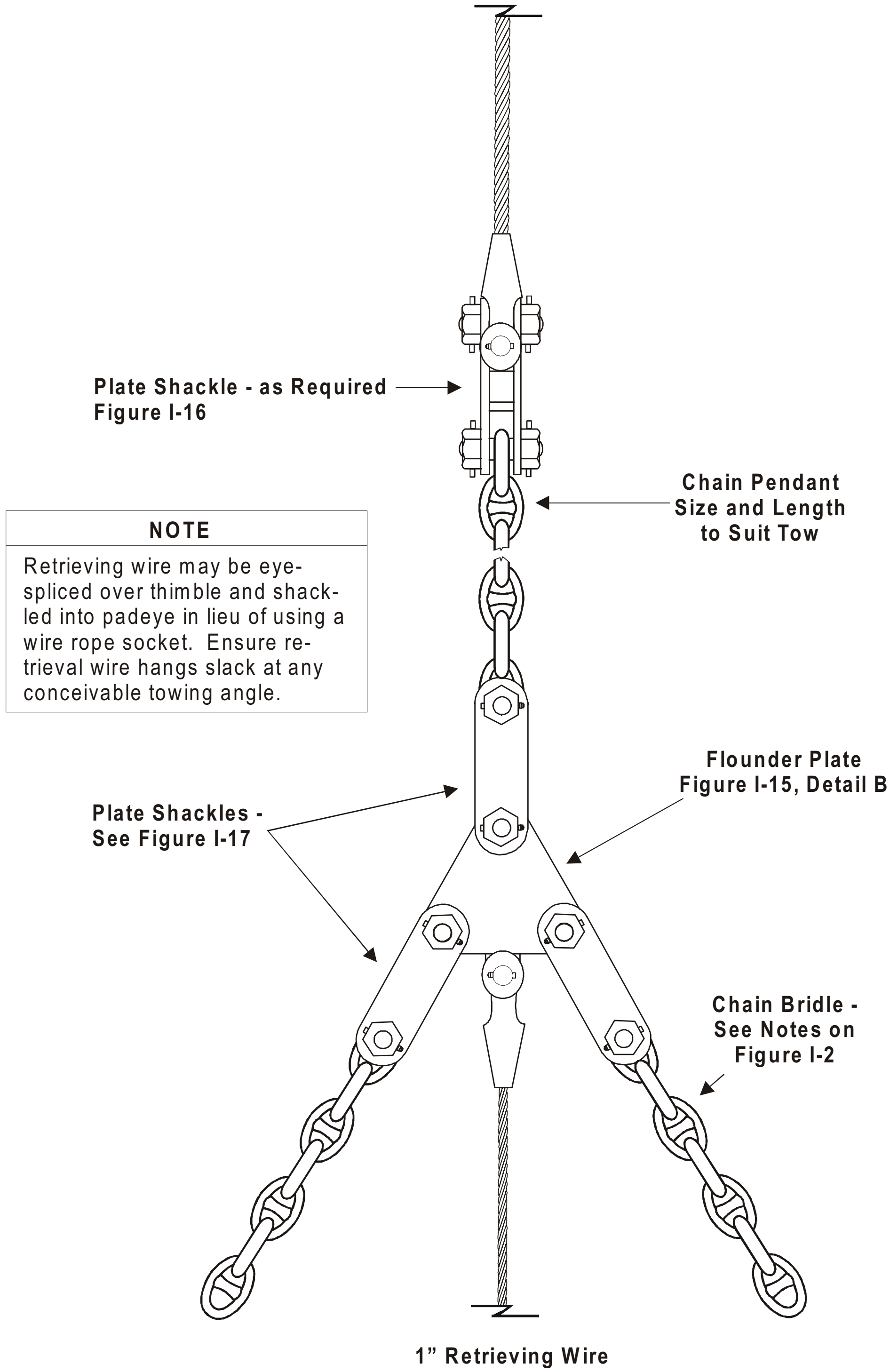
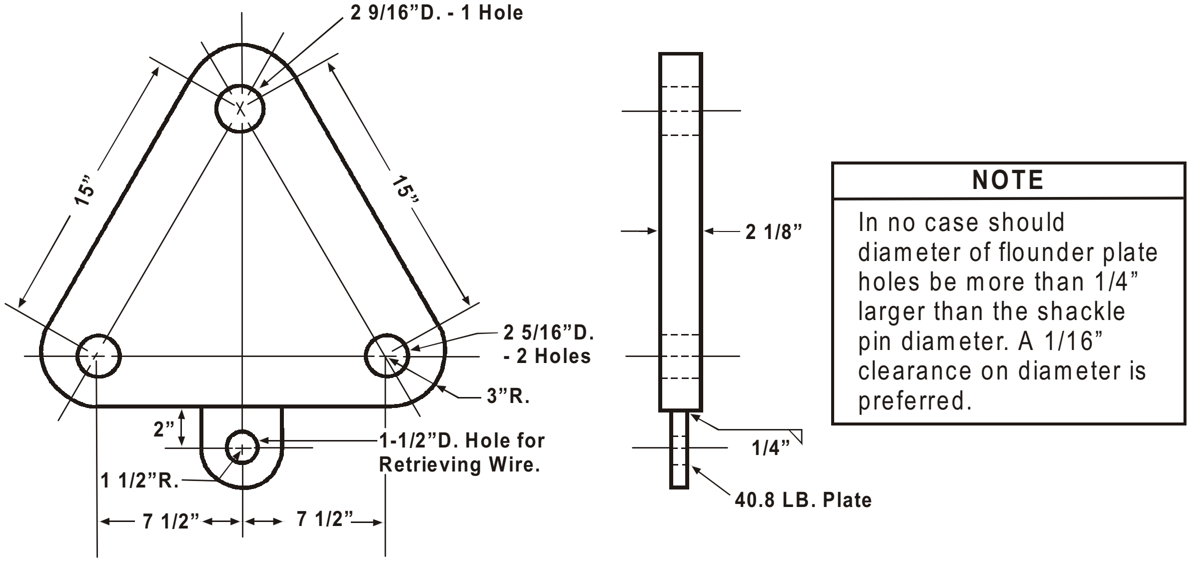
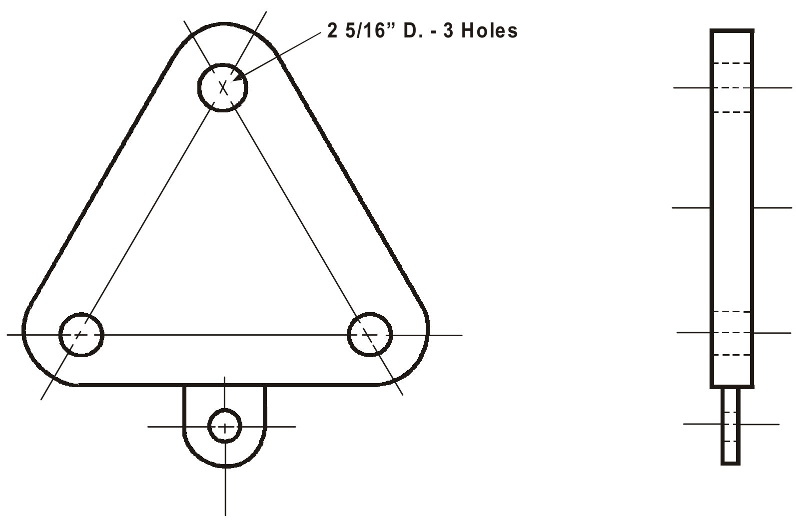


Figure I-14. Example of Chain Bridle and Pendant.

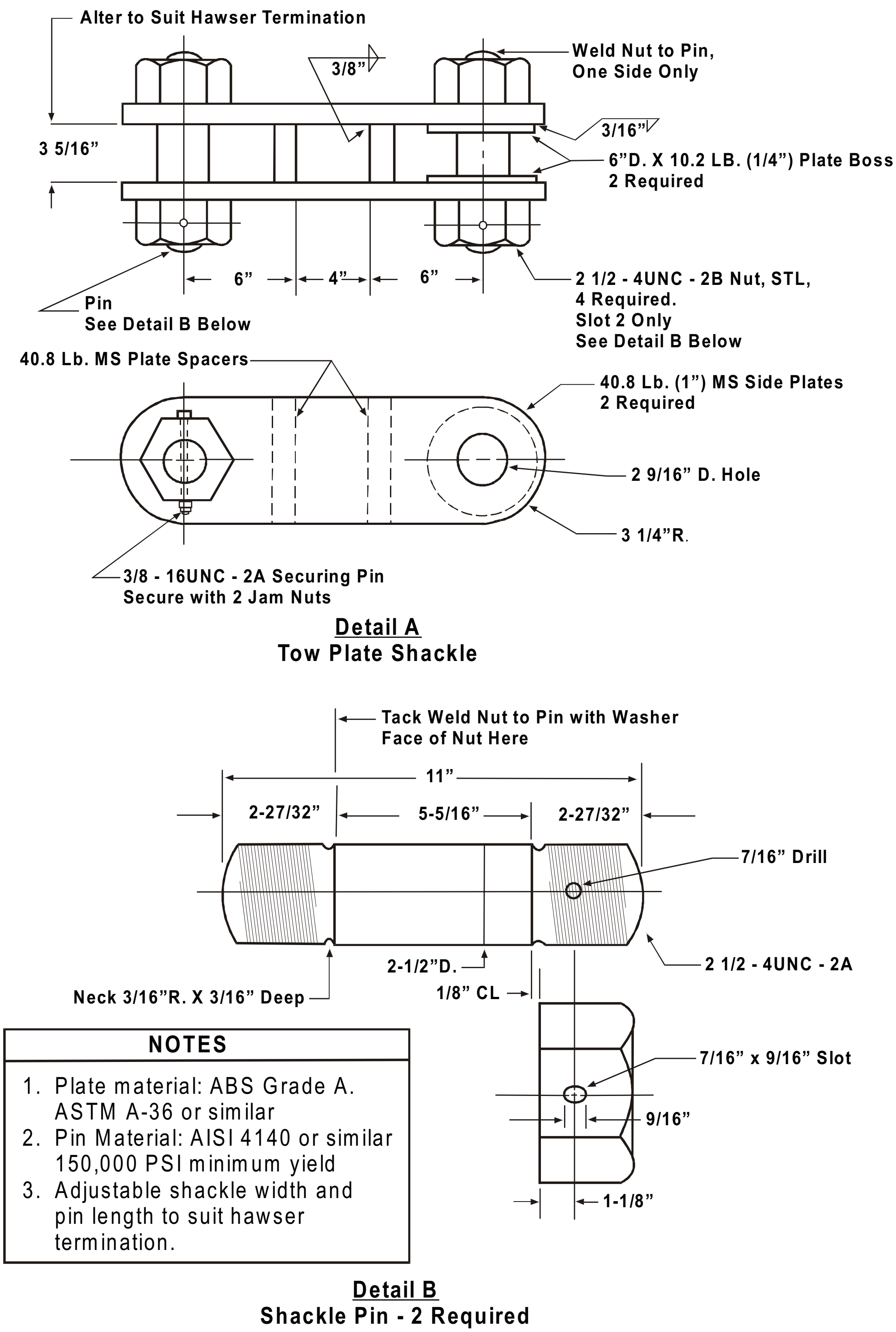


Detail A - Flounder Plate Medium Steel for Use with 2-1/2" Pin Shackle and 2-1/2" Shackles



Detail B -- Flounder Plate Medium Steel Similar to Detail 'A' Except as Noted. ABS Grade A, ASTM A-36 or Equal

Figure I-15. Flounder Plate.



NOTES

1. Plate material: ABS Grade A. ASTM A-36 or similar
2. Pin Material: AISI 4140 or similar 150,000 PSI minimum yield
3. Adjustable shackle width and pin length to suit hawser termination.

Figure I-16. Plate Shackle and Pin for 2-Inch Closed Socket.

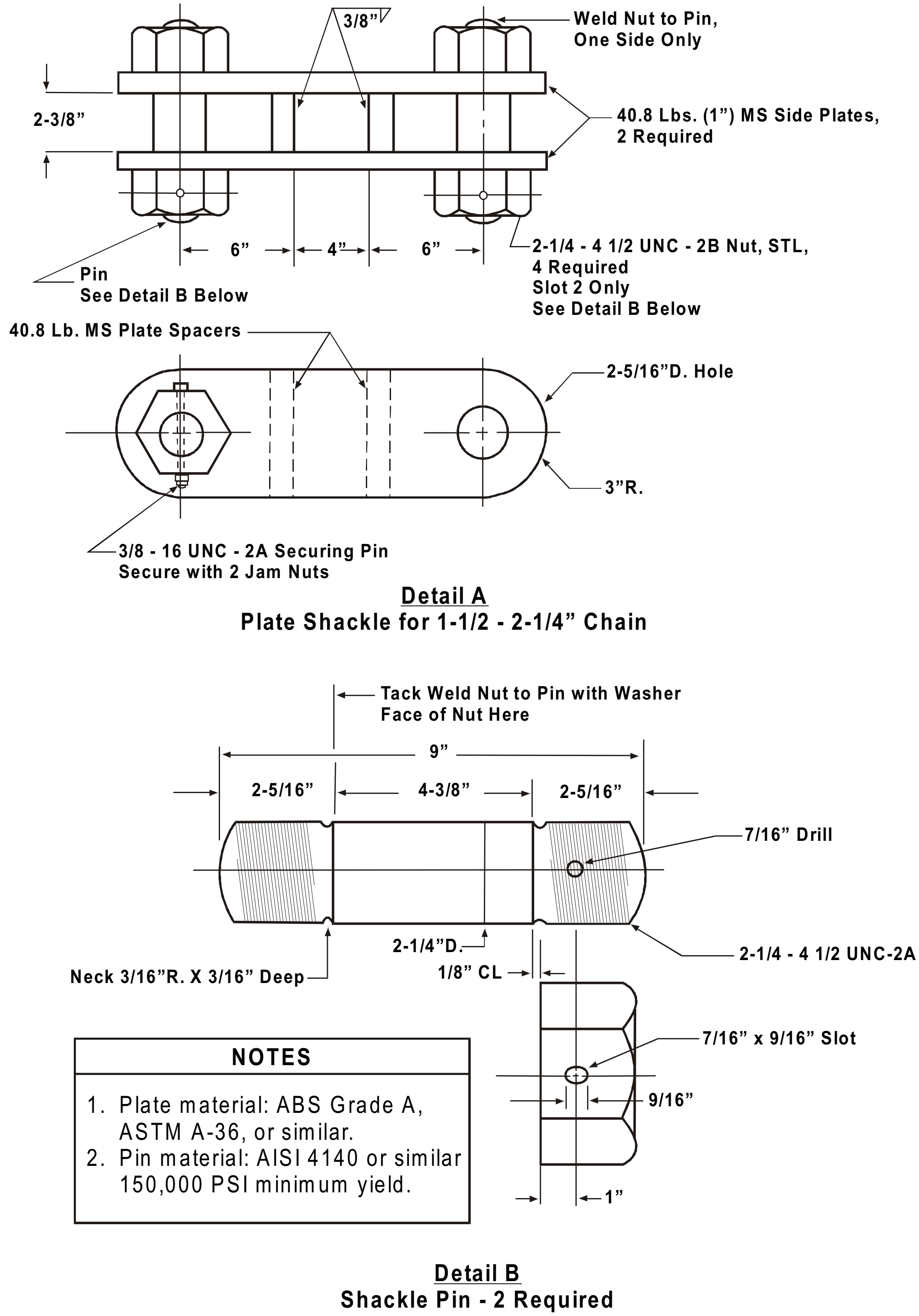
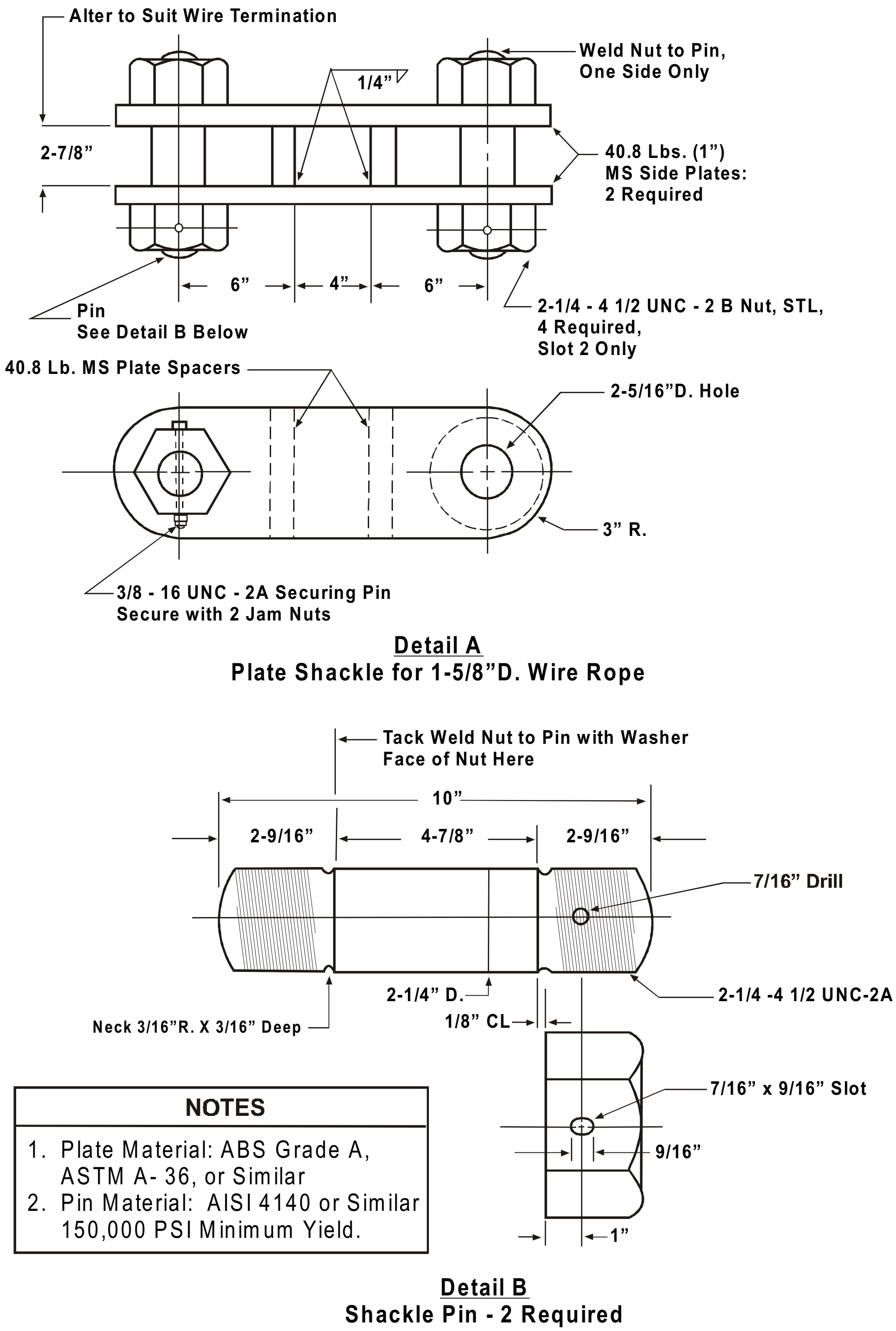


Figure I-17. Plate Shackle and Pin.



NOTES
1. Plate Material: ABS Grade A, ASTM A- 36, or Similar
2. Pin Material: AISI 4140 or Similar 150,000 PSI Minimum Yield.

Figure I-18. Plate Shackle and Pin.

Appendix J

EMERGENCY TOWING OF SUBMARINES

This appendix provides information on the towing attachment points of several classes of submarines. This information is provided to assist the tow ship in planning an emergency (that is, unplanned) tow of a submarine. The information is not all-inclusive, but covers most submarine classes. The principles can be adapted to other submarine designs.

Every U.S. Navy submarine has a plan for being towed that is described in the ship's information book. In general, all submarines built prior to the SSN 688, SSN 21, and SSBN 726 Classes have similar towing arrangements; these earlier submarines are discussed here as one group. The SSN 688, SSN 21, and SSBN 726 Class submarines are discussed separately. Table J-1contains relevant technical data for the 594, 616, 637, 688, 21, and 726 Classes of submarines.

J-1 Submarines Prior to the 688 and 726 Classes

J-1.1 Tow Attachment Points

Most submarines built prior to the 688, 21, and 726 Classes have a tow pad at or near the base of the forward end of the sail or attached to the forward escape trunk. Lateral strength is considerably reduced, so a tow fairlead must be used. The hole size in the padeye is 2 9/16 inches in diameter in all cases.

Most of these submarines have retractable mooring cleats, forward fairlead chocks, and capstans. Many have capstans and fairlead chocks aft as well. The inside dimensions of all the chocks are 10½ x 16½ inches except for chocks on the 594 Class (which have an 8-inch diameter) and the 598 Class (which are 7½ x 12 inches). The oldest SSNs (578 and 585 Classes) have fairleads of insufficient strength for towing. For these submarines, either the towing pendant will have to be centered laterally by using the mooring cleats or an alternative tow connection will have to be made. For all other submarines, the fairlead can and should be used. The smaller fairleads must be checked carefully to confirm that towing jewelry and chafing chain will pass through the small dimensions provided.

Submarine capstans are designed to handle mooring lines and can withstand the breaking strength of the mooring lines. The capstan can be used, with caution, as an emergency towing connection if a tow pad is not available. The capstan, however, is neither powerful nor fast. It will generally provide a 3,000-pound pull at 40 fpm and a 4,500-pound pull at creep. Accordingly, the capstan will be of little use in passing the tow hawser. The tow ship should plan this procedure to minimize the use of the submarine's capstan.

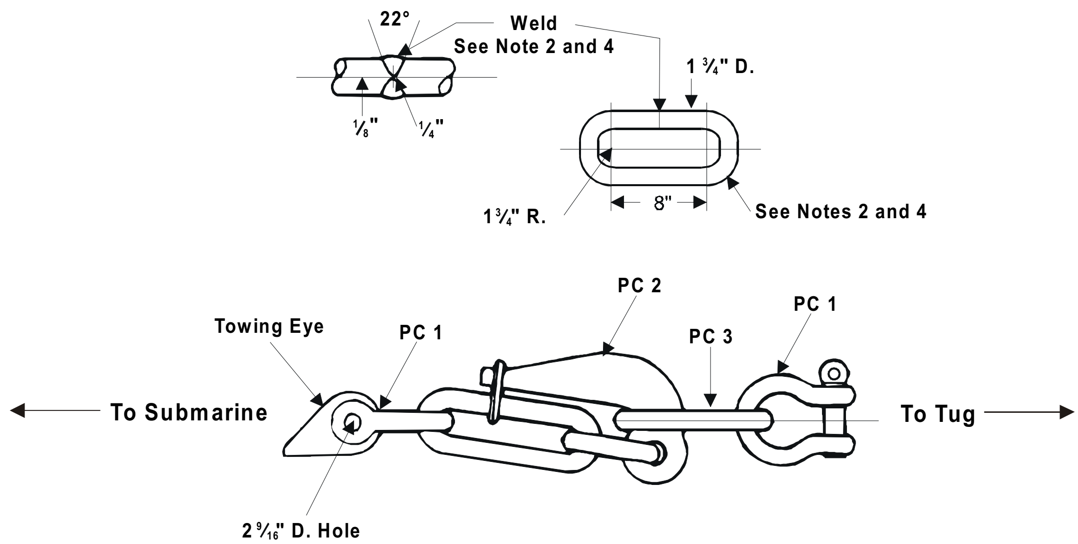
J-1.2 The Towing Rig

CAUTION
Do not tow submarines with the screw-pin shackles or the pelican hook provided with the submarine's towing rig. The towing ship should substitute appropriate safety shackles with the required bolt-locking fitting.

Most of the submarines in this group carry designated towing gear onboard. In general, this gear includes shackles, a pelican hook, and a wire chafing pendant of 1-inch diameter or larger. See Figure J-1 which is adapted from a typical submarine towing plan. The proof test of the rig is 80,000 pounds. This towing rig is designed for short intra-harbor tows. **It should not be used for planned open-ocean towing.** The shackles shown in .

Table J-1. Towing Arrangement for Higher-Population Submarine Classes.

Ship/Class	Designed Tow Arrangement (See Text Caveats on Use)	Tow Point Location/Strength (SWL)	Fairlead Chock Size/Strength (SWL)	Capstan Location, Linepull, Max Pull, Structural Strength	Anchor Location Anchor wt. Chain size
TRIDENT SSBN 726 Class	Cleats - 2" wire bridle including coupling for 450' x 8 1/2" DB nylon hawser. Note: entire tow rig stored ashore.	FR 15 P/S 70,000 lbs (ea)	Aft only 5.5" x 11" 70,000 lbs	Forward. Only 3000 lb/40 fpm 4500 lb max 70,000 lbs	Aft 4600 lbs 1" chain
SEAWOLF SSN 21 Class	Onboard Emergency Towing Pendant - 1.125" chafing chain, and 1.25" wire rope with two NATO standard links concealed in trough with ready access on port side of sail. Cleats - 1 5/8" wire bridle including flounder plate provided by the tug.	FR 12 Port FR 16 Stwb 70,000 lbs (ea)	Aft only 5.5" x 11" 140,000 lbs	Forward. Only 3000 lb/40 fpm 4500 lb max 70,000 lbs	Aft 1985 lbs 7/8" chain
LOS ANGELES SSN 688 Class	Cleats - 1 3/8" wire bridle, pelican hook, 31' x 1 3/8" chafing pendant, coupling for 450' x 5" DB nylon hawser. Towing gear carried aboard	FR 21 P/S 70,000 lbs (ea)	Aft only 5.5" x 11" 70,000 lbs	Forward. Only 3000 lb/40 fpm 4500 lb max 70,000 lbs	Aft 2800 lbs 3/4" chain
STURGEON SSN 637 Class (SSN 671 AND 685 have similar tow arrangements	Padeye - fairlead chock 1 7/8" pelican hook with 1 3/4" screw pin anchor shackles and link. Towing gear may be carried aboard	FR 27 (at sail) 47,000 lbs	Fore and aft 10.5" x 16.5" 47,000 lbs	Fore and aft 3000 lb/40 fpm 45000 lb max 25,000 lbs	Aft 2800 lbs 3/4" chain
LAYFAYETTE SSBN 616 Class	Two Baxter Bolt type padeyes, 1" wire bridle legs, each with pelican hook plus flounder plate. Some ships have arrmts similar to SSN 637 CL.	FR 43 50,000 lbs (ea)	Fore and aft 10.5" x 16.5" 50,000 lbs	Fore and aft 6,000 lb/40 fpm unspecified max 36,000 lbs	Aft 2800 lbs 1"chain
Permit SSN 594 Class	Padeye, pelican hook and clevis	FR 18 (at forward escape hatch) 47,000 lbs	Fore and aft 8" dia 47,000 lbs	Fore and aft 3000 lb/40 fpm 4500 lbs max 25,000 lbs	Aft 2800 lbs 3/4" chain



Arrangement of Towing Gear

NOTES:

1. PC 1 TO BE SIMILAR TO FIG. 6–208 NO. 950–2 OF CROSBY-LAUGHLIN CO., FORT WAYNE, INDIANA OR EQUAL.
2. PC 3 TO BE FORGED AT 2000–2200ºF AND COOLED SLOWLY. PREHEAT TO 400–600ºF BEFORE WELDING. WELDING TO BE FINISHED BEFORE HEAT TREATMENT. HEAT TREAT TO 1525–1575ºF. QUENCH IN OIL AND TEMPER AT 1200ºF TO GIVE PHYSICAL PROPERTIES AS FOLLOWS:

   TENSILE STRENGTH – 125,000 MIN.
   YIELD STRENGTH – 95,000 MIN.
   ELONGATION IN 2″ – 16% MIN.

3. PROOF TEST ASSEMBLY TO 80,000 LBS.
4. LINK PC 3 TO BE WELDED WITH ELECTRODE TY NT 4140 OF MIL-E-88979.
5. GALV PC 3 TO SPEC ASTM/A 153.
6. BEFORE GALV AND AFTER PROFF TESTING PC3 SHALL BE MPI INSPECTED.

Piece #	Name / Dimensions
PC–1	Shackle - Anchor, Screw Pin, 1-3/4″
PC–2	Pelican Hook 1-7/8″ Stock, For 1-1/4″ Wire
PC–3	Link 1-3/4″ X 15″

WARNING

Do not use this towing rig for ocean tows. Screw pin shackles should never be used in ocean towing.

Figure J-1. SSN 637 Class Towing Gear (Harbor Towing Only).

the submarines towing plans are 1¾-inch **screw-pin** anchor shackles. Do not use these shackles for towing. Use only comparable safety shackles. Note that the standard tow pad will accept the pin of a standard 2-inch safety shackle. The tug should provide more robust gear if time permits.

J-1.3 Chafing Pendant

The submarine's own towing rig may include a short wire chafing pendant. It may be only a 3/4-inch or 1-inch pendant, however, and may not provide adequate chafing protection for a long-distance, deep-catenary tow, especially in the fairlead chock. The tow ship should provide its own chafing pendant of sufficient length to make the final connection to the tow hawser on the fantail of the tow ship. The pendant should be made up to include a short length of chain to ride in the fairlead chock for chafing protection.

Some submarines may carry a 450-foot, 5-inch circumference nylon tow hawser. **This hawser is not recommended for use when a tow ship can provide longer or heavier gear**. In this regard, note the current limitations on the use of synthetic towing hawsers discussed in Appendix C.

J-2 SSN 688 Class Submarines

Submarines in the SSN 688 Class have no tow pads or forward fairleads. There is a small 5 1/2-inch x 11-inch fairlead aft. The ship is designed to be towed using a bridle attached to the forward pair of hinged mooring cleats. Each cleat has a safe working load of 70,000 pounds. Figure J-2 is a diagram of a hinged cleat and Figure J-3 is a schematic of the towing rig carried onboard the SSN 688 Class. It requires modification for use in open-ocean towing.

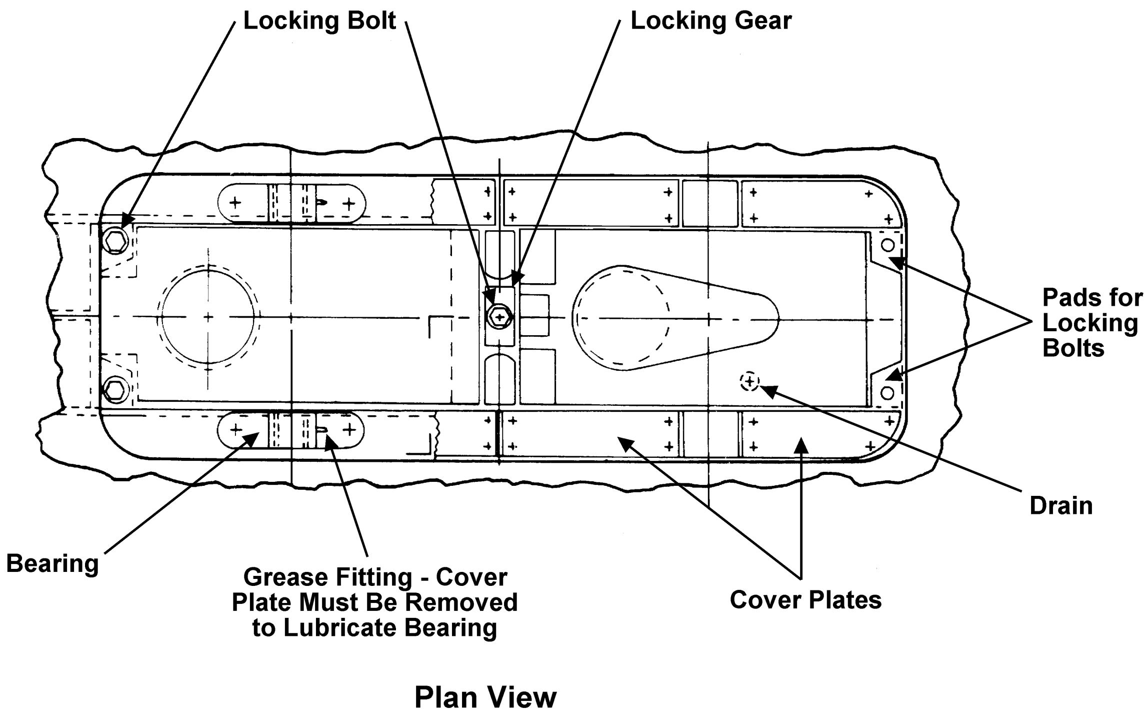
The bridle is made up of two 15-foot lengths of 1 3/8-inch, 6 x 37 galvanized IPS steel wire. The chafing pendant is 31 feet of 1 3/8-inch wire and the intended towing hawser is 450 feet of 5-inch circumference double-braid nylon with a 5 1/2-inch rope coupling at each end. As noted previously, neither the intended pendant nor the hawser is recommended for ocean towing of this submarine. The tug should provide a 1 5/8-inch chafing pendant of sufficient length to make the hawser connection on its own fantail.

Use of the 1 3/8-inch bridle provided for this submarine is acceptable for towing this class. The soft eyes in the bridle legs must be appropriately lashed to ensure that they do not jump off the cleats. Use of a pelican hook is not recommended for ocean tows unless a quick release is mandatory. If a pelican hook must be used, it should be installed such that the jaw will open away from the submarine (towards the tug) if released in an emergency (see Figure J-3 for proper configuration).

J-3 SSBN 726 Class Submarines

These large submarines, like those of the SSN 688 Class, are designed to be towed with a bridle attached to the forwardmost pair of mooring cleats (see Figure J-4). This bridle is more robust than the bridle used on other submarines, but it is **not** carried onboard the submarine. The bridle and associated hardware is stored at Trident Refit Facilities.

Figure J-4 shows two 14-foot, 2-inch diameter wire bridle legs with soft eyes for connecting to the cleats. Unless the tow originates at a Trident Refit Facility, where the designed towing rig is stored, this bridle may not be available. If an SSBN 726 Class must be picked up in an emergency, the tug can easily make up its own bridle rig using equal length legs of at least 1 5/8-inch diameter wire, safety or plate shackles and a flounder plate. **The chafing pendant should be at least 1 5/8-inch wire, although heavier wire is preferred**. The pendant should be long enough



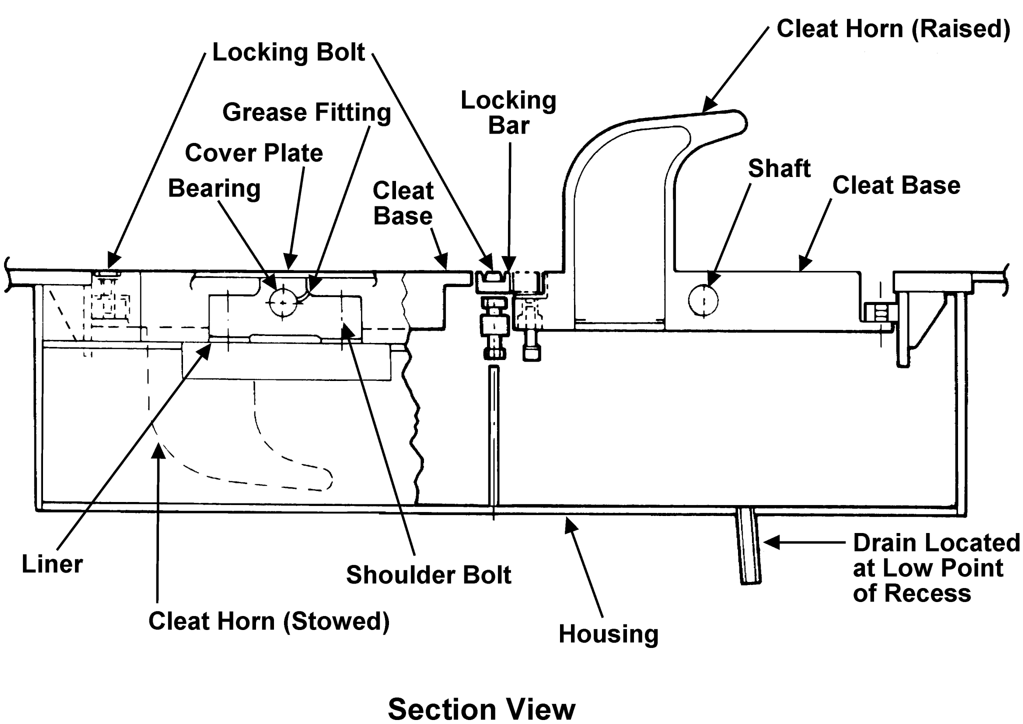


Figure J-2. Hinged Cleat for SSN 688 Class.

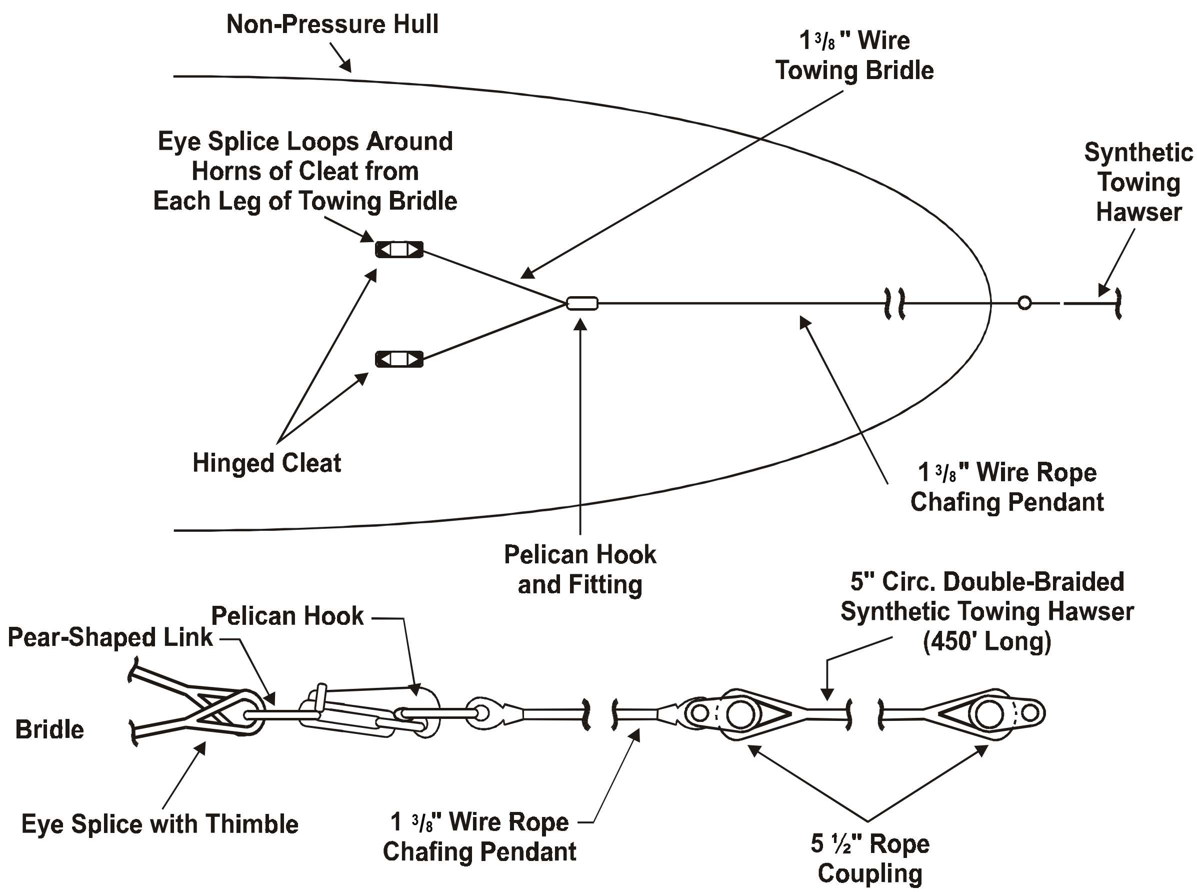


Figure J-3. Towing Gear Arrangement for SSN 688 Class (Harbor Towing Only).

to permit connection to the main tow hawser onboard the tow ship.

Because of the weight of the towing gear, a retrieving wire (100 feet of 5/8-inch wire) is recommended, as shown in Figure J-4. The retrieving wire will reach the capstan 32 feet aft of the cleats for rigging purposes. Otherwise, the retrieving wire is secured to the No. 2 set of mooring cleats in such a way as to preclude it from being placed under strain under any possible towing bridle orientation.

To prevent damage from the flounder plate, the No. 1 and No. 2 main ballast tank vent covers must be installed prior to rigging the SSBN 726 Class for tow.

J-4 SSN 21 Class Submarines

These large submarines have an on board emergency towing pendant designed for emergency towing.

The emergency towing pendant assembly consists of a towing padeye, towing chock, chafing chain, wire rope and sockets, and two North Atlantic Treaty Organization (NATO) standard links. An intermediate fitting in the towing pendant is four feet above the hull on the port side of the sail at fram 24 where the pendant is stowed and faired to the sail. This fitting, consisting of a NATO standard link, allows a towing line to be attached. The entire towing assembly is normally not visible. It is stowed in a trough, covered with Neat Dura-1 material and faired to the hull and sail. See Figure J-5 for emergency towing pendant assembly details.

Under certain conditions, the ship may be towed using a bridle attached to the forward pair of hinged mooring cleats. Each cleat has a safe working load of 70,000 pounds. The towing ship can easily make up its own bridle using appropriate lengths of at least 1 5/8-inch diameter wire, safety or plate shackles, and a flounder plate. **The chafing pendant should be at least 1 5/8-inch wire, although heavier wire is preferred.** The pendant must be long enough to permit connection to the main tow hawser onboard the tow ship.

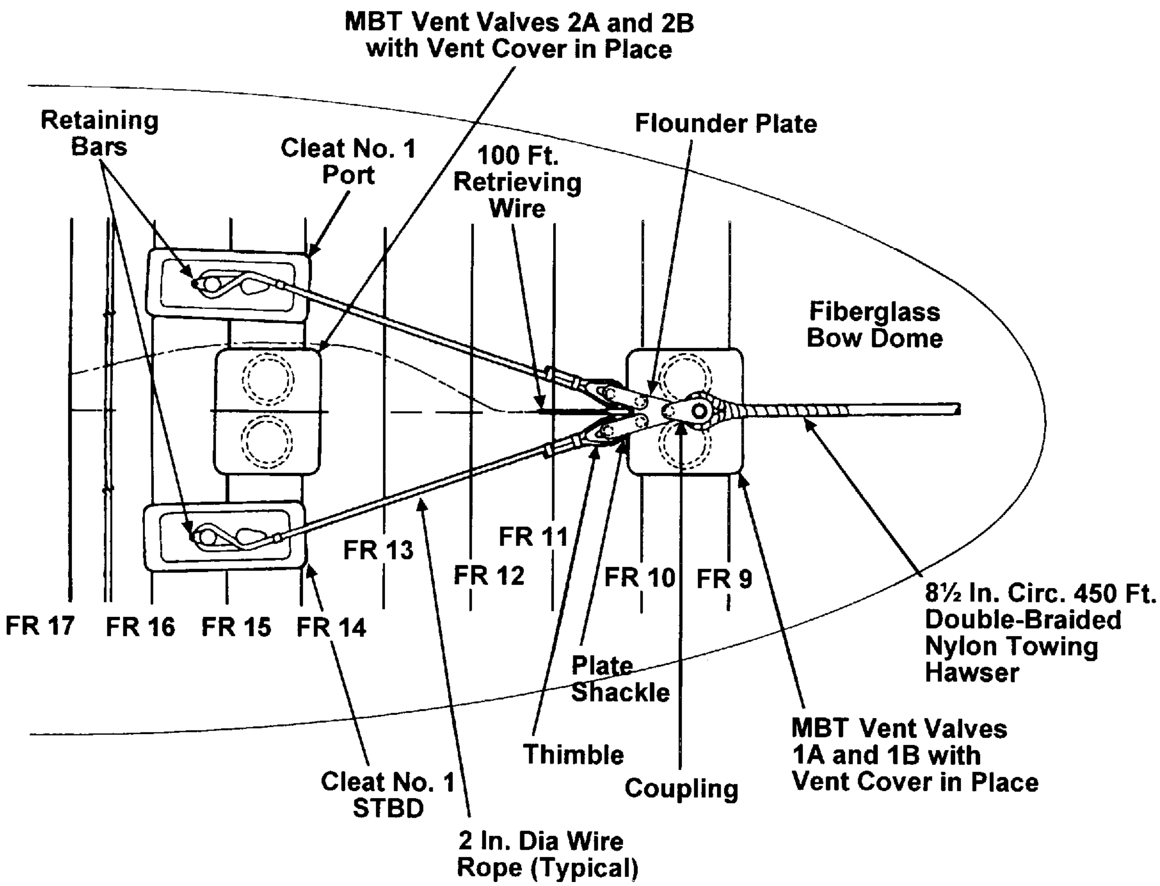


Figure J-4. Towing Arrangement for SSBN 726 Class.

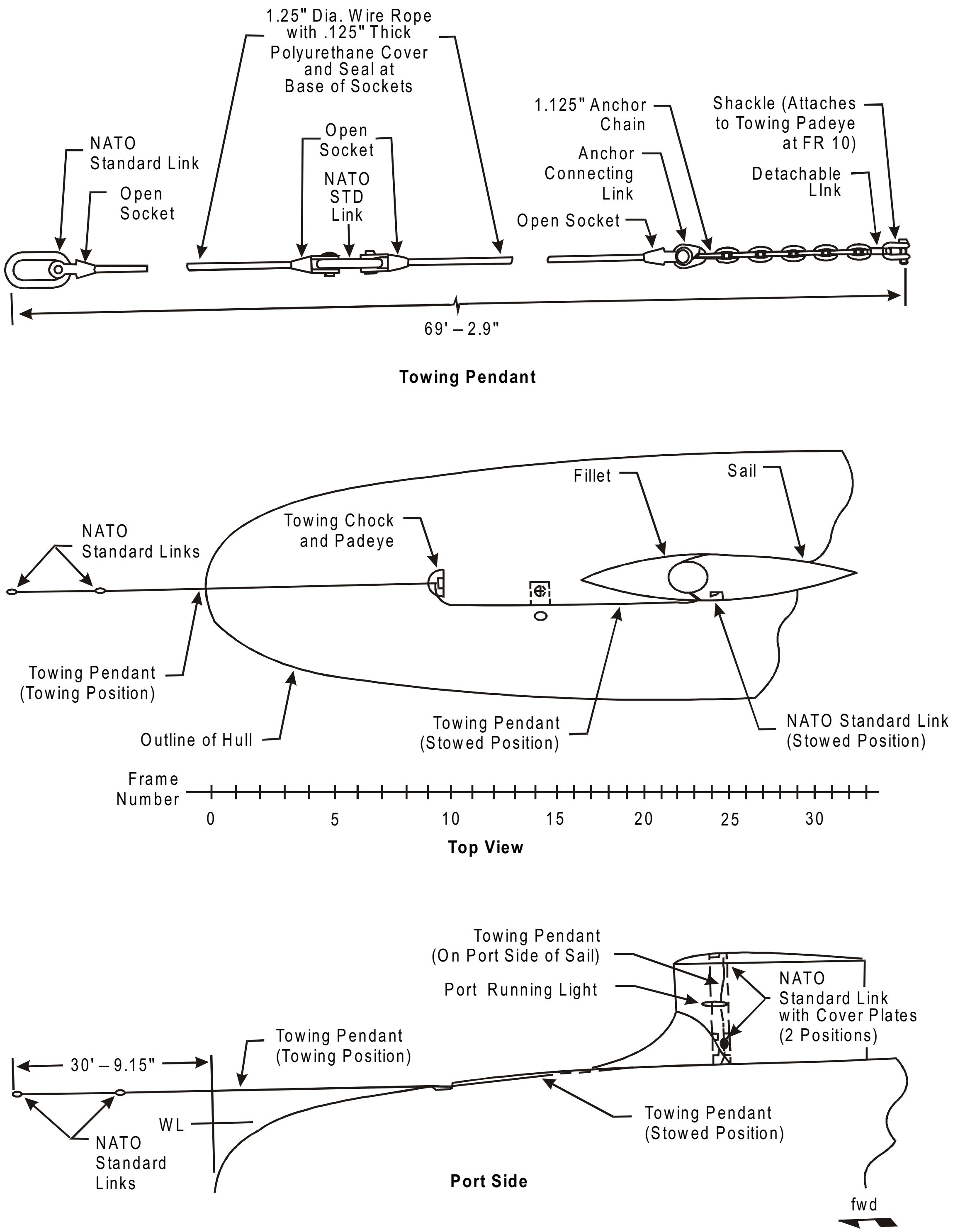


Figure J-5. Emergency Towing Pendant Assembly for SSN 21 Class.

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Appendix K

COMMERCIAL TUG CAPABILITIES

K-1 Introduction

This appendix addresses considerations and features of commercial ocean-going tugs, both foreign and domestic, that may be called upon for planned or emergency use by the U.S. Navy. It provides information to assist towing planners and to encourage careful selection of commercial tugs to fulfill Navy requirements.

K-2 Tug Characteristics

This section addresses features of ocean-going tugs, with emphasis on salvage tugs. This is not to suggest that other types of tugs are not capable of safely executing assigned tasks. In fact, specialized tugs are usually more economical to hire than fully equipped and fully manned salvage tugs. The salvage tug is used here, however, as the benchmark by which to compare others, since it is the most versatile type of tug.

K-2.1 Salvage Tug Attributes

Salvage tugs are large, powerful, and extremely seaworthy tugs. They can perform many different tasks and carry a wide variety of equipment and material as well as a relatively large crew. They have the crews and equipment to execute salvage tasks and the high power needed to refloat stranded vessels. They are excellent in rescue missions; they possess sufficient speed to reach the casualty promptly, the extra manpower and gear to make the tow connection under strenuous conditions, and the power to tow the casualty to safety. Finally, salvage tugs have the power, stores, and fuel capacity to make them excellent for long-distance tows of large ships and heavy objects. In terms of capital cost and operating expenses, each of the three salvage tug missions—salvage, rescue, and towing—could probably be accomplished more economically and efficiently by a tug specializing in only one of these areas. No other type of tug, however, can fulfill all three missions, under all kinds of circumstances, as well as the salvage tug.

Not surprisingly, the lines separating the classes of tugs are sometimes blurred by overlapping design features, and often by what owners choose to call their tugs. There is no universal acceptance of any particular salvage tug description. In fact, few owners actually refer to their salvage tugs as such, preferring simply to list them as “tugs.” Some that are called “salvage tugs” may be low-powered vessels intended for support of salvage operations, often inshore, and would be totally unsuited for a rescue mission, long ocean tow, or stranding on an unprotected shore.

The problem of identifying tugs by type is further complicated by the advent of many high-powered but very specialized support craft involved in the offshore oil industry. Consequently, there are anchor-handling tugs, supply tugs, and anchor-handling/supply tugs. These can be useful in an emergency situation, but may have minimum crew sizes, limited cruising range, and a lack of the wide assortment of gear useful in rescue towing or salvage.

The following sections describe the attributes of salvage tugs.

K-2.1.1 Length

Length is a major contributor to seaworthiness and provides for good arrangements and ample storage for crew, stores, and equipment. Length promotes efficient free-running speed. The disadvantages of incremental length are higher construction cost and less maneuverability. Salvage tugs generally exceed 200 feet in length.

K-2.1.2 Draft

Draft promotes seaworthiness and directional stability against off-center towing forces and provides for efficient propeller, design, and placement. Salvage tugs, however, must work in shallow water around strandings, so their drafts must be compromised. Salvage tugs generally have drafts of 16 to 20 feet.

K-2.1.3 Freeboard/Depth

High freeboard forward improves seaworthiness. Freeboard aft is a compromise between the desire to provide a work space that is safe and dry versus one that is located conveniently close to the work site, which is often near the waterline.

K-2.1.4 Beam

Beam improves stability, provides the internal volume for storage and other functions, and promotes efficient work spaces. Too much beam, however, handicaps free-running speed and increases fuel consumption. Salvage tug beams are 45 feet or more.

K-2.1.5 Crew

The crew of a salvage tug is significantly larger than the crews of other tugs. Commercial salvage tug crews vary from 15 to 25. Less tangible is the experience level of the crew. The best salvage and towing people often gravitate toward the salvage tugs; man-for-man, the experience level is often superior in these ships.

K-2.1.6 Towing Equipment

Some salvage tugs have automatic towing machines. Most commercial salvage tugs have at least an automatic rendering winch. This is an important clue to the capabilities of salvage tugs. Appendix L has a more complete discussion of towing machines and winches. Section 4-2 discusses strength of towing hawsers and related equipment.

K-2.1.7 Power

Power is obviously a critical attribute for tugs because it provides for prompt transit to the location of the casualty, assists in refloating the stranded ship, and facilitates towing the casualty. The citation of horsepower rating for tugs varies; this must be understood to make valid comparisons between tugs. This subject is addressed in Section K-2.2.

K-2.1.8 Bollard and Towline Pull

Bollard and towline pull are measures of maximum pull while dead in the water and available pull when the tow is underway. These attributes are also discussed in Section K-2.2.

K-2.2 Power, Bollard Pull, and Towline Pull

Towing is a very competitive endeavor, with business often sold on the basis of tug power. Custom, along with regional differences, dictates different methods for reporting a tug's attributes, as described below.

K-2.2.1 Power

The power of a tug can be quoted in shaft horsepower, horsepower, indicated horsepower, or kilowatts, as follows:

Shaft Horsepower (shp) is the power delivered to the propeller. Generally, only Navy tugs use shaft horsepower to describe their power; this, however, is the truest measure of power delivered by the tug.

Horsepower (hp) is generally the brake horsepower (bhp) of the tug's propulsion engines—that is, the power delivered at the engines shaft (not propeller shaft). This description ignores the reduction gear and propeller shaft losses, which may be considerable. Most American owners and the worldwide offshore oil industry use horsepower to describe their tugs. Some foreign shipowners use kilowatts as units of power. Kilowatts (1 kW = 1.341 hp) may be assumed to be measured at the engine.

Indicated Horsepower (ihp) originates from the days of reciprocating steam engines and ignores heat, friction, valve, and engine-driven auxiliary losses within the engine. Furthermore, some owners may add the generator engines and thruster power to the total, so indicated horsepower may exceed horsepower by a factor of 1.2 to 1.6 or more. Of course, an owner reporting in horsepower also may add generators and other power sources or users to the total. Most European and Asian salvage operators report tug power in indicated horsepower and are reluctant to report otherwise for fear of losing a competitive advantage. It has been noted, however, that more owners are now reporting in kilowatts to avoid the confusion between horsepower and indicated horsepower.

K-2.2.2 Bollard Pull

Bollard pull is the zero speed pulling capability of the tug. It is a measure of the usefulness of the ship in a stranding scenario or in holding a large tanker or aircraft carrier off a lee shore. Keep in mind, however, that bollard pull figures, like horsepower, may be open to interpretation.

Ideally, bollard pull is tested when a tug is built and certified by one of the classification societies. Bollard pull tests are also sometimes performed after major engine overhauls. Tug owners whose tugs have been tested usually provide a copy of the certificate attesting to the bollard pull figure.

Bollard pull, like horsepower, is a selling point for tugs and is sometimes overstated. For instance, there are rules of thumb for converting propeller power (shaft horsepower) to bollard pull, such as one ton pull per 100 horsepower for a conventional propeller or 1.2 to 1.5 tons pull per 100 horsepower for a propeller fitted with a nozzle. The owner may save the cost of a bollard pull test and simply apply one of the factors to convert propeller power to bollard pull without ever knowing what the real figure is. It is unlikely that the owner would ever select a conservative conversion factor.

European owners generally report bollard pull in their literature and reputable salvage tug owners are generally able to produce a certificate to document the test. American owners and the worldwide offshore oil support industry, on the other hand, rarely report bollard pull. When they do, the figure may not have been validated by a test. Horsepower is probably a more reliable measure among ships of these types.

K-2.2.3 Towline Pull

Bollard pull is not the only useful measure of the pulling capability of a tug. Except in stranding cases, the objective of the tug is to move its tow. In towing, some of the tug's power is spent on overcoming the hull resistance of the tug itself and some is spent on the hydrodynamic resistance of the towing hawser. Bollard pull can be maximized by propeller and nozzle design, but only at the expense of towline pull at towing speeds. This adversely impacts free-running speed and fuel usage. Most tug designs, however, are optimized for towing.

Tugs are generally expected to operate in the 4- to 8-knot speed range. Modern tugs usually use advanced propeller designs so that bollard pull still is quite high, but tug speed and fuel consumption are significantly reduced. A tug optimized for rescue towing, on the other hand, would probably not employ nozzles, being more concerned with high speed running to the casualty than in efficiency of the tow itself. Figure K-1 displays towline pull vs. speed for typical tug designs using controllable-pitch propellers turning inside nozzles. The figure is adapted from Blight and Dai, *Resistance of Offshore Barges and Required Tug Horsepower,* OTC 3320, 10th Offshore Technology Conference Proceedings (Ref. AE).

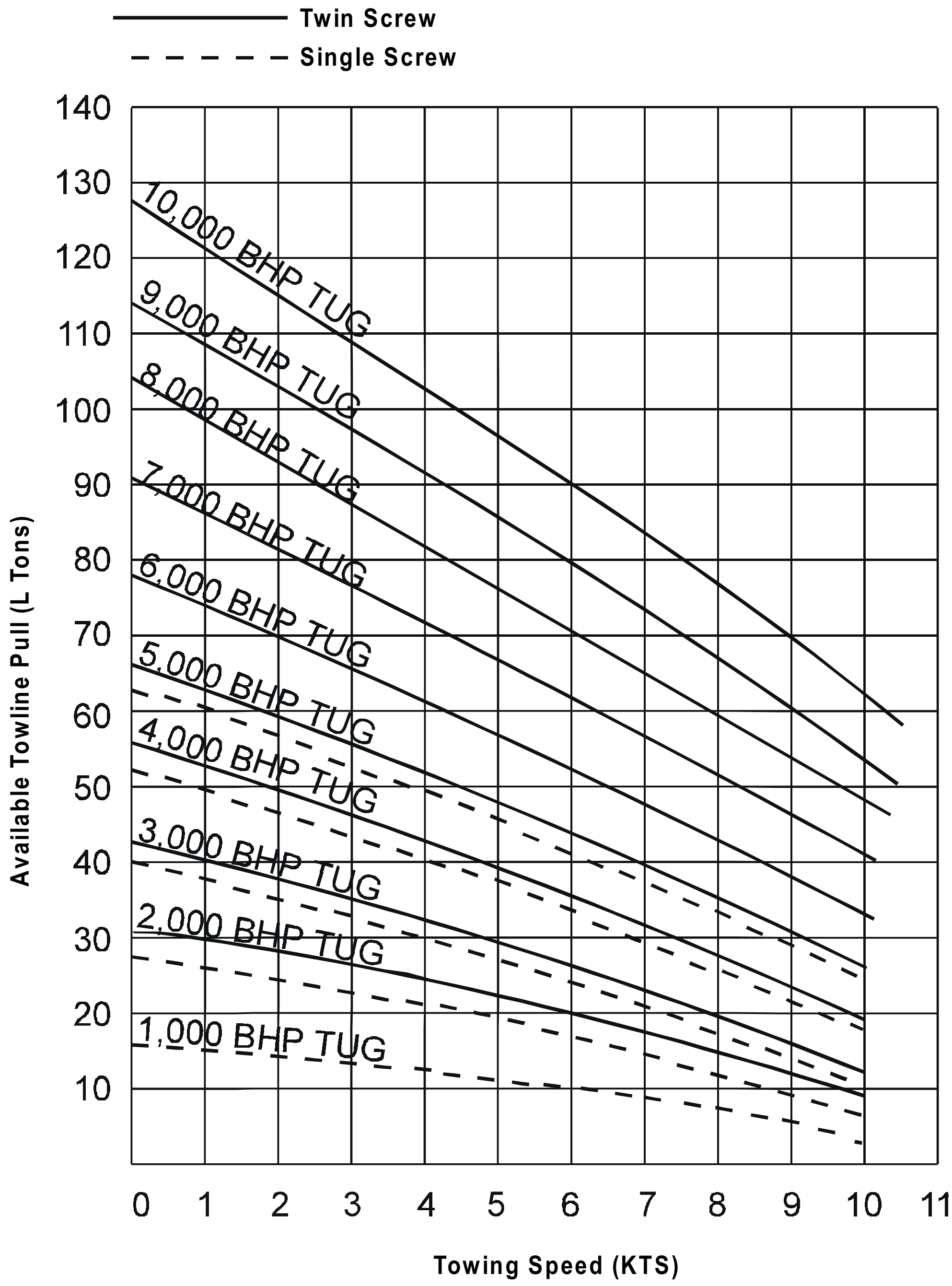

Figure K-1. Towline Pull vs. Towing Speed for Tugs with Controllable-Pitch Propellers and Nozzles.

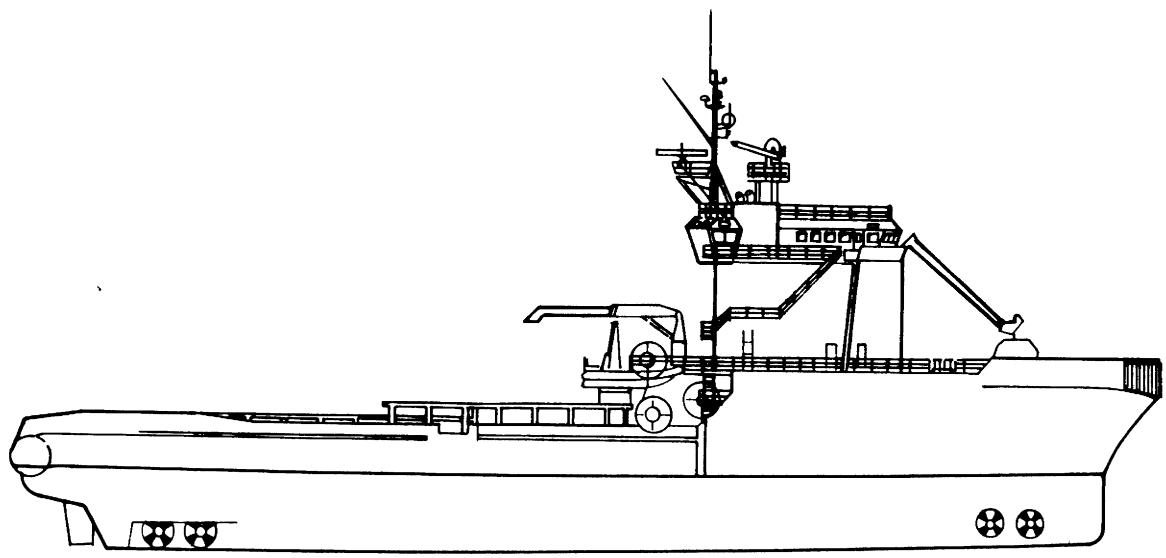

Figure K-2. Anchor-Handling/Supply Tug.

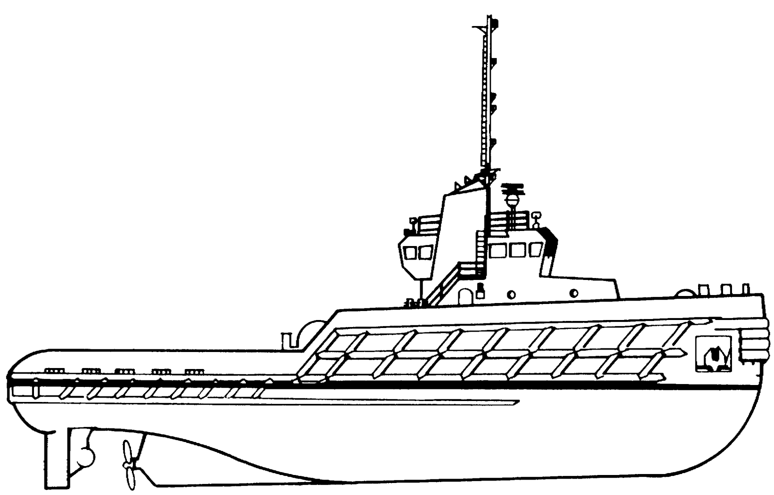

Figure K-3. Point-to-Point Towing Tug.

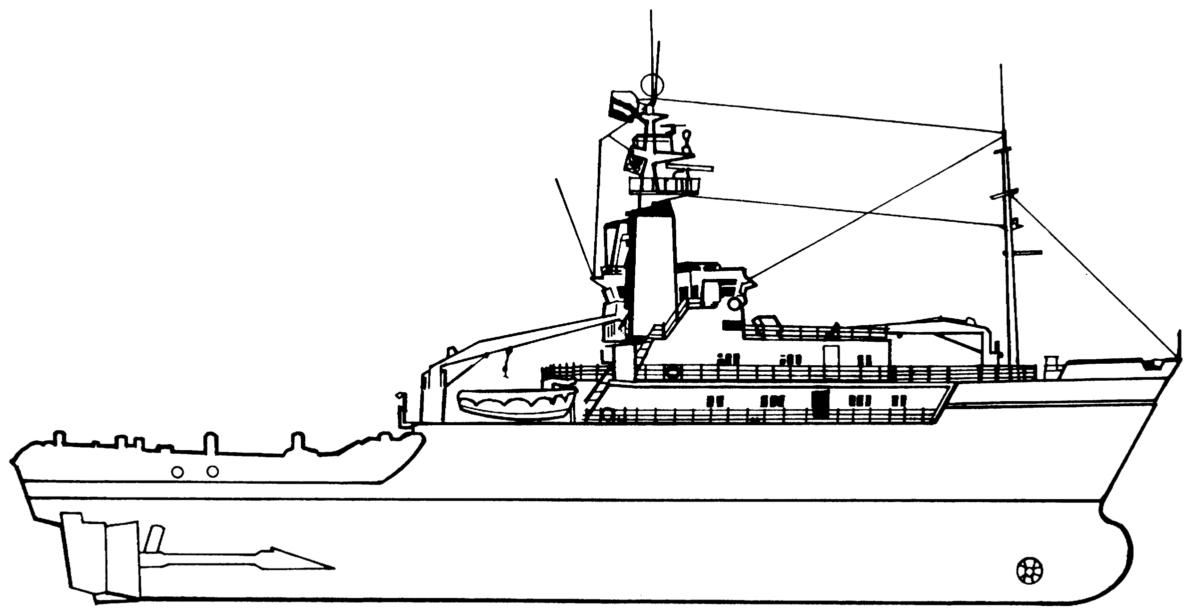

Figure K-4. Salvage Tug.

K-2.2.4 Maneuverability

Tugs are available with both ocean-going towing capabilities and enhanced maneuvering characteristics. Examples of these are tugs equipped with azimuthing Z-drive propulsion or Voith propulsion systems. The azimuthing Z-drive propulsion is trainable through 360 degrees and can be positioned in the hull during design to provide either a stern drive or a tractor tug. A tug such as Point Chebucto has two azimuthing stern drive units with a reported bollard pull of 64 tonnes and a speed of 12 knots.

The Voith-Schneider propeller generate thrust at right angles to the axis of rotation which, through control of the angle of attack of the vertical propeller blades, can be directed through 360 degrees thus acting as both propeller and rudder. This permits abandoning the conventional stern propulsion position and allows placing the propeller at the point of best interaction between the vessel, propeller, and towing. With the Voith-Schneider in the forebody there is free inflow and outflow in all directions and thrust forces act ahead of the vessel pivot point.

The main point of this discussion is that a tug should be considered as a balanced design, with some tugs being more suitable for some types of tasks than other tugs. This point applies to the task as well. Chartering a 20,000-ihp salvage tug to tow a 200-foot barge would be just as inappropriate as sending a 5,000-hp platform supply ship, with no tow hawser or winch, on a rescue tow mission.

K-3 Ocean-Going Tugs for Hire

This section provides sample specifications for typical ocean-going tugs and statistics on the number of tugs available for hire.

K-3.1 Ocean-Going Tug Examples

Figures K-2 through K-4 are drawings of typical salvage tugs, point-to-point towing tugs, and anchor-handling/supply tugs. Table K-1 provides data on these and other tugs.

Table K-1. Typical Commercial Salvage/Towing Vessels for Hire Compared with US Navy Salvage Ship.

Name	*USS Safeguard*	*Atlantic Salvor*	*Fotiy Krilov*	*Baraka II*
Type	USN Salvage and Rescue	Towing and Salvage	Salvage	Salvage
Year	1985	1975	1989	1994
LOA (ft)	255	254	321.5	227
Beam (ft)	51	43.25	64	51
Draft (ft)	15.5	21.5	23.5	24.25
Horse Power	4200	8800	24482	16000
Bollard Pull (tons)	54	127	250	161
Max Speed (kts)	13.5	16	18	17

Name	*Smit Singapore*	*Otto Candies*	*Star Sirius*	*Salvigour*
Type	Towing and Salvage	Anchor Handling	Anchor Handling	Salvage
Year	1984	1985	1985	1990
LOA (ft)	247	140	213	218.1
Beam (ft)	50.1	42	47.5	48.2
Draft (ft)	25	20.1	24.25	20.7
Horse Power	13500	7200	9180	6600
Bollard Pull (tons)	188	100	112	110
Max Speed (kts)	13	14	12	16

K-3.2 Decline in Salvage Tug Availability

Traditionally, salvage and towing companies maintained their best ships "on station" waiting for a casualty to occur. The "station" could be a semipermanent strategic location such as Jamaica, Gibraltar, Aden, or Singapore, with backup by a shore base, or a seasonal location such as the North Sea in winter or the Cape of Good Hope during the Southern Hemisphere's winter. Work was contracted on the well-understood Lloyd's Open Form "No Cure—No Pay" terms, and usually went to the first tug to arrive.

Several factors have led to the decline of the traditional "fire house" nature of the salvage and towing business. To list a few:

- Improved navigational aids resulted in fewer casualties.
- The advent of large offshore oil structures and VLCC and ULCC tankers required construction of large, very powerful, and expensive salvage tugs.
- Increased ship size resulted in fewer ships to potentially suffer casualties. Furthermore, since fewer ships were operating, marginal operators and crews were gradually forced out.
- Crews demanded improved habitability, working conditions, and wages.
- The worldwide reduction in oil consumption caused a reduction in shipping and, therefore, casualties, in the early 1980s.
- Owners of casualties tended to avoid the "no cure—no pay" contract in favor of more price competitive bidding. This placed the traditional salvage tug operators at a disadvantage because of their higher equipment, labor, and standby costs.

Consequently, tug owners sought routine, long-distance towing tasks to keep their expensive assets at work. Others laid up their ships or went out of business. Consequently, "stand-by" assets were greatly reduced.

K-3.3 Availability of Ocean-Going Tugs

A 1996 survey reported 221 tugs and 841 supply tugs having 1,000 brake horsepower (bhp) or greater. Of these, 97 tugs and 52 supply tugs claim 6,000 to 10,000 bhp and 18 tugs and 2 supply tugs are listed at over 10,000 bhp. The total numbers are probably understated, since some well-known salvage/towing firms are not listed in the survey and only a few former Communist bloc ships listed. On the other hand, the ships were listed as reported by the owners, without comment. Many of the smaller, less-powerful tugs are unsuited for any but the most benign tows. In addition, many quite powerful tugs, in the 4,000- to 8,000-ihp range, are well under 150 feet in length. The ships are optimized beautifully for point-to-point towing but may be handicapped seriously in a rescue tow scenario under strenuous sea conditions. Again, tugs must be matched to particular missions very carefully.

K-4 Obtaining Tug Assistance

This section provides guidance in obtaining commercial tug assistance.

K-4.1 Emergency Tug Assistance

Since a Navy ship requiring emergency towing assistance communicates with its operational and administrative superiors by designated means, it is helpful (subject to security restrictions) to query the UHF and VHF emergency channel frequencies to determine if competent assistance is available close by. Salvage tugs always monitor the distress frequencies; most other tugs monitor these channels frequently. Availability information along with pertinent data on the tug and its owners, is useful to the operational superiors in resolving the problem.

K-4.2 Restrictions in Contracting

U.S. Navy ship Commanding Officers are not authorized to commit the U.S. Government to indefinite obligations or claims. A Lloyd's Open Form contract requires arbitration in, and is subject to, the laws and courts of Great Britain. The United States will not permit itself to be subject to such requirements. Furthermore, even a per diem (fixed rate) salvage contract involves an indefinite value. The net result is that the Commanding Officer of a U.S. Navy ship is severely restricted in contracting for emergency assistance.

K-4.3 Contracting for Emergency Commercial Towing Assistance

If Navy towing assets are not available, the appropriate superior in the chain of command can arrange for emergency commercial towing assistance in two ways:

- Contacting the cognizant U.S. Government procurement office. This office can provide data on potential nearby assistance and arrange for an appropriate per-diem-type contract with the tug's owners, who will immediately advise the tug.
- Contacting the U.S. Navy Supervisor of Salvage (Director of Ocean Engineering - NAVSEA 00C) by message (COMNAVSEASYSCOM WASHINGTON DC/00C) or by telephone at (202) 781-1731 (DSN 326-1731).

  NAVSEA 00C can be reached 24 hours a day through the NAVSEA Duty Officer at (202) 781-3889 (DSN 326-3889). SUPSALV maintains standing salvage contracts that can respond immediately worldwide. Frequently, the Navy salvage contractor subcontracts with the most appropriate salvage/towing firm anywhere in the world. Thus, an available commercial tug can be directed to provide emergency assistance with very little delay and without subjecting all parties to protracted legal efforts after the fact.

K-4.4 Arranging for Routine (Non-Emergency) Tows by Commercial Tugs

The tow planner will normally request the tow from the appropriate Navy operational Surface Force Commander, who will arrange for a U.S. Navy or Military Sealift Command tow. If neither is available, the tow should be arranged through the local supply/procurement agency. In the latter case, if tows are arranged infrequently, or the tow is technically unusual, obtaining advice/assistance from SUPSALV is recommended.

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Appendix L

TOWING MACHINERY

L-1 Introduction

For the purpose of tow planning, this appendix provides a brief overview of the different types of towing machinery installed in U.S. Navy tugs and towing ships. It describes the capabilities and limitations of the towing machinery in these ships. This appendix is not a substitute for specific design or operating data contained in the technical manuals for the equipment installed in any given ship.

This appendix addresses the machinery used in classic towing arrangement where the tug is attached to the tow by a fiber or wire hawser. It does not address tug-barge combinations (where the tug is mechanically attached to the tow).

L-2 Background

Because the primary mission of a tug is towing, the towing machinery must be carefully selected, designed, operated, and maintained. The value of the towing machinery cannot be underestimated. This point is supported by the president of a major, privately owned European salvage and towing company who once reported that, for modern, high power tugs, the cost of the towing machinery at least equals the cost of the ship's entire main propulsion plant.

L-2.1 Terminology

Automatic towing machinery evolved from the original *towing winch*. Application of steam power to the towing winch resulted in frequent use of the term *towing engine*. Today, *towing machine* is the preferred term for automatic towing machinery and is the one used in the NSTM. A nonautomatic towing winch is appropriately called a *towing winch*. The terms *traction machine* or *traction winch* are both used, depending on the number of automatic features installed.

L-2.2 Functions of Towing Machinery

All towing ships need a means for handling the towing hawser. The mechanism must be able to:

- Deploy/retrieve hawser
- Attach the hawser to the tug
- Adjust the deployed length of the hawser
- Stow the unused portion of the hawser
- Provide for quick release while the hawser is under tension
- Minimize damage and wear to the hawser while in use and while stowed.

L-2.2.1 Attachment of the Hawser to the Tug

Older, smaller tugs may have no more than a bollard or bitts for attaching the hawser. Smaller European tugs often use a towing hook that swivels about a strong bearing on a platform. More modern tugs generally combine the hawser securing function with the storage and/or transport system.

L-2.2.2 Hawser Scope Adjustment

Paying out additional line when the hawser is secured to bitts can be accomplished by hand, but at considerable personnel risk. When using a towing hook, which requires a permanent eye at the end of a hawser, paying out the line requires inserting a specific length of additional hawser. In each case, shortening the length of deployed hawser is difficult and requires power assistance if the hawser is under strain. Modern ships combine the hawser adjustment function into a powered winch traction machine.

L-2.2.3 Storage of Unused Hawser

On smaller, older tugs, hawsers may be simply "faked down" on deck or stored on reels, which may be powered. Since the advent of wire hawsers, larger ocean tugs generally combine the hawser securing, adjusting, and storage functions into a self-contained winch. More recently, traction machines have been developed to overcome problems inherent in the typical winch. Two factors that led to this development are:

- The advent of very powerful tugs (10,000 hp or more) require very long, heavy wire hawsers. These ships, not yet seen in the U.S. Navy, often have two hawsers and towing machines. Each hawser may be 72 mm (2-7/8 inch) in diameter and up to 1800 meters (5900 feet) long. Each such hawser weighs about 38 long tons and requires a massive reel for storage that must be robust enough to withstand direct application of tensile loads. Optimal location of the towing point is at the main deck, on centerline, close to mid-length of the ship. This is prime space for arrangement purposes and presents a significant drawback to stability when large weights are needlessly located at that height. Consequently, these large tugs frequently use traction machines to adjust and hold the wire, while the unused wire is stored at more appropriate locations on relatively light storage reels. These reels need only sufficient power to take up the slack between reel and traction machine. Wire hawser traction machines are similar in principle and appearance to the fiber line machines used by the U.S. Navy.

- The use of large, long, synthetic fiber hawsers. The poor compression rigidity of these hawsers precludes towing directly from a storage reel because the part of the line under tension would embed itself in the preceding layers of stored line. Furthermore, synthetic lines are relatively bulkier than wire hawsers, making reel-type storage impractical. The unused fiber hawser is generally stored in a bin or dedicated compartment, which may be adjacent to the traction machine. The traction mechanism operates on the hawser and separates the hawser's unloaded, stored portion from its deployed, tensioned portion.

L-2.2.4 Quick Release of the Hawser under Tension

Emergency conditions, such as the tow's sinking or being set toward danger, require quick release of the hawser, often while under strain. Fiber hawsers may be cut with an axe. Wire hawsers may be cut with an oxyacetylene torch or power cutters. Cutting the hawser is hazardous and may be impossible in a heavy seaway. The towing hook has an advantage in that it can be tripped, often remotely, to release the hawser. For the typical reel-type towing winch, the reel can be disconnected from the driver mechanism so that it will freewheel, allowing the hawser simply to pull itself off the reel. The bitter end of the wire is easily disconnected by the momentum of the wire coming off the reel. Traction winches can generally be disconnected the same way, but a rapidly-running, large-diameter fiber hawser presents significant hazards to personnel and equipment. Unless the bitter end of the hawser is very close to the traction mechanism, the unloaded portion of the hawser may have to be cut.

L-2.2.5 Protection of the Hawser

The hawser must be protected from two principal hazards. The first is damage and wear to the hawser from scuffing, abrasion, small diameter bending, crushing of stored layers under loaded turns on a reel, and adverse environmental conditions. This damage is minimized by the careful arrangement of towing machines and deck equipment. The second principal concern is protection of the hawser from overload due to surges caused by relative movements of tug and tow in a seaway. This is addressed in part by proper operating parameters (speed, scope of hawser, and course) and often by including automatic payout and retrieval features in towing machinery. Both concerns are further addressed by using towing machinery instrumentation that provides hawser tension and scope readouts. This instrumentation may operate independently of towing machinery. The next section discusses reasons for including automatic features on towing machinery.

L-3 Automatic Tension Control

This section provides a historical perspective and brief discussion of surge loading of towing hawsers and the advantages of automatic tensioning towing machinery.

L-3.1 Tow Hawsers Surge Loading

Most seamen do not perceive the surge motions of ships at sea, because there is no reference from which to measure the motion. When two ships are connected by a tow hawser, however, the affects of surge motion are quite apparent. Towing people have long been aware of the relative motion of tug and tow in ocean wave systems. For small tugs and/or tows, the hawser itself exerts considerable restraint to the motion of the ships from their completely independent states. But if the tug and tow are both relatively large, a strenuous sea state can easily impart sufficient relative motion to cause hawser failure.

L-3.1.1 Early Automatic Towing Machinery

Experienced tug seamen have known the dangers of load surges for at least a century. Steam power led to larger, more powerful tugs, and to the use of wire hawsers when manila hawsers grew to unmanageable sizes. As steam deck machinery was developed, it was in course applied to a winch for the towing hawser. The throttle to the winch steam engine could be cracked open (by trial and error) to provide an automatic feature to the winch. When the steam pressure behind the pistons was overcome by the tension of the hawser, the winch would pay out; likewise, slack would be taken in automatically when the load eased. Simple controls were added to quantify the set point and to limit the total amount of wire paid out, or taken in, without human intervention. Through this arrangement, large potential surges in hawser loading were significantly reduced with the “automatic” steam towing winch. This improved safety and wire wear and permitted use of more power than otherwise would have been available.

L-3.1.2 Electric Towing Machinery

The introduction of diesel power to large tugs in the 1930s was a major advance for propulsion power and endurance, but a setback for automatic towing machinery. The steam-powered winch was no longer an option. Electric-driven automatic towing machinery was developed, but it tended to be relatively expensive and complex. While the U.S. Navy was a leader in the use of automatic towing machinery, beginning early in World War II, much of the rest of the world returned to nonautomatic towing machinery.

Arguments against the use of automatic features are often heard. Among other things, automatic towng machines are thought to be inaccurate, unreliable, too heavy, too expensive, too noisy, too complex, and impossible to maintain. Nevertheless, the arguments *for* automatic towing machines are compelling when one understands the magnitude of surge tensions, as described below.

L-3.1.3 Wire Surge Example

Section 3-4.2 provides data on catenaries of wire towing hawsers. As the strain increases, the catenary becomes flatter, with less “spring” available. In fact, if it were not for the stretch of the wire itself, it can be shown that a 1000-foot, 2-inch FC hawser, with a steady tension of 50,000 pounds, would break if the tug and tow were separated by only an additional 2 feet. Fortunately, the hawser has considerable elasticity. Figure 3-13 compares tug-tow separation to hawser tension for 1,000 foot and 1,800-foot hawser scopes. A 1,000-foot length of 2-inch wire, with initial tension of 50,000 pounds, will have tension increasing to the wire's safe working limit of 187,000 pounds (.65 x 288,000) when the tug and tow are separated by an additional 9 feet, still a relatively low figure. Further stretch will permanently damage the wire, and it will break when increased separation has reached a total of 15 feet beyond the separation characterized by the 50,000-pound initial tension. The same wire, with initial tension of 100,000 pounds, can absorb increased tug-tow separation of only approximately 10 feet.

The figures for 1,800 feet of the same hawser at 50,000 pounds initial tension are somewhat more advantageous. The system can absorb 19 feet of increased tug-tow separation before reaching its safe working limit. Overall, the ability of wire hawsers to absorb changes in the distance between tug and tow is relatively limited, compared to probable ship motions under strenuous sea conditions.

L-3.2 Automatic Features on Towing Machines - General

The full-featured automatic towing can be set to maintain hawser tension within a selected range. It will pay out hawser if the hawser tension exceeds the set point, and will recover hawser when tension falls below another set point. Typically, the total amount of hawser allowed to be paid out or retracted is limited. Some towing machinery will pay out, but not retract, automatically.

L-3.3 Limitations in Quantitative Understanding

The responsiveness of actual U.S. Navy automatic towing machines to real dynamic loading of their towing hawsers is not well understood at present. The automatic payout feature does reduce the potential peak tension, but quantitative data on towing machine time constants and responsiveness need study. The landmark work leading to the data contained in Appendix M is very recent. It significantly improves the understanding of the dynamic demands placed on the towing system. Further work is needed to better understand how the automatic towing machine handles these dynamic demands; at-sea testing will undoubtedly be required to validate the model predictions. There is a distinct possibility that this work will ultimately result in lowering traditional factors of safety—which are really "factors of ignorance"—while maintaining or improving efficiency and safety in towing operations.

L-4 Types of Towing Machines

This section provides an overview of the types of towing machines used by the U.S. Navy, with reference to other types of machines for technical interest.

L-4.1 Conventional Towing Winches and Machines

Conventional towing winches and machines, which store the unused hawser on a horizontal drum, are the most prevalent.

L-4.1.1 Drum Arrangements

Units may have one or two main drums; one for each hawser if there is more than one. In the U.S. Navy, two-drum units have drums side by side. Commercial tugs often have the second drum forward and above the first drum in a "waterfall" arrangement. The drums are generally capable of independent operation. They may be equipped with level wind apparatus and may be strong enough to withstand the breaking tension of the wire applied directly onto the drum. Some U.S. Navy units are equipped with one or two auxiliary drums to accommodate work on mooring lines or long target-towing hawsers.

L-4.1.2 Drum Securing Features

Towing hawser drums can generally be secured with a pawl or “dog.” For control, a brake system is also provided.

L-4.1.3 Drum Prime Movers

The more sophisticated units use DC electric motors to provide infinitely variable speed control. Some newer machines use an electro-hydraulic arrangement. These machines have a very quick response time. The double drum units may have two drive units that can be clutched separately (one to each drum) or in tandem to a single drum for increased power. Less sophisticated units have a self-contained diesel engine drive, connected through a torque converter and/or an appropriate mechanical transmission.

L-4.1.4 Automatic Features

The most desirable automatic feature of a towing machine is the ability to increase the hawser scope when towline tensions exceed a certain level. All machines have brake systems that will slip at some point, but the set level may not be very reliable and the drum can be locked by a dog or pawl. The next highest level of sophistication is automatic payout of the line when the tension exceeds a set level. There may be a limit on the total length of hawser permitted to be paid out automatically. Finally, the most sophisticated machines have an automatic reclaiming capability, with a limitation on the net allowable length to be reclaimed.

L-4.1.5 Instrumentation and Controls

All units can be controlled locally and many have a remote operation station. Instrumentation generally includes cable tension, length of cable paid out, motor speed indicator, and automatic pay out/reclaim set points. Some of the instrumentation may be repeated on the bridge.

L-4.2 Traction Winches

In the U.S. Navy, traction winches were introduced for use with the large synthetic hawsers that gained popularity in the 1960s. Traction winches also are finding application with wire hawsers in powerful commercial tugs.

L-4.2.1 General Description

Traction winches have two parallel cylinders with grooves sized to accept the intended hawser (see Figure L-1). There are four or more complete wraps of the hawser around the two cylinders. Both cylinders are powered, to transport the hawser. The orientation of the cylinders or drums can be either horizontal or vertical. In principle, traction winches are similar to capstans. The two-drum arrangement eliminates the axial skidding of the rope inherent in capstans and provide grooved drums that improve support and reduce wear on the line.

Unlike drum-type winches, a long line can be loaded onto a traction winch at any point within its total length. This is used for mooring purposes and was the reason for their first marine use—for control of mooring lines on large ships and for Single Point Moorings used in the offshore oil industry.

L-4.2.2 Hawser Storage

Conventional winch designs are not used with fiber towing hawsers for two reasons—the large size required and problems inherent in wrapping and storing a tensioned, highly elastic line on itself. Storing the untensioned fiber hawser on a drum is feasible, but storage bins are universally used. The traction winch can easily pull the hawser from its storage location, via appropriate fairleads. Re-stowing the hawser as it is recovered, however, is more difficult and sometimes requires hands-on effort.

L-4.2.3 Traction Winch Operation

Traction winches are motor-driven and some are equipped with variable speed capability. They have brakes and clutches for control.

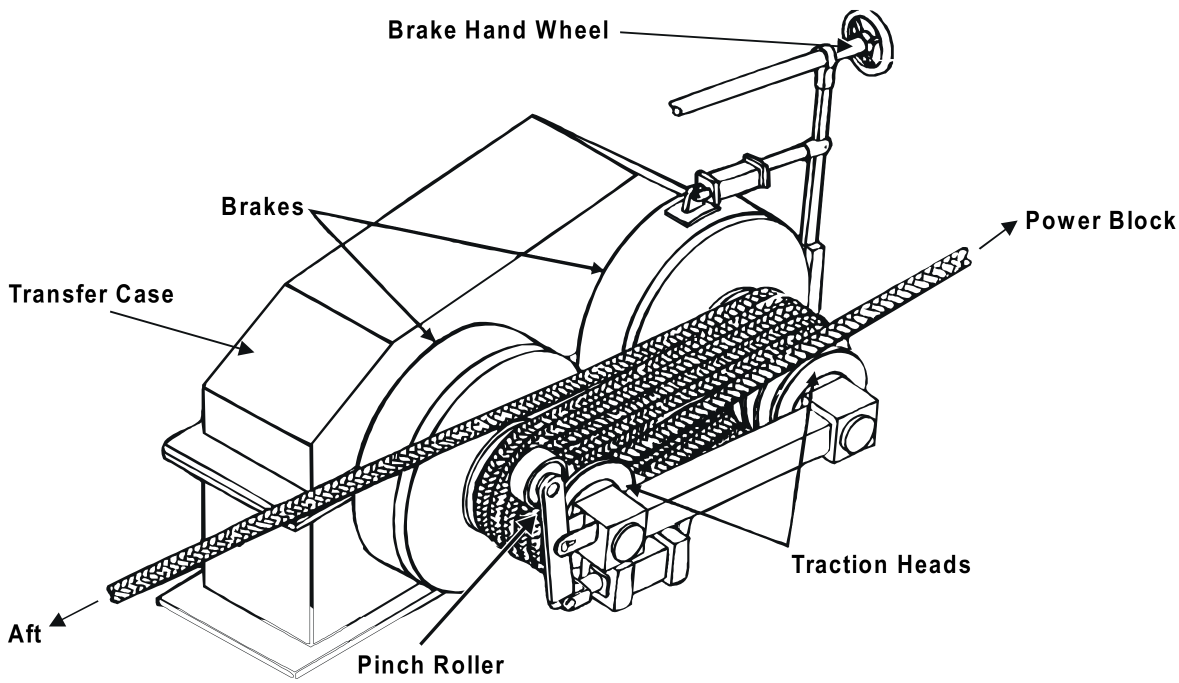

Figure L-1. Multi-Sheave Traction Winch.

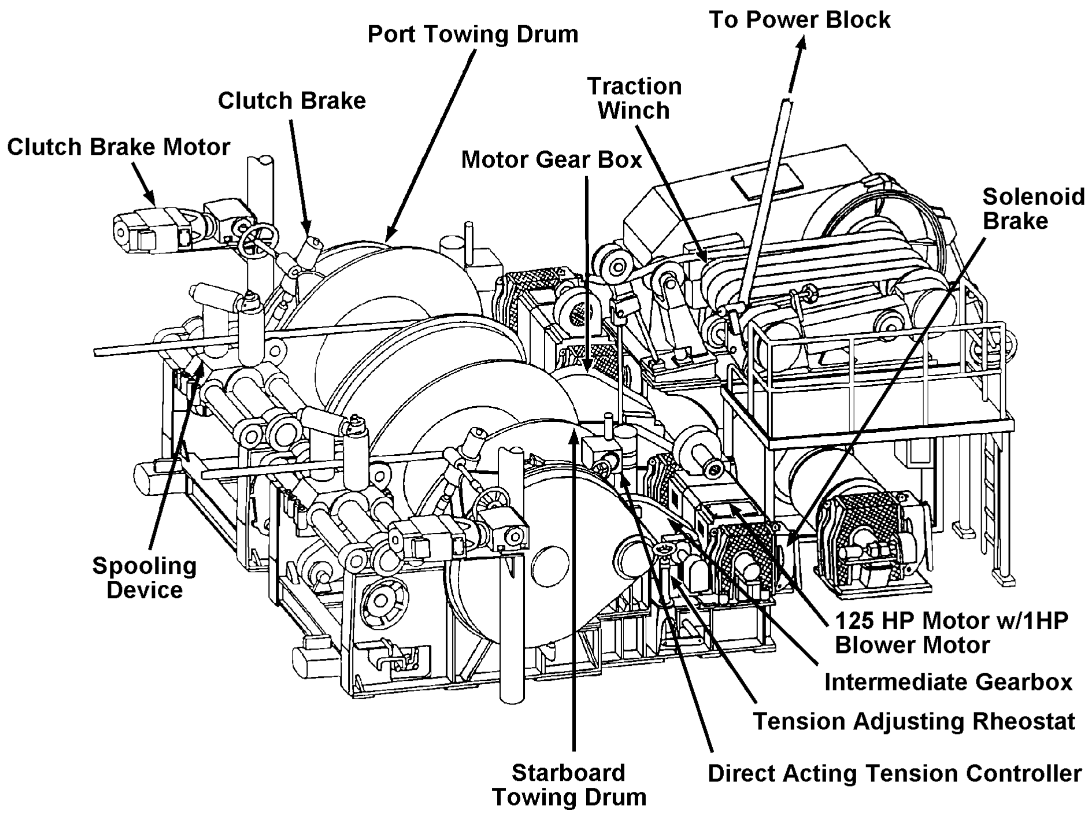

Figure L-2. ARS 50 Towing Machinery.

When the clutch is released, the winch can be overhauled by the hawser to provide for free release of the hawser in an emergency. Some traction winches have an automatic tension payout capability, but automatic reclaim is rare on fiber line systems because of the hawser storage system described above.Controls and Instrumentation

Traction winches have local and/or remote station controls. Most have tension readouts and some have hawser scope instrumentation (without stretch compensation). Some traction winches have end-of-hawser warning or shutdown systems.

L-5 U.S. Navy Towing Machinery Descriptions

This section provides more detailed descriptions of specific towing machinery installed on U.S. Navy towing ships. This is not a substitute for technical manuals for the specific machines. Towing machinery installed on mine warfare ships is not addressed. In the following sections, “AAJ” refers to Almon A. Johnson, Inc., a major designer and builder of towing machines.

L-5.1 ARS 50 Class Towing Machinery

The ARS 50 Class is equipped with an AAJ Series 322 automatic towing machine which has two side-by-side main drums, each capable of spooling 3,000 feet of 2 1/4-inch wire (see Figure L-2). It has level winds that can be adjusted to spool 2 1/2-inch wire as well. Power is provided by two 125 hp DC electric motors, which can be connected singly or in combination to either drum. Each drum can heave a maximum 110,000 pounds at 37 fpm at an average layer. Maximum line speed is 100 fpm. Each drum can be set for automatic operation within the range of 25,000 to 115,000 pounds. Automatic operation includes payout and reclaim, with limits on maximum and minimum hawser scope.

The ARS 50 has a Series 400 traction machine located adjacent to, and forward of, the Series 322 machine. The traction winch is designed for use with 3½-inch to 14-inch circumference fiber line. It has a power block that back-tensions the line and assists in transporting the line to the storage bin. The traction winch has an automatic payout capability, with a set range of 15,000 to 110,000 pounds, but has no automatic reclaim capability. The machine requires some monitoring to control the towline tension without gradually paying out all the line, although it does have a "cable-off" device that will control the winch. Maximum heave is 110,000 pounds at 20 fpm; maximum line speed is 90 fpm.

Both machines are totally enclosed within the ship's deck house. Normal operation is from an enclosed operating station in the aft portion of the space, which is equipped with all controls and instrumentation. Much of the instrumentation is repeated in the pilot house. Emergency shutdown controls are located in the towing machine compartment. The ARS 50 towing machine has no auxiliary drum incorporated into the design.

L-5.2 T-ATF 166 Class Towing Machinery

The T-ATF 166 Class is equipped with a SMATCO Type 1 towing winch and a Lake Shore traction winch. The SMATCO winch is a single-drum machine capable of spooling 2,500 feet of 2 1/4 inch wire. A level wind is provided (see Figure L-3). There is no automatic payout or reclaim capacity in the initial design. Wire tension measurement is provided by strain gauges in the winch foundation. There is a remote tension readout, but no instrumentation for scope out of wire. Maximum hawser heave-in is 179,000 pounds at 14 fpm; maximum hawser speed is 280 fpm at 18,000 pounds tension on the first wrap. At the top wrap (twelfth layer) maximum line speed is 775 fpm at 6,000 pounds tension. Maximum pull on the twelfth layer is 64,000 pounds at 38 fpm.

A major difference between the SMATCO towing winch and those found on other Navy towing ships is that the SMATCO is diesel-driven through an air-operated clutch, a torque converter, and a gear train. For various reasons, towing is frequently accomplished with the drum locked on a "dog," rather than riding the brake. To increase hawser scope, or even let it run free in an emergency, the engine must be started, engaged, and the load taken off the dog before the dog can be released. The problem is aggravated by the fact that the pneumatic control system on the SMATCO winch can fail in the "open" position. In this event, there is no way to release the dog. However, if the winch is not dogged, loss of air will lead to free-wheeling and loss of the towline. Managing the hawser with this system is more difficult than with the standard U.S. Navy towing machines.

Some T-ATF vessels have had their SMATCO towing winch modified by Almon A. Johnson, Inc., to allow for automatic operation. This new configuration is labeled as an AAJ Type Series 332 towing winch. Modifications include the replacement of the diesel drive system with a closed-loop electro-hydraulic drive, and the addition of a programmable logic controller (PLC) based solid state

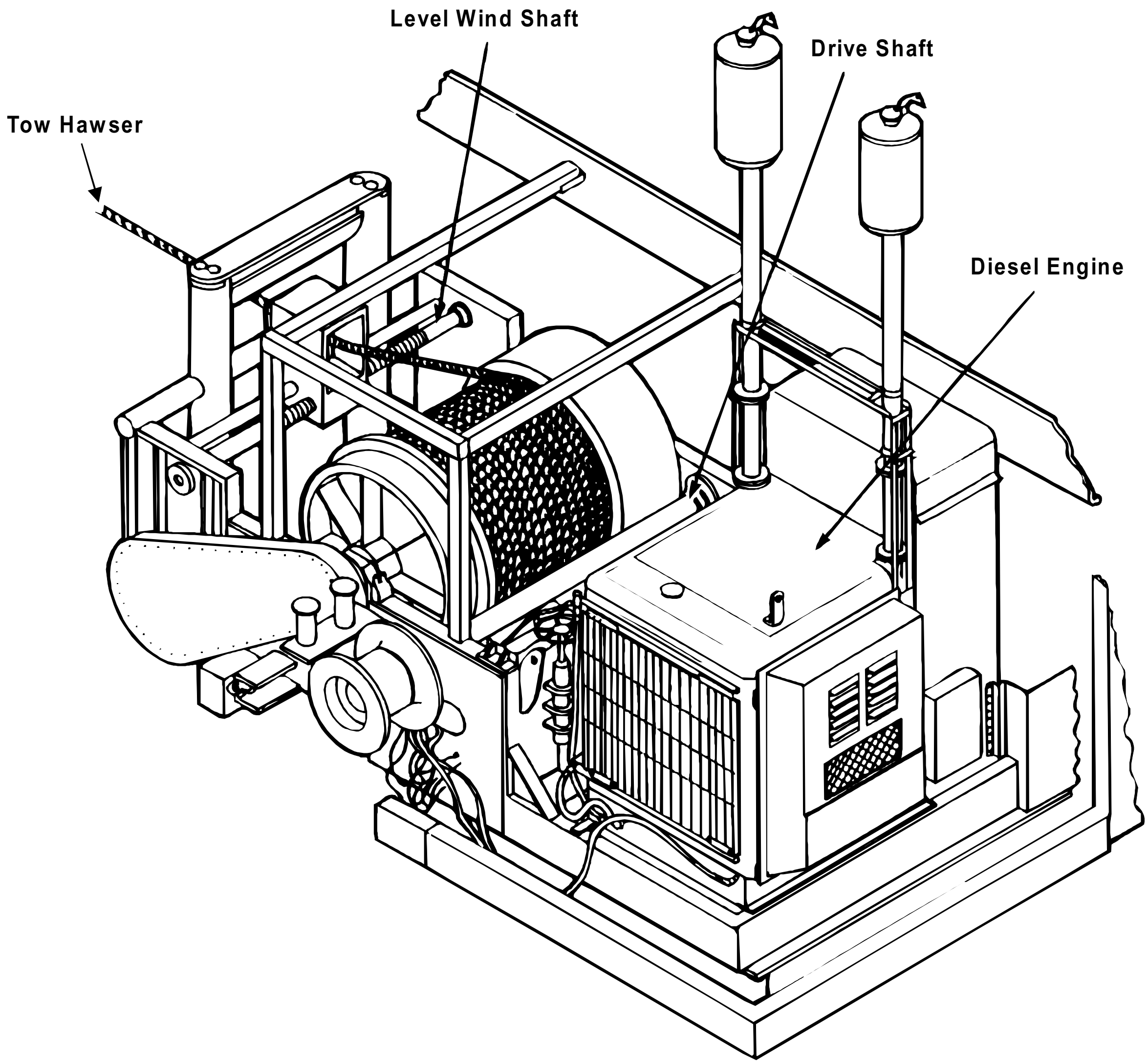

Figure L-3. T-ATF Towing Machinery (SMATCO Winch).

control system. Hydraulic fluid flow and pressure for the hydraulic drive motor is supplied by a hydraulic power unit mounted immediately forward of the towing machine. Automatic operation is achieved by PLC control of the hydraulic pump swash plate as determined by tow line scope and tension.

As shown in Figure L-4, the AAJ Type Series 332 is a single-drum machine capable of spooling 2,500 feet of 2 1/4-inch wire with a level wind. It is capable of automatic operation in a range of 30,000 pounds to 110,000 pounds, and manual operation to 250,000 pounds. The modified towing winch has a line speed rating of 0 to 36 feet per minute at 110,000 pounds at the mid layer of the drum. The operator control panel is located on the 01 level overlooking the fantail. A remote panel located on the bridge shows line pull, line scope, and status lights and alarms.

The T-ATF 166 Class has a separate Lake Shore traction winch suitable for fiber hawsers up to 15-inch circumference. The hawser is stored in a below-deck storage room with appropriate fairleads to the winch. The winch has no automatic functions. The Lake Shore Traction Machine is electric motor-driven, with infinite speed adjustment available. Maximum line pull is from 175,000 pounds at 12 fpm. No-load maximum line speed is 370 fpm in payout, 134 fpm heaving in. The unit can be declutched to permit the lines to run free in emergencies. There is a manual brake to control disconnected payout. The winch will hold and structurally withstand the breaking strength of a 15-inch circumference double-braided nylon hawser.

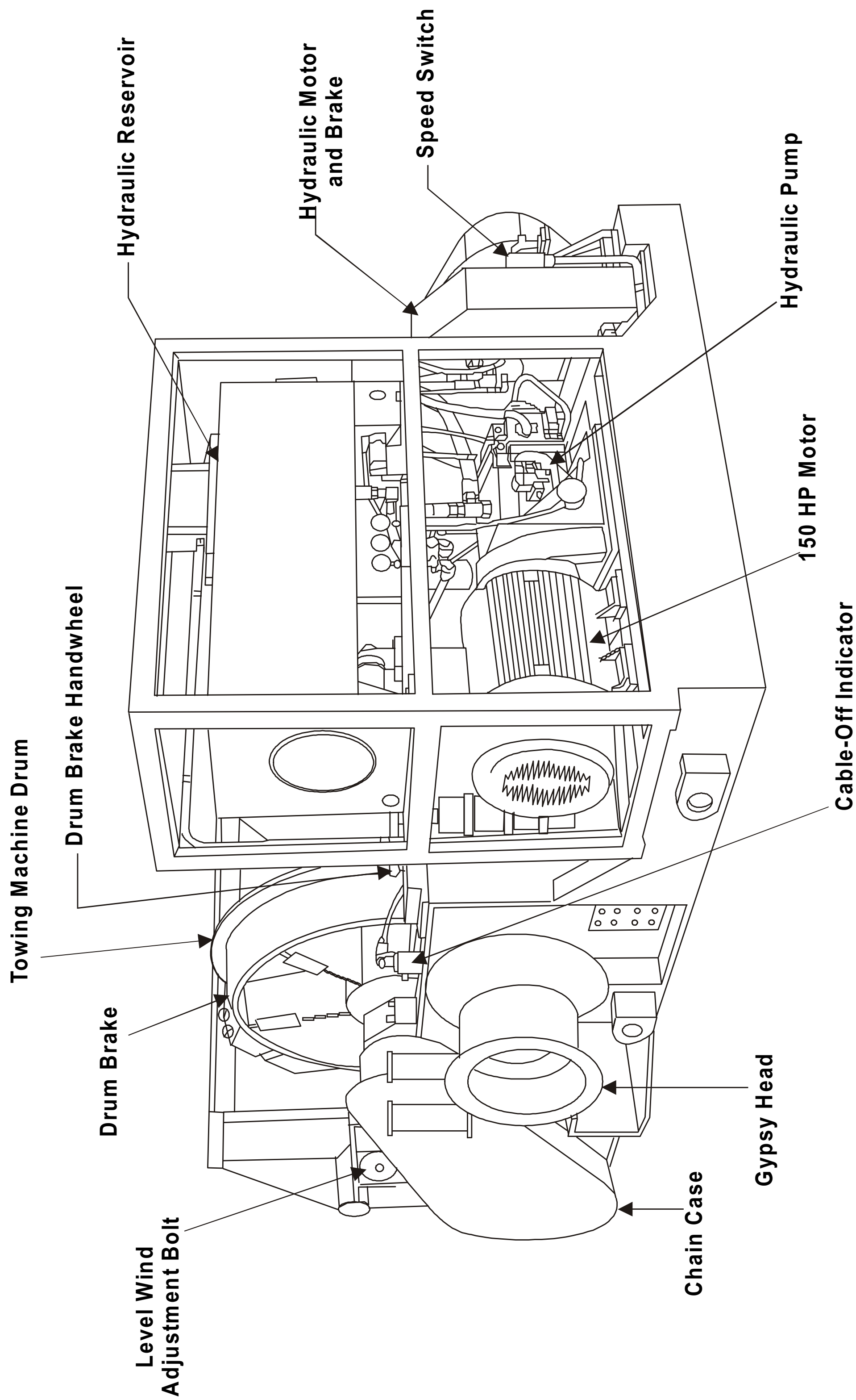

Figure L-4. T-ATF Towing Machinery (Series 332 Automatic Towing Machine).

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Appendix M

ESTIMATING DYNAMIC TOWLINE TENSIONS

M-1 Introduction

This appendix addresses the impact of ship motion on towline tension. This information can be used by the tow planner if sea conditions are known. More importantly, the data can be used to predict acceptable risks of extreme dynamic towline loadings, rather than relying solely on traditional factors of safety that are based on steady-state tensions.

M-1.1 Ship Motion

All seamen are aware of ship motions in a seaway, particularly rolling, pitching, and yawing. Three additional types of ship motion—heave, sway, and surge—are somewhat less apparent. Each ship, therefore, experiences a total of six independent types of motion (see Figure M-1). In a towing situation, both the tug and tow experience these motions, so the towline between them is subjected to 12 independent motions. The towline also acts on both ships. These dynamic effects can cause the towline to fail at unexpected times, when average tensions are well within apparently acceptable limits.

Traditionally, these dynamics could not be quantified. The problem was addressed by using the conventional method for handling unknown quantities—applying a factor of safety. In towing, the factors of safety are applied to the steady-state towline tensions (as described in Chapter 3) and the new strength of the towline. The factors of safety used are primarily based on experience. Nonetheless, failures still occur.

M-1.2 Wire Towline Behavior

A heavy wire hawser forms a catenary between the tug and tow. The catenary acts as a spring, flattening and deepening to compensate for relative motions between the tug and tow. In a steady-state condition, the shape of the catenary is easily estimated.

Questions exist about the cross-flow hydrodynamic resistance on the wire as it rises and falls. It has been suggested that, for the motion frequencies found in most towing situations, the wire towline does not have time to fully resume its former deep catenary when the tension eases before the next surge in tension occurs. The net result over time is that the wire catenary remains flat, thereby providing somewhat less spring than previously thought. Following this line of thought, more of the spring remaining in the system must be attributed to the elastic stretching of the wire itself. (See Section 3-4.3 for a discussion of the stretch of wire hawsers.)

M-1.3 Synthetic Towline Behavior

Fiber hawsers are much lighter than wire hawsers and do not form an appreciable catenary. They rely almost totally on their elastic stretch to meet constantly changing towing demands. The advent of strong, highly elastic synthetics, especially nylon, was expected to be a boon to towing, because their elasticity easily absorbed relative ship motion. Such hawsers could be easily handled and employed without a dedicated towing winch or an automatic towing machine. As the use of nylon became more prevalent, however, unexplained failures were reported, often under towing tensions far below the supposed strength of the towline. As a result, factors of safety were increased to the point where the advantages of nylon over wire hawsers were lost.

A separate problem with nylon was caused by its elasticity. The large amount of energy stored in the stretched hawser is released ex-

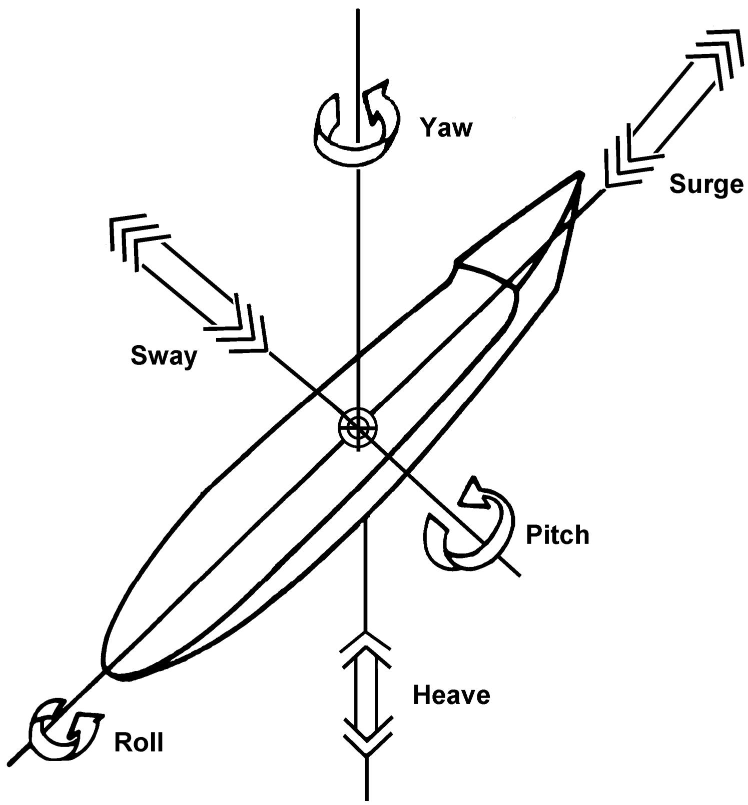

Figure M-1. Types of Motion.

plosively when the hawser fails. This often has disastrous effects, especially on personnel. Ultimately, the U.S. Navy restricted the use of synthetic towlines.

The problems with nylon hawsers led to major studies of the mechanical and chemical properties of rope. Basically, the studies found that the strength of such ropes is affected by sunlight, chemicals, salt water, and, above all, the cyclic load history of the rope. NAVSEA's continuing investigation into the use of improved and composite designs of synthetic hawsers has led to the approval for general use of single and double braided polyester lines in all routine and emergency towing applications with the exception of nuclear towing. The specifications of polyester line approved for use are provided in Appendix C.

M-2 Design of the Extreme Tension Study

This section briefly describes the project to assign quantities to towline dynamics. The behavior of a wire stretched in water between variably distant endpoints is discussed first, because this knowledge is a prerequisite to understanding the ship motion problem.

M-2.1 Understanding Wire Towline Behavior

The challenge of understanding the motions of two ships connected by a towline required a significant escalation of ship motion theories. A mathematical model was developed to predict the behavior of a wire towline and account for the wire's normal mechanical properties, plus the following factors:

- Cross-flow hydrodynamic drag on the wire that tends to flatten out the catenary and increase dynamic tensions
- The changing spring constant of the wire.

Tests were conducted in a model towing tank where the towline was pretensioned and one end point could be moved longitudinally to simulate the varying separation between tug and tow. The test results validated the numerical model describing the behavior of a wire towline.

M-2.2 Motions of the Tug and Tow

A computer can predict statistics of ship motion in a seaway, given ship characteristics, size and frequency of the ocean waves, angle of encounter with the waves, and ship speed. For towing, the motions of two ships connected by the towline model are examined. This does not directly predict the towline tension, however, because the motions of both the seas and the ships are random. The statistical nature of the effort does provide the probability that a tension will be exceeded during a 24-hour period of towing.

Given a steady-state tension, and selecting a probability of 0.1 percent, the program calculates “extreme tension,” the tension level that has one chance in a thousand of being exceeded in 24 hours of towing. This is comparable to once in 1,000 days of towing—a very small risk. (Of course, the “once” can occur in the first hour. There is always a risk.) With the low probability involved, however, extreme tensions can be compared to the strength of the towline using a lower factor of safety than is otherwise required when the dynamic effects are unknown. A factor of safety of 1.5 is indicated by this study. In other words, for a wire in good condition, limiting the extreme tension to 67 percent of the new breaking strength is reasonable.

Until experience is gained in applying the data to real-life tows, two factors of safety are applicable to towing operations: 1.5 when dynamic effects are quantified and the appropriate factor of safety from Table 3-2. Both must be checked. The more severe criterion must be considered the limit until significant quantitative experience is gained with the dynamic theory. Tow tensions should be limited so neither criteria is exceeded.

M-2.3 Description of Physical Variables and Influences on Extreme Tension

The numerical model describing wire hawser behavior was incorporated into the ship motion program. Thousands of individual computer simulations were performed, using the following variables:

- Size of the tug and tow
- Wave size, angle, and frequency
- Average towline tensions
- Weight and scope of towline used
- Towing speed.

Each of these variables is discussed below.

M-2.3.1 Size of Tug and Tow

Sea motions of both the tug and its tow are unique. It was therefore necessary to study the problem for four different tug classes: T-ATF 166, ARS 38, ARS 50, and ATS 1. For each tug, the following tow sizes were examined:

- 3,200-ton FFG 1 Class frigate

- 650-ton YRBM berthing barge
- 6,707-ton DD 963 Class destroyer
- 20,000-ton AE 26 Class ammunition ship
- 40,000-ton LHA 1 Class assault carrier.

The motion characteristics of the ARS 50 and ATS 1 were found to be so similar that they were combined into one category. Although the ARS 38 and ATS 1 Class vessels have been decommissioned, the data are still included here to demonstrate the scope of the study.

M-2.3.2 Wave Size, Angle, and Frequency

Ocean waves cause various motions in the tug and the tow, which in turn cause variations in towline tension. The ship motion having the most influence on towline tension is surge, but the other motions—sway, heave, roll, pitch and yaw—play roles as well. Although methods for predicting most types of ship motion have been used for some time, surge was normally not addressed. Surge has been included in these efforts.

Generally, the larger waves cause the greatest tension, but it is not only the size of any one wave that counts—ship position and motion at any given point depend on the several most recent waves. In addition to wave size, the wave frequency is influential. For very high frequency waves, ships do not have time to respond to each wave, so the motions resulting from such waves are small. At very low frequencies, ships move significantly, but there is enough time for the catenary to adjust. At somewhat higher frequencies, changes in catenary depth are restricted by the cross-flow drag of the water on the catenary as it tries to rise and fall. This results in larger extreme tensions.

The wave height estimated by an experienced seaman has been found to be approximately the average height of the third-highest waves, called $H^{1/3}$. Values of $H^{1/3}$ used in the computer program for predicting extreme tensions are as follows:

Wind Speed	$H^{1/3}$
15 knots	4.0 feet
20 knots	7.2 feet
25 knots	9.1 feet
30 knots	16.4 feet

Another important factor is the angle at which waves are encountered. Changing course to encounter waves on at a different angle can sometimes reduce towline tension. Sometimes head seas are better; at other times, seas from 60 degrees are better. Computations were based relative wave directions of “dead ahead” (0 degrees) and 60, 120, and 180 degrees.

M-2.3.3 Average Towline Tension

For a wire rope towline, the average (mean) towline tension is critical for predicting extreme tension, since it is the base to which the dynamic tension effects are added in the analyses. When average tension is low, the towline hangs in a deep catenary and can change its depth to accommodate large ship motions without large changes in the tension. When the average tension is high, the towline is nearly straight and can accommodate ship motions only by stretching, which requires large increases in the tension of wire rope.

Methods for estimating average towline tension appear in Section 3-4.1 and Appendix G of this manual. One of the effects influencing average tension, the added resistance due to waves, cannot be estimated with great accuracy. Results for added resistance, obtained from the methods presented in Appendix G, are approximate. Because average tension is critical for estimating extreme tension, especially for wire rope towlines, it is preferable to use mean tension measured with an accurate tension meter rather than using calculated mean tension.

For the purposes of this study, mean towline tensions were assumed to be the following:

- 10,000 pounds
- 20,000 pounds
- 40,000 pounds
- 80,000 pounds
- 120,000 pounds

M-2.3.4 Weight and Scope of Towline Used

The towline catenary depends upon the weight and scope of the wire used. All of the computations were based on the actual hawsers used by each towing ship (see Table B-1). Computations also assumed that the final connection to the tow uses one shot of 2¼-inch chain, with 20 feet on the deck of the tow and 70 feet extending outward from the tow's bow. Computations were made for hawser scopes of 1,000, 1,200, 1,500, 1,800 and 2,100 feet.

M-2.3.5 Tow Speed

Speed contributes to extreme tension for two reasons. First, the wave encounter frequency for head seas increases with incremental speed, thereby raising slightly the added resistance due to tensions. Secondly, and far more significant, is that increased speed creates higher average towline tension. It increases dynamic factors by raising the base to which purely dynamic parameters are added, and creates a stiffer towline system (that is, one with less catenary). A stiffer system also increases dynamic effects.

Because of the association between mean tension and extreme tension, estimates of the latter are based on accurate estimates of mean tension rather than towing speed. The primary effects of speed are automatically included in the mean tension number. The less-important influences of speed were accounted for in the study, however. Computations were based on towing speeds of 3, 6, and 9 knots.

M-2.3.6 Yawing and Sheering

In towing terminology, "sheering" is the movement of the tow off to the side of the towing track. This motion can be steady, with the tow staying to one side, or unsteady, with the tow moving from side to side and taking several minutes to go through a complete cycle. Occasionally, sheering is called "yawing." This term should not be confused with "yawing" in seakeeping terminology, which is a variation in heading caused by waves. The effects of yawing are included in the computations, but effects of sheering are not. Section M-3.2.6 provides guidance for addressing a badly sheering tow.

M-2.4 Display of the Data

To recap, calculations were based on:

- Three classes of tugs (T-ATF 166, and ARS 50)
- Five tow sizes (FFG 1, YRBM, DD 963, AE 26, and LHA 1)
- Four wind speeds (15, 20, 25, and 30 knots)
- Three towing speeds (3, 6, and 9 knots)
- Five hawser scopes (1,000, 1,200, 1,500, 1,800, and 2,100 feet)
- Four wave angles (0, 60, 120, and 180 degrees)

The results of these numerous calculations are displayed in 15 tables—one for each tug-tow combination (see Tables M-1 through M-10). Each table, in turn, has 12 blocks—one for each wind speed/towing speed combination. Each block contains four rows (for the four wave angles) and five columns (for the five hawser scopes). The end result for each combination is a curve number. This number indicates which curve should be used to calculate extreme tension from average tension. One hundred different curves are presented in Figures M-2 through M-5.

When there is not an obvious choice, the program selects the curve number that best minimizes the error at higher tension ranges—that is, at about 70 percent of the strength of the wire used by the tug. Precise accuracy at higher tension levels is not needed, since there is too much risk associated with towing at these tensions. Errors at lower levels are not a problem, since the wire is not highly loaded.

For example, for a T-ATF towing a 40,000-ton LHA at 3 knots with an 1,800-foot hawser into head seas generated by 30-knot winds, the table identifies curve number 6 (see Table M-5). If the predicted average towline tension is 52,000 pounds, curve 6 predicts extreme tension at 140,000 pounds (see Figure M-2). In other words, there is only a 0.1 percent probability that a tension of 140,000 pounds will be exceeded in a day of towing under the specified conditions. Assume that the tow now sheers out to one side, remaining off the tug's quarter for a significant period. The tug's towing winch tension meter now reads 70,000 pounds. Curve 6 predicts the extreme tension of 195,000 pounds—still well below the allowable tension for the T-ATF's towing hawser.

M-3 Use of the Data

This section presents guidelines on using the extreme tension curves.

M-3.1 Allowable Extreme Tension

Given an estimated or measured average towline tension, the curves provide an extreme tension (dynamic plus average) that has only one chance in a thousand of being exceeded in 24 hours of towing. The allowable tension for a given wire can therefore be much closer to the hawser's ultimate strength than can tension computed relying on the traditional factors of safety described in Section 3-4.1.5. Keeping extreme tension under 67 percent of new breaking strength is recommended. This is equivalent to a factor of safety of 1.5. Each ship might draw a horizontal line on each of Figures M-2 through M-5 at 67 percent of the catalogue strength of its towing hawser. This represents the limit of acceptable extreme towline tension for that tug.

Again, the 1.5 safety factor described above does not supersede factors of safety listed in Table 3-2. These latter factors of safety, which describe limits on average or steady-state tension, must still be checked. Tow speed and tow line tensions should be controlled such that neither factor of safety be exceeded.

M-3.2 Interpolation Within the Tables

This section describes how to interpolate data within the tables for a particular set of circumstances.

M-3.2.1 Ship Size

For tugs that are different from those described, use the next smaller ship listed. The rationale for this choice is that smaller ships are generally affected more by a given sea state than larger ships. For towing ships smaller than the 2,000-ton ARS 38, use the ARS 38 as the basis for evaluating dynamic tension. For tows different from the examples used, use the next smaller tow unless the particular tow's displacement is within 25 percent of that of the next larger vessel.

M-3.2.2 Tow Speed

Because extreme tension is calculated from average tension, not towing speed, an incorrect prediction of speed is not too serious. Examination of the curves and tables will show that the secondary effects of speed, at a given average tension, are not great. Thus, without resulting in major error, the table values for 3 knots can be applied to speeds from 1.0 to 4.5 knots; similarly, the 6.0 knot table values can be applied to speeds from 4.5 to 7.5 knots, and so forth. Again, it is far more important to know the actual average tension than the actual speed. To find the maximum allowable speed for a given scope, interpolation or extrapolation is acceptable.

M-3.2.3 Towing Hawser Scope

Shorter hawser scope results in a "stiffer" hawser system and higher dynamic components. To be conservative, enter the tables with the next-lower scope (i.e., 1,500 feet for a 1,700-foot hawser scope). Extrapolating beyond 2,100 feet is acceptable.

M-3.2.4 Wave Angle

Data in the tables are presented for relative wave directions of 0, 60, 120, and 180 degrees. The data for 0 degrees can be used for head seas and seas to angles of 40 degrees relative. The 60 degrees results can be used for seas from 40 to 70 degrees relative. Results are not provided for predominantly beam seas (between 70 and 110 degrees relative) because the tow's rolling and sheering present much larger difficulties than towline dynamics for these angles. The 120 degrees results can be used for quartering seas between 110 and 140 degrees relative, respectively, whereas the 180 degrees results are appropriate for following seas between 140 and 220 degrees relative.

M-3.2.5 Wind Strength and Wave Height

If the seas are not fully developed, the relationship between wind speed and wave characteristics will be different from that used in the computer program. Factors for which seas would not be fully developed include small fetch or changes in wind speed or direction, since it takes many hours for the sea state to reach equilibrium with the wind.

When seas are not fully developed, data for wind speeds corresponding to actual wave heights should be used (as listed in Section M-2.3.2) instead of data for existing wind speeds. For example, a sudden 45-knot wind can develop waves estimated at 9 feet. In the tables, use the data for a 25-knot wind speed, which assumes $H^{1/3}$ at 9.1 feet.

M-3.2.6 Adjust Calculations for Sheering

A tow sheering badly to one side or the other will raise the average tension. This is due to significantly increased hydrodynamic resistance of the towline and (possibly) increased resistance of the tow because of a relatively long-term yaw angle from the course of the tug. Such sheering movements generally occur at a low frequency, so that they in themselves do not generate dynamic effects. The tug, typically with a constant-torque engine setting, will simply slow down to compensate for the increased average resistance. The effects of sheering were not included in the extreme tension model. With a sheering tow, the tow ship should observe the average tension, over a minimum of 30 seconds, when the tow is at its extreme deviation from the tug's track. This figure should be used on the curves to determine the extreme tension. If a badly sheering tow is also rolling heavily, and has a high bow, increasing the dynamic factor of safety to 2.0 is appropriate.

M-4 Response to Worsening Sea Conditions

When encountering rising seas, the towing ship Commanding Officer has several options.

M-4.1 Reduce Speed

Reducing speed is probably the single most effective action, because of the multiple effects in extreme tension—reduction of towline stiffness (with consequent dynamic component reduction) and reduction of the average tension.

M-4.2 Increase Towline Scope

While not as effective as reducing tow speed, increasing towline scope is usually the first action taken, assuming adequate water depth and towline length. This reduces the stiffness of the system and therefore reduces the dynamic component of the extreme tension.

M-4.3 Change Course

Examination of the tables and curves reveals that changing course to encounter the waves on a different relative heading can reduce towline tension. Sometimes seas from 60 degrees relative are better than head seas. This is demonstrated in the ATS 1 Class example below. In general, stern seas at a given average tension are worse, but in some cases, the tug can reduce RPM and might still make headway with acceptable towline tensions. Specific examples will have to be worked out carefully.

M-5 Examples

The following section provides additional examples for using Tables M-1 through M-10 and Figures M-2 through M-5.

Use of the extreme tension charts and curves first requires a predicted or observed mean towing hawser tension. For the sake of simplicity, all of the following examples are based on the tow of a 7500 LT DD 963 Class destroyer into seas generated by a 25-knot wind. These are the same set of circumstances used in Example 2 of Appendix G. Example 2 predicts the hawser tension for several speeds, including the hydrodynamic resistance of 2,000 feet of 2¼-inch wire towing hawser with one shot of 2¼-inch chain. It also predicts the maximum safe speed for each of the most common Navy towing ships.

This example shows fairly modest changes in hawser hydrodynamic resistance over the tension range of interest. For the following examples, therefore, the effects of different scopes and different hawsers can be ignored. Alternatively, tow resistance alone can be considered and the wire resistance of the specific hawser in use added back at the appropriate points. However, the method used here is simpler and will make the results somewhat conservative.

The tables are developed for each towing ship class towing a DD 963 Class destroyer displacing 6,707 LT. The assumed tow, being heavier at 7,500 LT, will experience somewhat less motion; the results will slightly overstate extreme tensions but are sufficient for estimating purposes.

M-5.1 ATS 1 Class

For the ATS 1 Class, Example 2 predicts a maximum tow speed of 7.2 knots with a total hawser tension of 106,000 lbs.

In Table M-8, look at the 25-knot wind/6-knot tow speed block. Find the curve numbers for several hawser scopes; look at the curves at 106,000 pounds to find several predicted extreme tensions as folllows:

Wave Angle	Scope	Curve No.	Extreme Tension
0°	1,200	5	270,000 lbs.
0°	1,500	4	234,000 lbs.
0°	1,800	3	203,000 lbs.
0°	2,100	29	177,000 lbs.
60°	1,200	33	235,000 lbs.
60°	1,500	31	198,000 lbs.
60°	1,800	30	217,000 lbs.
60°	2,100	29	177,000 lbs.

The ATS 1 Class towing hawser has a new breaking strength of 300,000 pounds. Using a 1.5 dynamic factor of safety for evaluating extreme tensions, the allowable extreme tension is 240,000 pounds. Note that the predicted extreme tensions for hawsers of at least 1,500 are all under 240,000 pounds. Note also that predicted extreme tension is reduced in some cases when the seas are met at 60 degrees relative, rather than head-on.

Not shown here is the extreme tension when towing downwind under these conditions. Assume tow speeds up to about 9 knots with the same tension, because of the following wind and seas. Predicted extreme tension is beyond the curve display limits of 400,000 pounds for all towline scopes listed.

The steady state, or mean, tensions must also be checked against the safety factors listed in Table 3-2. When towing on automatic tension control, the minimum factor of safety is 3, and the allowable tension is:

360,000/3=120,000 lbs.

This is greater that the mean tension of 106,000 pounds, so the tow described is within limits, the actual control being the towing capacity of the ATS 1 at the speed of 7.2 knots.

M-5.2 ARS 50 Class

The ARS 50 class uses the same tables as the ATS 1 Class, therefore, the curve numbers will be the same. But the ARS 50 can tow the 7500 LT DDG 963 Class destroyer at only 6.9 knots with a mean hawser tension of 98,000 pounds. Therefore, extreme tensions will be less than for the ATS 1 at 7.2 knots. For example, with a hawser scope of 1,800 feet, the extreme tension prediction is 186,000 pounds. The ARS 50 has a stronger hawser than the ATS 1, so the example needs to be carried no further to check factors of safety. The tow will be limited by the maximum towing speed attainable by the ARS 50.

M-5.3 T-ATF 166 Class

Example 2 predicts that the T-ATF can conduct the tow at 7.6 knots with a hawser tension of 117,000 pounds. However, if the T-ATF tows without its automatic tension feature, the minimum factor of safety from Table 3-2, would be 4, and the allowable mean tension is:

360,000/4 = 90,000 lbs.

This will limit the towing speed to about 6.9 knots.

The extreme tension must also be checked with a mean tension of 90,000 pounds using Table M-3.

Wave Angle	Scope	Curve No.	Extreme Tension
0°	1,200	4	195,000 lbs.
0°	1,500	3	170,000 lbs.
0°	1,800	30	162,000 lbs.
0°	2,100	29	148,000 lbs.

Applying the dynamic factor of safety of 1.5, the maximum allowable predicted extreme tension is 240,000 pounds. Therefore, predicted extreme tensions from ship motion theory is satisfactory for this tow at 6.9 knots. The 90,000-pound steady-state tension condition limits this tow.

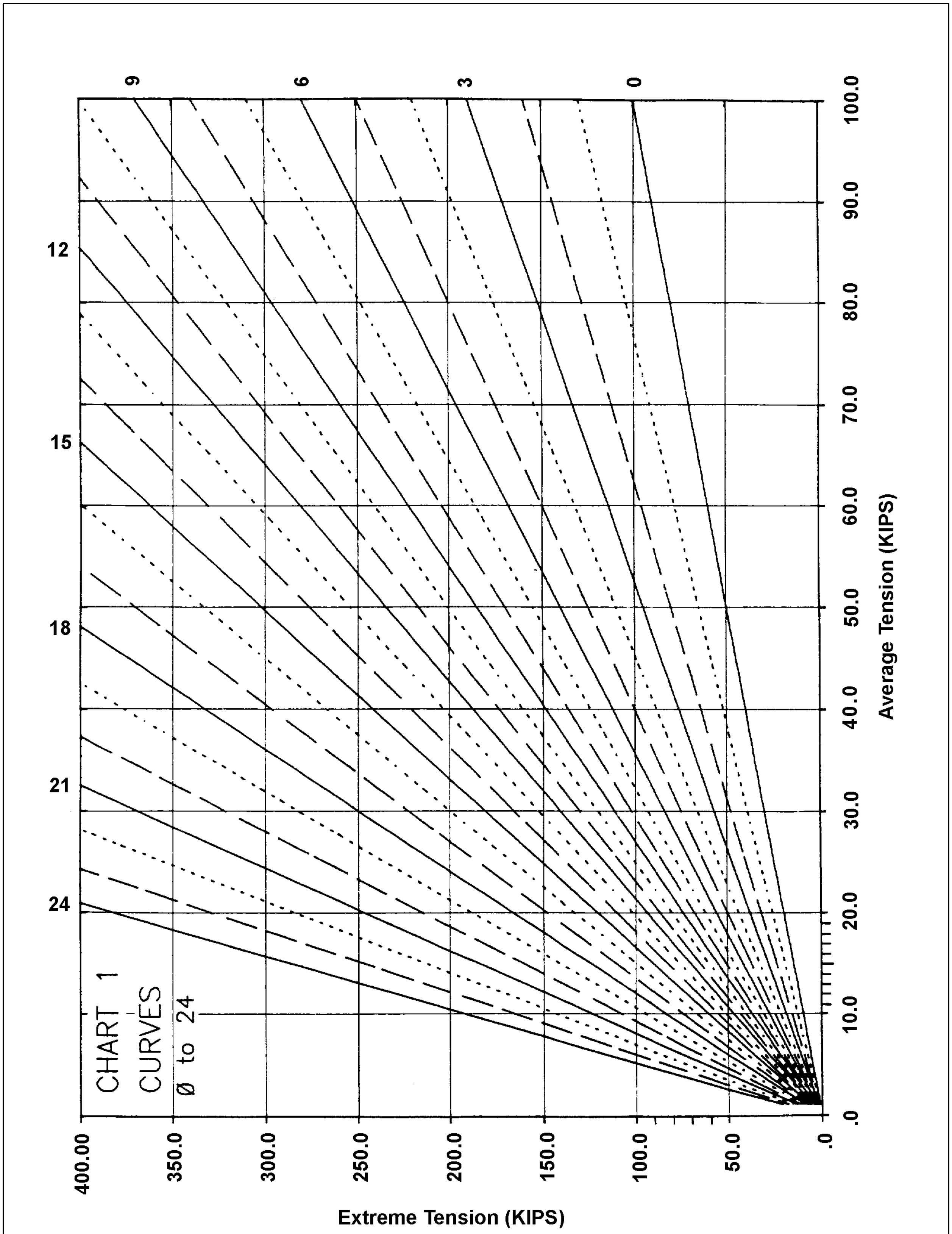

Figure M-2. Extreme Tensions (Curves 0 to 24).

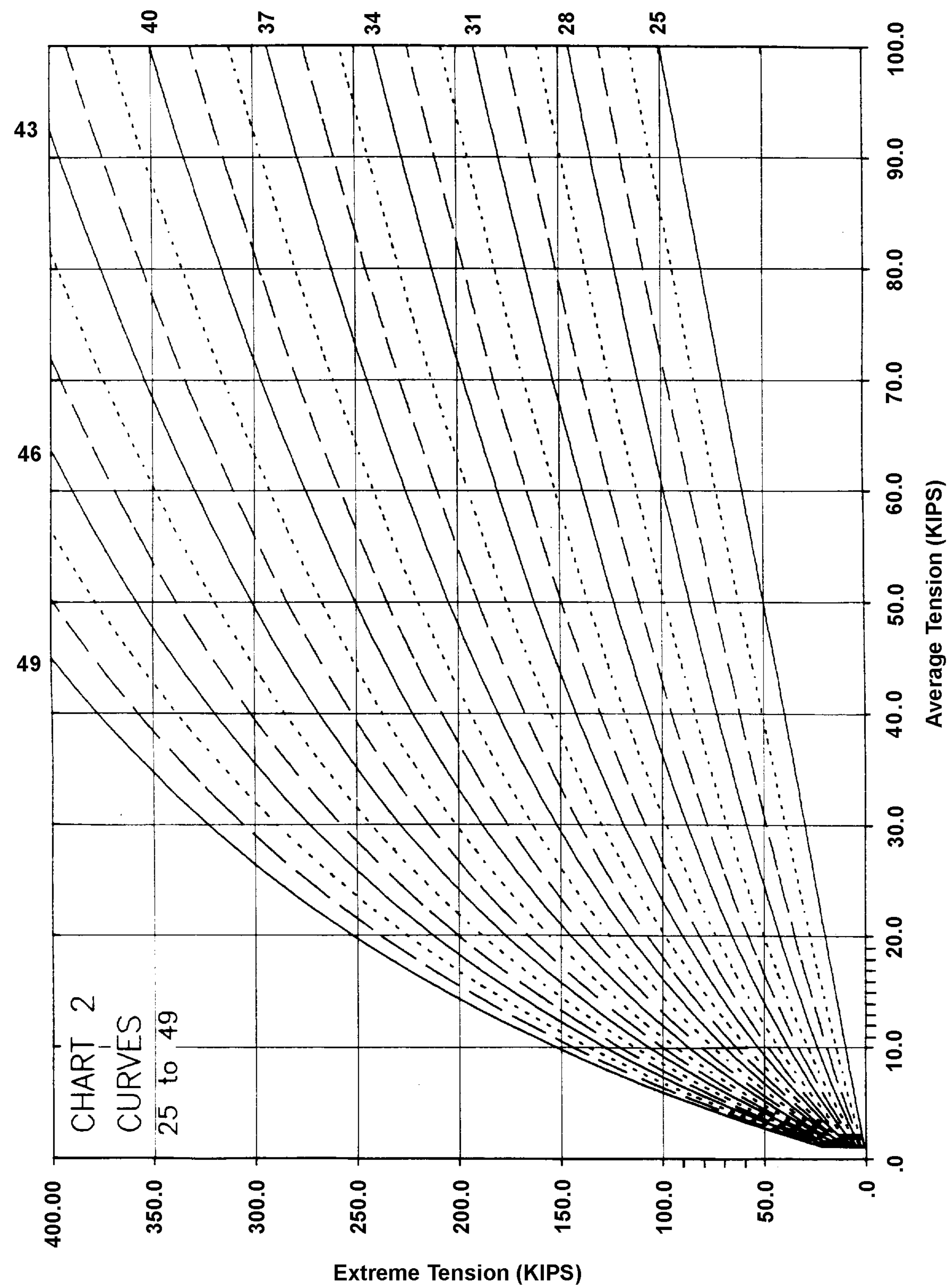

Figure M-3. Extreme Tensions (Curves 25 to 49).

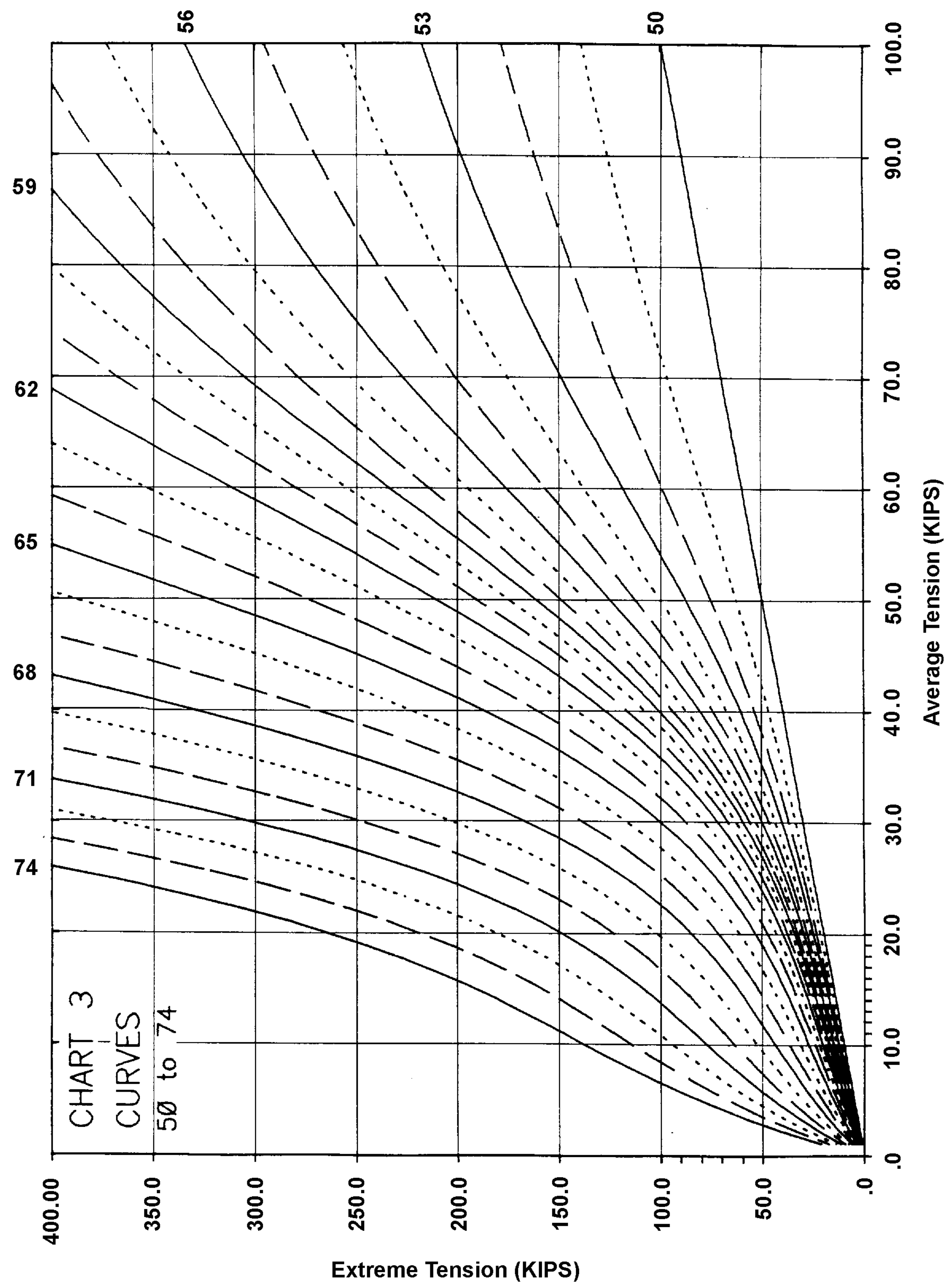

Figure M-4. Extr eme Tensions (Curves 50 to 74).

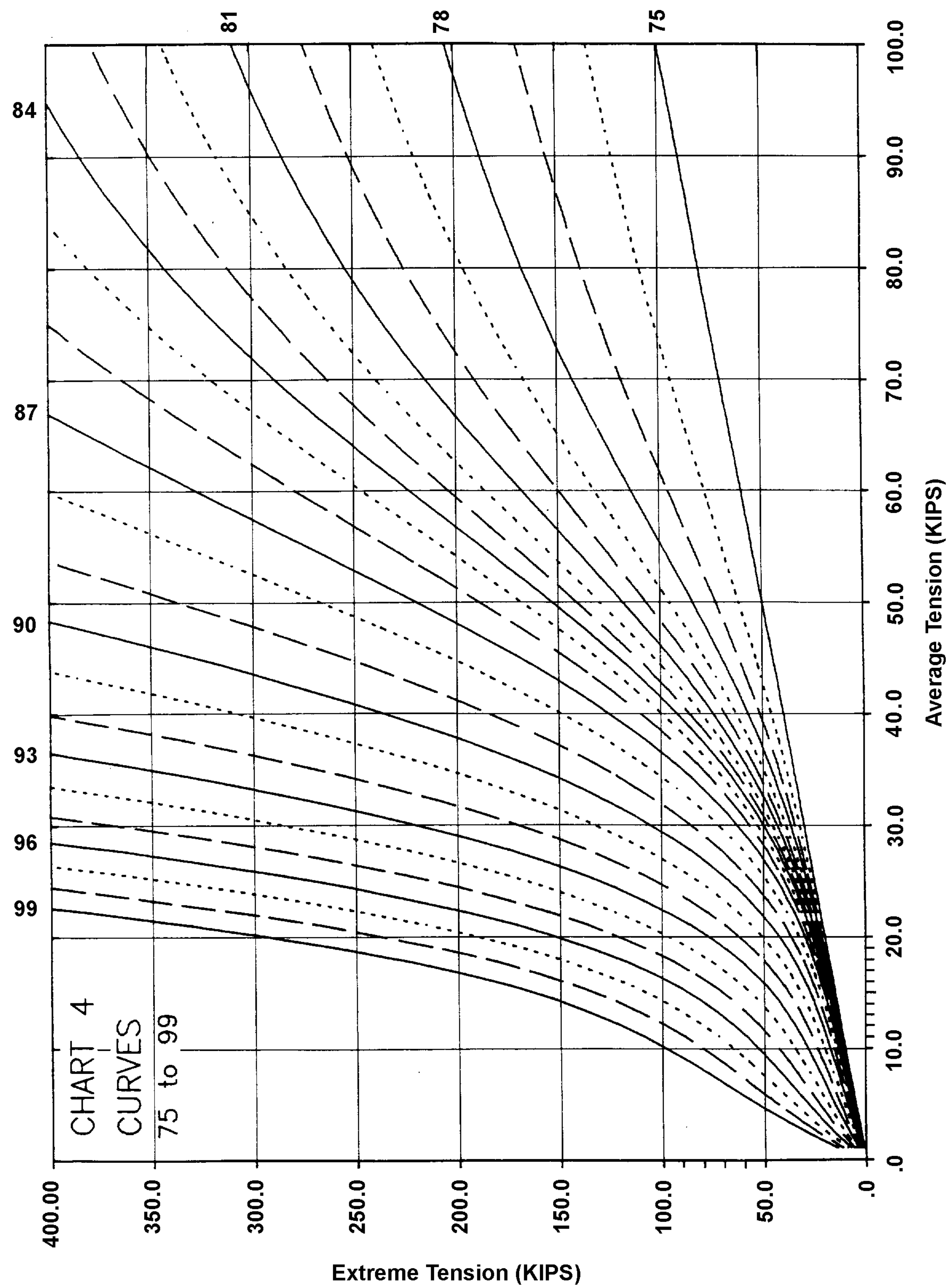

Figure M-5. Extreme Tensions (Curves 75 to 99).

Table M-1. T-ATF Towing YRBM Barge Displacing 650 Tons.

Curve Numbers for Various Towline Lengths

Rel Wave Dir	15 Knot Wind - 3 Knots Approximate Tow Speed					15 Knot Wind - 6 Knots Approximate Tow Speed					15 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	79	51	1	26	26	51	1	26	26	26	1	26	26	26	26
60º	79	2	1	26	26	77	51	26	26	26	51	1	26	26	26
120º	81	79	2	51	76	86	81	52	2	51	60	82	53	52	77
180º	89	86	53	77	76	64	87	86	80	77	37	35	34	82	81

Rel Wave Dir	20 Knot Wind - 3 Knots Approximate Tow Speed					20 Knot Wind - 6 Knots Approximate Tow Speed					20 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	90	89	84	79	77	63	85	79	52	51	81	79	52	28	27
60º	89	63	86	79	77	63	85	79	52	28	82	54	52	2	51
120º	89	89	87	82	79	67	64	86	81	54	67	64	62	82	55
180º	69	90	89	63	84	95	68	90	89	87	46	43	17	65	88

Rel Wave Dir	25 Knot Wind - 3 Knots Approximate Tow Speed					25 Knot Wind - 6 Knots Approximate Tow Speed					25 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	94	68	90	89	87	69	90	88	60	56	16	62	83	55	4
60º	68	90	66	88	86	67	89	87	84	80	15	61	83	80	53
120º	70	91	90	89	88	70	91	65	88	62	71	69	66	63	61
180º	97	94	68	67	90	99	96	93	68	90	24	97	71	69	68

Rel Wave Dir	30 Knot Wind - 3 Knots Approximate Tow Speed					30 Knot Wind - 6 Knots Approximate Tow Speed					30 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	74	96	69	91	90	73	71	91	66	64	71	69	65	62	84
60º	96	70	91	90	89	72	69	66	88	62	71	17	62	60	82
120º	97	95	68	90	66	98	95	68	66	89	99	95	68	66	64
180º	24	74	71	69	68	24	99	95	69	69	24	24	74	72	69

Note: Numbers listed under each hawser length correspond to curves found in Figures M-2 through M-5. Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0.1 percent of occurring in 24 hours of towing under the stated conditions.

Table M-2. T-ATF Towing FFG 1 Frigate Displacing 3,200 Tons.

Curve Numbers for Various Towline Lengths

Rel Wave Dir	15 Knot Wind - 3 Knots Approximate Tow Speed					15 Knot Wind - 6 Knots Approximate Tow Speed					15 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	26	26	26	26	0	26	26	0	0	0	26	26	0	0	0
60º	1	26	26	26	26	27	26	26	26	26	26	26	26	26	26
120º	76	26	26	26	26	51	76	26	26	26	71	51	76	26	26
180º	76	76	26	26	26	77	51	76	76	26	83	53	77	51	76
Rel Wave Dir	20 Knot Wind - 3 Knots Approximate Tow Speed					20 Knot Wind - 6 Knots Approximate Tow Speed					20 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	3	2	28	51	1	29	28	27	27	26	29	28	27	27	26
60º	30	29	28	28	27	30	29	28	28	27	29	29	28	27	27
120º	4	3	2	28	51	80	78	52	28	28	56	79	78	2	2
180º	83	54	78	77	2	65	83	80	53	3	68	66	60	81	54
Rel Wave Dir	25 Knot Wind - 3 Knots Approximate Tow Speed					25 Knot Wind - 6 Knots Approximate Tow Speed					25 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	13	7	79	3	30	8	5	32	30	29	36	33	31	30	29
60º	61	83	31	30	29	57	33	30	30	29	7	32	30	30	29
120º	64	83	54	31	52	66	63	55	4	3	66	63	82	54	53
180º	68	90	11	81	54	70	68	64	10	56	73	70	67	64	61
Rel Wave Dir	30 Knot Wind - 3 Knots Approximate Tow Speed					30 Knot Wind - 6 Knots Approximate Tow Speed					30 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	18	66	13	8	5	17	15	9	6	33	16	14	7	34	32
60º	67	67	61	34	32	67	65	58	33	31	66	63	36	32	31
120º	68	67	63	56	5	69	67	65	60	80	71	68	66	61	56
180º	73	70	67	65	11	99	72	69	67	15	24	98	71	69	67

Note: Numbers listed under each hawser length correspond to curves found in Figures M-2 through M-5. Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0.1 percent of occurring in 24 hours of towing under the stated conditions.

Table M-3. T-ATF Towing DD 963 Destroyer Displacing 6,707 Tons.

Curve Numbers for Various Towline Lengths

Rel Wave Dir	15 Knot Wind - 3 Knots Approximate Tow Speed					15 Knot Wind - 6 Knots Approximate Tow Speed					15 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	26	26	26	26	0	26	26	26	0	0	26	26	0	0	0
60°	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26
120°	76	26	26	26	26	51	1	26	26	26	51	51	1	26	26
180°	76	1	26	26	26	77	51	76	76	26	80	78	77	51	76

Rel Wave Dir	20 Knot Wind - 3 Knots Approximate Tow Speed					20 Knot Wind - 6 Knots Approximate Tow Speed					20 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	3	2	51	51	1	2	28	51	1	26	28	51	1	26	26
60°	29	29	28	27	27	29	28	28	27	27	29	28	28	27	27
120°	3	52	2	27	1	4	3	77	28	51	80	4	3	2	28
180°	6	4	3	77	28	61	82	79	78	52	67	63	82	80	53

Rel Wave Dir	25 Knot Wind - 3 Knots Approximate Tow Speed					25 Knot Wind - 6 Knots Approximate Tow Speed					25 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	9	6	4	3	52	6	4	3	30	29	5	32	30	29	28
60°	83	32	31	29	29	35	32	30	29	29	33	31	30	29	29
120°	61	6	4	3	29	89	58	5	53	3	65	60	55	79	78
180°	91	63	82	80	4	69	67	13	8	6	73	69	66	14	9

Rel Wave Dir	30 Knot Wind - 3 Knots Approximate Tow Speed					30 Knot Wind - 6 Knots Approximate Tow Speed					30 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	17	15	10	7	5	16	13	7	5	32	15	9	6	33	32
60°	67	63	6	33	31	66	62	34	32	31	65	62	34	32	31
120°	68	66	60	5	4	68	67	63	81	5	19	67	63	82	6
180°	72	69	66	13	8	98	72	68	16	13	24	98	71	69	16

Note: Numbers listed under each hawser length correspond to curves found in Figures M-2 through M-5. Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0.1 percent of occurring in 24 hours of towing under the stated conditions.

Table M-4. T-ATF Towing AE 26 Displacing 20,000 Tons.

Curve Numbers for Various Towline Lengths

Rel Wave Dir	15 Knot Wind - 3 Knots Approximate Tow Speed					15 Knot Wind - 6 Knots Approximate Tow Speed					15 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	26	26	26	0	0	26	26	0	0	0	26	26	0	0	0
60º	26	26	26	0	26	26	26	26	0	26	26	26	26	0	0
120º	1	26	26	26	26	76	1	26	26	26	51	51	1	26	26
180º	76	76	26	26	26	77	51	76	26	26	53	52	51	51	76

Rel Wave Dir	20 Knot Wind - 3 Knots Approximate Tow Speed					20 Knot Wind - 6 Knots Approximate Tow Speed					20 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	30	2	28	27	1	2	28	27	27	1	28	28	27	26	26
60º	30	29	28	27	27	30	28	28	27	27	29	28	28	27	27
120º	3	29	28	28	27	4	3	2	28	51	5	53	52	2	28
180º	5	53	52	2	28	8	6	4	3	77	16	61	38	54	53

Rel Wave Dir	25 Knot Wind - 3 Knots Approximate Tow Speed					25 Knot Wind - 6 Knots Approximate Tow Speed					25 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	7	5	4	3	30	35	33	31	30	29	34	32	30	29	29
60º	35	32	31	29	29	34	32	31	29	29	34	32	31	29	29
120º	8	51	3	30	29	12	6	4	31	30	62	8	5	4	3
180º	15	12	7	5	4	68	16	11	7	80	21	69	15	13	8

Rel Wave Dir	30 Knot Wind - 3 Knots Approximate Tow Speed					30 Knot Wind - 6 Knots Approximate Tow Speed					30 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	17	14	8	6	34	16	11	37	34	33	14	39	36	33	32
60º	16	10	35	32	32	15	39	34	32	32	15	37	34	32	31
120º	67	64	7	34	32	68	65	8	6	4	18	66	12	7	5
180º	20	68	15	12	8	22	71	67	15	12	24	74	70	68	16

Note: Numbers listed under each hawser length correspond to curves found in Figures M-2 through M-5. Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0.1 percent of occurring in 24 hours of towing under the stated conditions.

Table M-5. T-ATF Towing LHA 1 Displacing 40,000 Tons.

Curve Numbers for Various Towline Lengths

Rel Wave Dir	15 Knot Wind - 3 Knots Approximate Tow Speed					15 Knot Wind - 6 Knots Approximate Tow Speed					15 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	26	26	26	0	0	26	26	0	0	0	26	0	0	0	0
60º	26	26	26	0	26	26	26	0	0	0	26	26	0	0	0
120º	1	26	26	26	26	51	1	26	26	26	51	76	1	26	26
180º	76	26	26	26	76	77	51	76	26	26	78	77	51	76	76
Rel Wave Dir	20 Knot Wind - 3 Knots Approximate Tow Speed					20 Knot Wind - 6 Knots Approximate Tow Speed					20 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	52	2	28	51	1	2	51	1	1	26	28	51	1	26	26
60º	29	28	27	27	1	29	28	27	27	27	28	28	27	27	27
120º	3	2	28	27	27	4	52	2	28	51	4	3	52	2	28
180º	5	53	52	2	28	8	6	4	3	52	15	11	81	54	53
Rel Wave Dir	25 Knot Wind - 3 Knots Approximate Tow Speed					25 Knot Wind - 6 Knots Approximate Tow Speed					25 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	7	5	4	3	52	5	4	3	52	2	4	31	52	2	28
60º	34	32	30	29	29	33	31	30	29	29	34	32	30	29	29
120º	7	5	31	30	29	9	6	4	3	52	12	7	5	4	3
180º	15	10	6	5	4	18	15	10	7	80	20	68	15	12	8
Rel Wave Dir	30 Knot Wind - 3 Knots Approximate Tow Speed					30 Knot Wind - 6 Knots Approximate Tow Speed					30 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	17	13	8	6	4	14	9	6	5	4	12	38	35	33	32
60º	15	8	34	32	31	15	37	33	32	31	13	38	35	33	32
120º	66	63	6	4	32	68	64	7	5	4	18	15	9	6	5
180º	20	18	15	10	7	22	20	17	15	11	24	22	70	18	15

Note: Numbers listed under each hawser length correspond to curves found in Figures M-2 through M-5. Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0.1 percent of occurring in 24 hours of towing under the stated conditions.

Table M-6. ARS 50 or ATS 1 Towing YRBM Barge Displacing 650 Tons.

Curve Numbers for Various Towline Lengths

Rel Wave Dir	15 Knot Wind - 3 Knots Approximate Tow Speed					15 Knot Wind - 6 Knots Approximate Tow Speed					15 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	83	80	51	1	26	79	77	1	26	26	77	1	26	26	26
60°	83	78	77	1	26	80	53	1	26	26	53	51	1	26	26
120°	88	86	78	51	51	88	89	83	52	77	89	88	84	54	78
180°	89	89	82	53	51	41	90	89	86	54	36	35	34	7	60

Rel Wave Dir	20 Knot Wind - 3 Knots Approximate Tow Speed					20 Knot Wind - 6 Knots Approximate Tow Speed					20 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	91	90	87	82	78	90	90	85	79	77	89	63	82	52	28
60°	90	88	90	83	53	89	90	86	55	52	89	63	60	53	2
120°	68	90	88	84	55	93	91	89	88	83	94	91	89	89	63
180°	94	68	90	90	63	96	93	91	90	90	44	42	93	16	89

Rel Wave Dir	25 Knot Wind - 3 Knots Approximate Tow Speed					25 Knot Wind - 6 Knots Approximate Tow Speed					25 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	95	92	67	89	89	94	68	90	89	63	92	91	90	88	59
60°	93	91	67	89	88	92	91	66	89	63	68	90	89	88	86
120°	95	92	90	65	88	96	92	91	90	88	97	94	91	90	90
180°	98	95	68	91	90	22	96	93	68	91	24	98	71	93	67

Rel Wave Dir	30 Knot Wind - 3 Knots Approximate Tow Speed					30 Knot Wind - 6 Knots Approximate Tow Speed					30 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	98	96	69	91	67	97	95	92	91	90	96	94	68	67	66
60°	97	94	68	90	90	96	94	91	90	90	97	93	67	90	89
120°	98	96	92	90	90	98	96	93	91	90	99	97	93	91	67
180°	24	98	95	92	68	24	22	72	70	68	24	24	96	96	70

Note: Numbers listed under each hawser length correspond to curves found in Figures M-2 through M-5. Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0.1 percent of occurring in 24 hours of towing under the stated conditions.

Table M-7. ARS 50 or ATS 1 Towing FFG 1 Frigate Displacing 3,200 Tons.

Curve Numbers for Various Towline Lengths

Rel Wave Dir	15 Knot Wind - 3 Knots Approximate Tow Speed					15 Knot Wind - 6 Knots Approximate Tow Speed					15 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	26	26	26	26	0	26	26	0	0	0	26	26	0	0	0
60°	27	27	26	26	26	27	27	26	26	26	27	27	26	26	26
120°	76	1	26	26	26	51	76	26	26	26	77	51	76	26	26
180°	76	76	26	26	26	77	51	76	1	26	87	79	77	51	76

Rel Wave Dir	20 Knot Wind - 3 Knots Approximate Tow Speed					20 Knot Wind - 6 Knots Approximate Tow Speed					20 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	4	52	2	51	1	30	2	28	27	1	29	29	28	27	27
60°	32	30	28	28	28	31	30	28	28	28	31	30	28	28	28
120°	80	78	77	28	51	82	79	3	2	2	60	55	53	77	77
180°	61	55	53	52	77	89	61	55	79	78	92	91	61	82	80

Rel Wave Dir	25 Knot Wind - 3 Knots Approximate Tow Speed					25 Knot Wind - 6 Knots Approximate Tow Speed					25 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	65	62	80	4	3	13	7	4	31	30	8	35	32	30	29
60°	65	8	4	31	30	63	60	32	31	30	12	35	32	30	30
120°	66	63	55	4	3	67	64	59	54	53	91	65	85	55	79
180°	69	67	64	82	80	71	92	66	61	82	97	94	68	89	62

Rel Wave Dir	30 Knot Wind - 3 Knots Approximate Tow Speed					30 Knot Wind - 6 Knots Approximate Tow Speed					30 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	70	68	64	10	81	19	66	13	7	5	18	15	9	36	34
60°	19	67	62	6	33	18	67	63	35	33	18	66	61	34	32
120°	71	68	65	60	55	71	68	67	63	56	72	69	90	63	83
180°	73	71	68	90	61	99	96	93	91	65	24	98	95	93	91

Note: Numbers listed under each hawser length correspond to curves found in Figures M-2 through M-5. Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0.1 percent of occurring in 24 hours of towing under the stated conditions.

Table M-8. ARS 50 or ATS 1 Towing DD 963 Destroyer Displacing 6,707 Tons.

Curve Numbers for Various Towline Lengths

Rel Wave Dir	15 Knot Wind - 3 Knots Approximate Tow Speed					15 Knot Wind - 6 Knots Approximate Tow Speed					15 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	26	26	26	0	0	26	26	26	0	0	26	26	0	0	0
60°	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26
120°	76	1	26	26	26	51	76	76	26	26	2	51	76	26	26
180°	76	26	26	26	26	77	51	76	26	26	80	78	77	51	1

Rel Wave Dir	20 Knot Wind - 3 Knots Approximate Tow Speed					20 Knot Wind - 6 Knots Approximate Tow Speed					20 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	56	79	28	51	1	52	2	51	1	1	2	28	27	26	26
60°	4	3	28	27	27	30	29	28	27	27	30	29	28	27	27
120°	30	29	77	51	51	80	53	52	2	28	56	54	53	77	2
180°	3	77	78	77	2	65	82	54	78	52	68	64	83	80	53

Rel Wave Dir	25 Knot Wind - 3 Knots Approximate Tow Speed					25 Knot Wind - 6 Knots Approximate Tow Speed					25 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	13	56	54	53	52	8	5	4	3	29	6	4	3	29	29
60°	10	5	32	30	30	60	33	31	30	29	36	33	31	30	29
120°	64	83	54	53	3	90	61	55	79	78	67	63	82	54	4
180°	68	65	58	81	54	71	68	63	84	81	73	70	67	63	59

Rel Wave Dir	30 Knot Wind - 3 Knots Approximate Tow Speed					30 Knot Wind - 6 Knots Approximate Tow Speed					30 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	69	66	13	83	6	18	15	9	6	5	17	13	7	5	32
60°	68	65	8	34	33	18	64	7	33	32	17	64	65	33	32
120°	69	67	63	81	5	70	91	64	82	55	71	68	36	59	56
180°	73	70	67	63	11	98	72	69	66	14	24	98	71	69	66

Note: Numbers listed under each hawser length correspond to curves found in Figures M-2 through M-5. Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0.1 percent of occurring in 24 hours of towing under the stated conditions.

Table M-9. ARS 50 or ATS 1 Towing AE 26 Displacing 20,000 Tons.

Curve Numbers for Various Towline Lengths

Rel Wave Dir	15 Knot Wind - 3 Knots Approximate Tow Speed					15 Knot Wind - 6 Knots Approximate Tow Speed					15 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	26	26	26	0	0	26	26	0	0	0	26	26	0	0	0
60°	1	26	26	0	26	26	26	26	0	26	26	26	26	0	26
120°	76	26	26	26	26	51	76	26	26	26	77	51	76	26	26
180°	76	26	26	26	26	51	51	76	26	26	53	52	51	76	26

Rel Wave Dir	20 Knot Wind - 3 Knots Approximate Tow Speed					20 Knot Wind - 6 Knots Approximate Tow Speed					20 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	3	2	28	51	1	29	2	51	1	1	2	28	27	26	26
60°	31	29	29	27	28	31	29	29	27	28	30	29	29	27	27
120°	32	3	28	28	51	4	3	77	28	28	55	79	52	2	2
180°	80	79	52	77	51	10	81	79	78	77	66	61	82	54	53

Rel Wave Dir	25 Knot Wind - 3 Knots Approximate Tow Speed					25 Knot Wind - 6 Knots Approximate Tow Speed					25 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	9	6	4	3	30	37	34	32	30	30	36	33	31	30	29
60°	37	34	33	30	30	36	33	32	30	30	36	33	32	30	30
120°	9	6	4	31	30	63	7	5	4	3	15	10	81	79	53
180°	17	13	82	80	79	70	17	13	82	55	96	70	65	62	83

Rel Wave Dir	30 Knot Wind - 3 Knots Approximate Tow Speed					30 Knot Wind - 6 Knots Approximate Tow Speed					30 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0°	19	16	11	7	5	18	14	8	35	34	16	12	38	35	33
60°	18	13	37	34	33	17	11	36	33	33	17	40	36	33	32
120°	18	67	8	6	4	69	66	10	7	5	70	67	13	8	6
180°	72	70	16	13	83	98	72	68	16	13	24	98	71	68	16

Note: Numbers listed under each hawser length correspond to curves found in Figures M-2 through M-5. Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0.1 percent of occurring in 24 hours of towing under the stated conditions.

Table M-10. ARS 50 or ATS 1 Towing LHA 1 Displacing 40,000 Tons.

Curve Numbers for Various Towline Lengths

Rel Wave Dir	15 Knot Wind - 3 Knots Approximate Tow Speed					15 Knot Wind - 6 Knots Approximate Tow Speed					15 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	26	26	26	0	0	26	26	0	0	0	26	0	0	0	0
60º	26	26	26	0	26	26	26	26	0	0	26	26	26	0	0
120º	76	26	26	26	26	51	76	26	26	26	77	76	1	26	26
180º	76	26	26	26	26	51	76	76	26	26	78	77	51	76	1

Rel Wave Dir	20 Knot Wind - 3 Knots Approximate Tow Speed					20 Knot Wind - 6 Knots Approximate Tow Speed					20 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	3	2	28	51	1	2	28	51	1	1	28	51	1	1	26
60º	30	2	28	27	27	29	2	28	27	27	29	29	28	27	27
120º	3	52	2	51	1	4	3	77	2	51	5	53	52	77	28
180º	80	53	3	77	51	83	55	79	78	52	65	60	81	54	53

Rel Wave Dir	25 Knot Wind - 3 Knots Approximate Tow Speed					25 Knot Wind - 6 Knots Approximate Tow Speed					25 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	8	6	4	78	52	6	5	78	52	2	5	4	3	2	2
60º	36	33	31	30	29	35	33	31	30	29	36	33	31	30	30
120º	8	6	4	3	29	12	7	5	53	3	14	8	6	4	3
180º	16	13	82	80	79	69	16	12	82	55	99	69	16	13	83

Rel Wave Dir	30 Knot Wind - 3 Knots Approximate Tow Speed					30 Knot Wind - 6 Knots Approximate Tow Speed					30 Knot Wind - 9 Knots Approximate Tow Speed				
	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft	1000 ft	1200 ft	1500 ft	1800 ft	2100 ft
0º	68	15	9	7	3	16	13	7	5	4	15	10	7	5	32
60º	17	10	36	33	32	16	39	35	33	32	45	41	36	34	33
120º	18	14	7	5	4	19	66	9	66	5	20	17	12	7	5
180º	72	69	16	13	8	74	71	68	15	13	24	73	70	68	15

Note: Numbers listed under each hawser length correspond to curves found in Figures M-2 through M-5. Given the average tow hawser tension, these curves predict the extreme tension that has a probability of 0.1 percent of occurring in 24 hours of towing under the stated conditions.

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Appendix O

GLOSSARY

21-thread. A light line used to stop off a hawser or other heavy line.

Abrasion resistance. Material's ability to resist exterior damage due to frictional contact.

Advance. Distance gained in the direction of the original course when turning a ship, measured from the point at which the rudder is put over to the point where the ship has changed heading 90 degrees.

Amidships. In or toward the middle of a ship.

Anchor shackle. A U-shaped fitting with pin.

Anchor windlass. The machine used to hoist and lower anchors.

Assisting command. A naval shipyard, private ship yard, or naval station which installs towing systems, supplies riding crews, and provides other assistance.

Assisting tugs. Tugs used during slow speed maneuvers, namely getting underway, docking, and other harbor movements.

Athwartship. At right angles to the fore and aft centerline of a ship or boat.

Attachment point. Point of attachment between the tow and the towed vessel. The attachment point transmits the towing load from the towline to the vessel.

Automatic towing machine. A device which maintains safe tension on the hawser during towing without action by the operator.

Auxiliary towline. A tug's spare or secondary hawser used for multiple tows or secondary functions such as target towing.

Auxiliary vessel. A vessel that maintains, supplies, or supports combatants.

Backing down. Using a stern throttle to rapidly reduce the forward speed of a tug. A dangerous practice in towing due to the risk of failed tow lines or collision.

Bail. The part of a pelican hook or chain stopper that holds the hook closed.

Ballast. The weight added to a ship or boat to ensure stability; to pump sea water into empty fuel tanks.

Barrel. The rotating drum of a capstan or winch. Also, one of two standing posts of a bitt.

Beach gear. A generic term for specialized ground tackle, purchases, and ancillary equipment used to extract a grounded ship.

Beam. A ship's breadth at its widest point; any of the heavy horizontal crosspieces of a ship.

Beam sea. A sea that runs athwart the vessel's course.

Beam wind. A wind that blows athwart the vessel's course.

Bear down. To approach the target.

Beaufort No. A numerical value (from 0 to 12) used for rating wind velocity, in ascending strength.

Billboard. An inclined platform used to stow an anchor for rapid deployment.

Bird caging. The phenomenon of wires flaring out around the full diameter of a wire rope, with resulting kinks in the wires. This can occur when there is a sudden release of a heavy load on a wire rope.

Bitt. A pair of metal posts to which mooring or towing lines are made fast.

Bitter end. The absolute end of a piece of line or cable, especially the last link of anchor chain in the chain locker.

Bollard. Single posts secured to a wharf or pier and used for mooring vessels by means of lines extending from the vessel.

Bollard pull. The maximum pulling power that a tug can generate with zero forward speed.

Bowline. A classic knot that forms a loop that will not slip or become tighter under tension.

Bow (of the) shackle. The curved end of a shackle.

Bow thruster. A propulsor at the bow of the ship which aids in moving the bow sideways.

Breaking of a tow. The release of a towed vessel.

Breaking strength. The actual or ultimate rated load required to pull a wire, strand, or rope to destruction.

Breakwater. Structure that shelters a port or anchorage from the sea.

Bridles. A length of chain or wire extending from the bow of a tow. Usually refers to the rigging of a tow with two legs from the tow's bow to a flounder plate.

Broach. To be turned broadside to a surf or heavy sea.

Bulbous bows. An extension of the bow of a ship below the water line that is designed to reduce wave drag.

Bulkhead. Walls or partitions within a ship, generally referring to those with structural functions such as strength or water-tightness.

Bullnose. Closed chock at the bow of a ship.

Bull rope. Colloquial term referring to a towing hawser.

Bulwark. Section of a ship's side continued above the main deck as a protection against heavy weather.

BUSHIPS. Bureau of Ships, now Naval Sea System Command.

Cable. A heavy rope, chain, or wire of great strength. Applications include attachment to anchors and towing. Also a unit of length, equivalent to 120 fathoms or 720 feet.

Calculated risk. Accepting an operation or decision based on less than satisfactory conditions. As applied to towing, accepting a tow when the tow's material condition, seaworthiness, weather, etc., makes the tow less than satisfactory. This should be rarely used as a basis of acceptance of the tow.

Calm water resistance. The hydrodynamic resistance created by a tow without the influence of waves created by the weather, tug, tow, or other outside influences; approximates steady tension.

Caprail. Rounded radius on the stern of a towing vessel, over which the sweep of the tow wire rides.

Capstan. A revolving device with a vertical axis used for controlled deployment and retrieval of lines.

Careen. To cause a vessel to have a permanent list to one side. Specifically, as in a drydock, to rotate the dock 90°, placing one sidewall below the water line. This is done to reduce the beam to allow passage through canals or other restricted waterways.

Carpenter stopper. A mechanical device consisting of a cover that encloses a sliding wedge within the body that can be opened by knocking away a latch that holds them closed. Used for stopping off wire rope.

Catamaran. A twin-hulled vessel or boat on which the individual hulls are joined together by an above water line structure.

Catenary. The downward curve or sag of a rope, wire, or chain suspended between two points.

Center of gravity (CG). The point in a ship where the sum of all forces and moments of weight is zero.

Chafing. Wear or damage to a ship or ship materials due to friction.

Chafing gear. Material used to prevent chafing and wear on both the hawser and the tug's structure.

Chafing pendant. A length of chain used to reduce chafing or wearing.

Chain bridle. Two legs of chain joined by a flounder's plate extending from the bow of a tug.

Chain connecting link. See "Detachable link."

Chain pendant. A single length of chain extending from the bow of a tug used as a towing connection element, usually fitted with an eye at one or both ends.

Chain shackle. A U-shaped fitting with a pin used for chain connections in a towing rig.

Chain stopper. A device used to secure chain, thereby relieving the strain on the windlass; also used to secure the anchor in the housed position in the hawsepipe.

"Chinese" moor. Denotes that two ships are alongside each other in such a manner that the stern of one is facing the same direction as the bow of the other.

Chock. A heavy smooth-surfaced fitting usually located near the edge of the weather deck through which wire ropes or fiber hawsers may be led.

Cleat. An anvil-shaped deck fitting for securing or belaying lines.

Clip, wire. Fitting for clamping two parts of wire rope to each other.

Closed socket. A wire rope termination similiar to a padeye or ring.

COLREG. U.S. Coast Guard Rules of the Road.

Compartment. Room or space on board ship.

Condition ZEBRA. The condition of maximum watertight integrity of a ship.

Constructional stretch. The elongation of a wire rope caused by a virgin rope's helical strands constricting the core during initial loading. This property is no longer exhibited after several loadings.

Controllable pitch propeller (CPP). A screw propeller with separately mounted blades and in which the pitch of the blades can be changed, and even reversed, while the propeller is in operation.

Core. The axial member of a wire rope, about which the strands are laid. It may consist of wire strand, wire rope, synthetic or natural fiber, or solid plastic.

Cotter keys. Also called cotter pins, are used to secure or block nuts, clevises, etc. Driven into holes in the shaft, the eye prevents complete passage, and the split ends, deformed after insertion, prevent withdrawal. Cotter keys are not used in towing.

Crest. The top of a wave.

Cutwater. The stem of a ship, the forwardmost portion of the bow, which cuts the water as the ship moves.

Dewatering. Process used to remove flood water from a ship.

Deshackling kit. A tool set used to assemble and disassemble detachable links. Tools included in these sets are hammers, punches, lead pellets, spare taper pins, and hairpins.

Detachable link. A joining link that can be opened and is used to connect chain to mooring, towing, or beach gear equipment.

Die lock chain. Chain formed by forging.

Dipped shackle, padeye. The placement of a shackle through a padeye or connection, as opposed to passing the pin of the shackle through opening in the padeye. The padeye is shaped to accept a shackle as described.

Discharge head. A measurement of the discharge pressure of a pump in feet of water which takes into account friction losses and velocity head.

Displacement. The weight of water displaced by a vessel, expressed in long tons.

Dog. A pawl; a device applied to the winch drum to prevent rotation. See “On the dog.”

Draft. Depth of a ship beneath the waterline, measured vertically to the keel.

Drag. Forces opposing direction of motion due to friction, profile, and other components.

Drift rate. The motion of a vessel caused by the action of the wind, the sea, and the current.

Drogue. A device used to slow rate of movement, usually towed or attached astern of the vessel.

Drum. A cylindrical barrel, either of uniform or tapering diameter, on which rope is wound either for operation or storage; its surface may be smooth or grooved.

Dye-penetrant test. An inspection method used to detect weld surface discontinuances.

Dynamic load. Relating to energy or physical force in motion; as opposed to static load, a force producing motion or change.

Dynamic tension. Resistance of the ship to be towed, the tow hawser, and the vertical component of wire catenary.This resistance cannot be accurately predicted.

Eductor. A pumping device which uses the flow of water through a restriction to create a reduced pressure and cause the flow of water out of a space or compartment.

End link. The last link in a length of chain.

EIPS wire. Extra Improved Plow Steel wire.

Elastic stretch. The elongation of a wire rope or synthetic line caused by the deformation of the material during loading.

Extreme towline tension. The additive accumulation of the complex dynamic responses of tug, tow, and towline.

Eye splice. A loop formed in the end of a rope by tucking the strand ends over and under the strands of the standing part of the rope. A thimble is often used in the loop.

Fairlead. Metal fittings which lead lines in a desired direction.

Fairlead chock. A chock with a roller(s) installed to lead a line to a bitt or cleat.

Fake (faked down). To lay out a line lengthwise in long, flat bights, so that when needed, it will pay out freely.

Fantail. The open deck area or topside overhanging part of the deck at the stern of a ship.

Fatigue. The tendency for materials or devices to break under repeated (cyclic) loading.

Fenders. Energy-absorbing materials or devices used to reduce contact between vessels.

Fetch. The distance a wind blows over the sea surface without a significant change of direction. A factor in the buildup of waves.

Fiber core. Cord or synthetic fiber used as the axial member of a rope.

Fillet weld. A weld that has a triangular cross section, joining two surfaces that are perpendicular to each other.

“Fish hooks.” Outer wires of wire rope that break and cause short ends to project from the rope; a sign of wire rope deterioration.

Fish plate. See Flounder plate.

Fitting. A specially designed piece on a ship’s deck used to control or secure a line or rope (e.g., chock, bitts, padeye, etc.).

Flood effect diagrams. Diagrams which show the effect of flooding of a particular compartment.

Flounder plate. A triangular steel plate to which bridle legs are connected, sometimes called "fish plate."

Forecastle. Raised foreward section of a ship's weather deck. This area contains most of the ship's deck machinery and tow fittings.

Freeboard. Distance from the weather deck to the waterline.

Free-running speed. Maximum speed of a tug without a tow.

Free-spooling. To pay out scope by releasing the brake and allowing the towing drum to rotate as a result of the drag of the tow, with the tow motor disengaged.

Freshening the nip. Paying out or hauling in the hawser to move the contact point in order to distribute wear on the hawser, stern roller, towing bows, H-bitts, winch drum, etc.

Frictional resistance. The force created by an object as it moves through a fluid such as water or air.

Fuse pendant. A pendant of wire rope or chain specifically designed to fail at a known tension. May be used to protect the rest of the rigging arrangement. Also called a "weak link."

GM. See "Metacentric height."

Grapnel. A small, 4-armed anchor used mainly to recover objects in the water. This device may also be helpful in establishing a method of boarding a vessel without assistance from the deck.

Grommet. An endless circle or ring fabricated from one continuous length of strand or rope.

Ground tackle. General term for all anchoring equipment aboard ship.

Gypsy head. The horizontal drum of a winch, around which a rope is wound for heaving in or paying out.

H-bitt. Short steel posts mounted forward and aft that are used to lead or stop off a tow hawser. A hard point used for towing.

Hairpin. A metal pin which is used to secure a detachable link.

Harbor towing. Includes docking/undocking, standby duty, and safety escort duty in protected waters.

Hatch. Access opening in the deck of a ship, fitted with a hatch cover for watertight closure.

Hawse pipe. Heavy casting through which the anchor chain runs from deck down and forward through ship's bow plating.

Hawser. A heavy line or wire rope of over 5 inches in diameter.

Headed fair. An expression meaning bearing toward an object or an area. In towing, this refers to the tow bearing in the same direction as the tug.

Heave. Vertical displacement of a ship in a seaway, as distinct from pitching, which is essentially a rotation about an athwartships axis. Heave generally refers to an upward movement, bodily, of the entire ship. Also, to haul in or retrieve a line or rope.

Helix. The twist or curvature of the individual strands of a wire rope.

High line. A single line rigged between two ships under way transferring stores.

Hockle. Kinking of one or more strands of twisted fiber line or wires on a wire rope.

Hog (hogging). Deviation of the keel from a straight line, in which the keel is concave downward.

Hogging strap. A restraining line exerting force on the hawser to hold it close against the caprail and/or closer to the fantail.

Hookup. The process of making up the connections to tow a vessel.

Horizontal stern rollers. A large-diameter roller, set in the stern bulwarks on the centerline and faired to the caprail. Provides a minimum chafe point for the tow wire during heave-in and payout.

Horsepower, brake. The power delivered at the engine's shaft.

Horsepower, indicated. Power measured in diesel engine cylinders by means of an instrument (the "indicator"), which continuously records the steam or gas pressure throughout the length of the piston travel.

Horsepower, shaft. Power transmitted through the shaft to the propeller. It is usually measured aboard the ship as close to the propeller as possible by means of a torsionmeter. The power actually delivered to the propeller is somewhat less than that measured by the torsionmeter.

Hydrodynamic resistance. The force exerted by the motion of fluids upon a body immersed in the fluid. As applied to towing: the resistance created by water as a body moves through it.

Hummock. An irregular ridge or hillock on sea ice.

IMO. International Maritime Organization.

IPS. Improved Plow Steel.

"In Irons". An expression used by shiphandlers to indicate limited control in maneuvering the ship. In towing, this can be caused by a tow wire that is "captured" at the stern, reducing the effect of the rudder of the tug.

Inland towing. Point-to-point towing performed on inland waterways such as rivers.

"In step". An expression used to indicate that the towing ship and its tow are each riding the crests and troughs of waves simultaneously.

IWRC. Independent wire rope core. A wire rope used as the axial member of a larger wire rope.

Jack stay. Wire or line rigged for a special purpose, such as hanging seabags.

Jacob's ladder. Portable ladder, with rope or wire sides and wooden rungs, slung over the side for temporary use.

Jam nuts. A second nut installed hard against the first nut to prevent rotary motion of the first nut.

Jaw width. The dimension of the opening between the eyes of a shackle.

Jewelry. Gear used to fasten together system components.

Kenter detachable link. A type of connection normally used to join two pieces of stud link or cast chain. See "Detachable link."

Kink. A unique deformation of a wire rope caused by a loop of rope being pulled down tight. It represents irreparable damage to and an indeterminate loss of strength in the rope.

Kort nozzle. A nozzle used to enclose the propeller of a ship as a means of boosting power.

Lateral control wire. An auxiliary wire used to limit the motion of the tow hawser in the athwartships direction.

Lay. The direction of the twist of strands of a rope.

Lay length. The distance measured parallel to the axis of the rope (or strand) in which a strand (or wire) makes one complete helical revolution about the core (or center).

Layer. A single thickness, coat, fold, wrap, or stratum. In towing, wraps of wire around a towing winch are counted as layers.

Lazy jacks. Small lines used to tend and recover the towline when rigging a recovery for a Liverpool bridle.

Leading pendant. A length of chain or wire used between the tow and the towing hawser to ensure a safe distance during hookup and disconnect.

Lee. An area that is sheltered from the wind.

Leeward. Away from the wind.

Level wind. A device used during retrieval of a wire to move the wire along the length of the drum to allow it to be stored evenly on the drum of a towing machine.

Lighter. To use a boat or barge to service larger ships in harbors, or to remove fuel or cargo from a stricken vessel.

Line. A term frequently applied to a fiber or synthetic rope, especially if it moves or is used to transmit a force.

Links. A connecting component of towing systems.

Liverpool bridle. A method of rigging a tow hawser; most commonly used in refloating a stranded ship. This method allows the tow vessel to head into the predominant set while still pulling the strand directly to sea.

Load cell. An instrument for measuring tension or torque.

Locking pin (keeper). Device used to hold or maintain a chain stopper, shackle, or other similar devices in a designated position.

Longitudinal. A term applied to the fore-and-aft frames of a ship. Generally, the fore-and-aft direction on a ship.

NDT (Non-Destructive Test). Various methods of checking for imperfections in metals, especially welds.

Messenger. A light line used for hauling over a heavier rope or hawser.

Metacenter. The imaginary point through which the force of buoyancy acts for small angles of heel.

Metacentric height (GM). Distance between the metacenter and the center of gravity of a ship; a measure of stability.

Minimum bend radius. The safe minimum radius for a given diameter, material, and method of bending. Bends of less than this radius may cause damage to the rope or line.

Moment arm. The perpendicular distance from the point of application of a rotational force to the line of action of the force.

Mortise. The opening of a shackle or detachable link. The inside dimension, measured across the opening of a shackle or detachable link.

MPI (Magnetic Particle Inspection). A nondestructive test, using a magnetic field and steel filings or particles to locate and define flaws in steel structures.

Natural pivot point. The location on a tug about which the tug turns in the horizontal plane. It is generally located on the centerline of the ship about one-third of the ship's length from the bow.

NAVSEA 00C. Naval Sea Systems Command, Director of Ocean Engineering/Supervisor of Salvage and Diving, Washington, DC.

Nip. A sharp bend in a line or wire.

"Nipping" the wire. To periodically adjust the scope of the wire to reduce the wear on any one point.

Norman pins. Steel pins mounted along the aft bulwarks of a ship that limit the forward sweep of the tow wire.

OCIMF. Oil Companies International Marine Forum.

Ocean towing. Point-to-point towing outside of protected harbors.

Ocean tugs. Ocean-going vessels designed specifically for towing.

Offset plate shackle. A device used to connect towing components of different sizes.

"On the brake." Towing with the tow hawser restrained by the brake system of the towing machine or winch.

"On the dog." Towing with the winch having a pawl engaged in the ratchet teeth of the towing machine's drum.

Open socket. A wire rope termination that is shaped similarly to a shackle; mates with a closed socket.

OTSR. Optimum Track Ship Routing.

P-100. Self-priming, diesel-driven dewatering pumps that pump about 100 gallons per minute.

P-250. Gasoline-driven pumps used for dewatering.

Padeye. A metal fitting welded to a deck or bulkhead designed to accept a chain or shackle.

Parceling. Wrapping a line or wire with strips of canvas.

Pawl. A device that engages cogs in a wheel allowing rotation in only one direction.

Pay out. To slack off on a line, or let it run out.

Pear-shaped detachable links. A detachable link used to connect a small fitting or chain to a larger fitting or chain.

Pelican hook. A hook that can be opened while under strain by knocking away a locking ring which holds it closed; used to provide an instantaneous release.

Pendant (pendant rig). A single wire or chain that leads from the apex of a towing bridle to the towline; a single wire or chain that leads from the bow of the tow to connect to the tow hawser; a length of wire used as an underrider wire in a "Christmas Tree" rig.

Pitch. Fore-and-aft angular motion of a ship's bow or stern in a seaway about the athwartships axis. See also "sway" and "yaw."

Plate shackle. A connecting device made up of two metal plates and bolts, used to connect the towing pendant and the towline, or to serve as a connecting unit in other parts of a towing rig.

Point-to-point towing. Towing a vessel from one harbor to another.

Popped core. The phenomenon of wires flaring out on one side of a wire rope, exposiong the core of the wire. This can occur when there is a sudden release of a heavy load on a wire rope.

Port. The left-hand side of a ship when looking forward; the opposite of "starboard".

Poured socket. A wire rope termination installed by pouring molten zinc over splayed wire, often referred to as "spelter socket."

Power block (transport block). A portable, hydraulic motor-driven line sheave, providing back tension to the traction winch.

Preventer. Any line, wire, or chain whose general purpose is to act as a safeguard in case something else carries away.

Proof load. See page D-6, paragraph D-14 for a discussion of proof load as it applies to chain and to other forged hardware.

Quarter. One side or the other of the stern of a ship.

Racking. Horizontal movement of the shackle which tends to force the jaws of the shackle against the padeye plate causing the jaws to open.

Rail. An open fence or hand rail aboard ship.

Range. The layout of anchor chain in even rows.

Range up. To reduce the range between tow and tug, accompanied by the tendency for the tow to overtake the tug by sheering out to the side.

Reaching pendant. Used between the tow and the towing hawser to ensure a safe stand off during hookup or disconnect. (See also "Leading pendant.")

Reeving. The threading of a line or wire through a block, sheave, or other parts of a wire rope system.

Relative drift. The difference in the rates and directions of motion of two vessels caused by their differing reactions to wind, sea, and current.

Repair lockers. Storage spaces within the ship which contain damage control equipment for the repair and control of damage due to battle, flooding, or fire.

Rescue towing. Saving a stricken ship at sea, or towing a disabled ship from the scene of a successful salvage to a safe refuge.

Reserve buoyancy. A measure of the capability of a ship to be flooded or ballasted without sinking.

Resistance. A force that retards, hinders, or opposes motion.

Retrieval pendant. A wire rope leading from the deck of the tow to the end of the towing pendant or flounder plate to facilitate bringing the tow gear back onto the foredeck.

Riding lines. Lines used for greater manageability when the tow is brought close to the tug's stern.

Rockwell C. A measurement of material hardness.

Roll. Side-to-side angular motion of a ship about its longitudinal axis. See also "pitch," "sway" and "yaw."

Roll period. A measurement of the time required for a ship to roll from starboard to port and back to starboard or vice versa.

Roller chock. A chock fitted with a roller.

Saddle. A device on the stern of the towing vessel against which the bow of the tow can be brought up hard and maintained in position during ice operations.

Safe haven. An area that can provide shelter from the sea and the weather.

Safe working load. The load for which a rope, fitting, or working gear is designed. (See pg. for discussion.)

Safety factor. A multiple representing extra strength over maximum intended stress.

Safety shackle. A connecting device similar to the common shackle except that the mortise is held closed by a nut and bolt.

Safety track. A T-shaped track running the length of the submarine's topside to which personnel safety lines can be attached.

Sag (sagging). Deviation of the keel from a straight line when the keel is concave upward. Also, the concave curve of a towline said to have catenary.

Sail. The part of a modern submarine extending above the main deck or hull, housing the periscope supports, various retractable masts, and the surface conning station or bridge.

Sail area. The vertical hull surface of a ship on which the wind exerts force.

"Sally the ship." A term referring to the practice of imparting a rolling motion to a ship by the crew's repeatedly moving from one side of the ship to the other.

Salvage towing. Follows very closely after a salvage operation, such as fire fighting, flooding control, battle damage repair, or retraction from stranding.

Scope. The amount of towline streamed.

Screw. The propeller of a ship.

Screw-pin shackle. A type of shackle in which the pin passes through one side of the shackle and threads into the other side of it to form a closure.

Scuttle. Small, quick-closing access hole.

Sea anchor. A device, usually made of wood and/or canvas, streamed by a vessel or boat in heavy weather in order to hold the bow or stern into the sea.

Secondary towline. An emergency towline rigged on the tow prior to getting underway. It can be deployed rapidly without assistance from personnel on board the tow.

Section modulus. As used in reference to wire rope, the effective area of the steel in wire rope multiplied by the modulus of elasticity of the steel.

Seize. To bind with small stuff, as one rope to another or a rope to a spar.

Serving. To wrap small stuff tightly around a rope that has been previously wormed and parceled.

Shackle. U-shaped metal fitting, closed at the open end with a pin, used to connect wire, chain, and similar components.

Shaft horsepower. See “Horsepower, shaft.”

Sheave. A pulley with a rim, used to support or guide a rope in operation.

Sheering. In towing, the tow’s meandering from the towing vessel’s track. The tow may sheer out to a constant position on one side of the tug’s track, or it may swing from one side to the other with a fairly long period of several minutes or more.

Shoring. Process of placing props against structure or cargo to prevent braking, sagging, or movement in a seaway, or to hold ship upright in drydock.

Short stay. SA minimum distance between tug and tow used during harbor operations; “to bring to short stay.”

Shot. A standard length of chain, 15 fathoms (90 feet).

SHP. Shaft horsepower. See “Horsepower, shaft.”

Side-slipping. Moving sideways through the water.

SITREP. Situation Report. A special report generally in a prescribed format, required to keep higher authority advised. Required under certain predictable circumstances, but also may be required at any time.

Skeg. A portion of the underwater hull with significant longitudinal and vertical dimensions but without appreciable transverse dimensions. Its purpose is to give directional stability to the hull. On some moveable twin-skegged tows the skeg may be moved to increase directional stability and reduce yawing.

Slip. To part from an anchor by unshackling the chain. To release completely or let run overboard.

Small stuff. Any small-circumference line used for general purposes.

Smit towing bracket. Two vertical plates similar to a pair of free-standing padeyes with an elliptical pin fitted between them.

Snapback. The sudden recoil occurring when a line parts.

Snatch block. A type of fairlead that can be opened easily to insert a bight of line.

Socket. A wire rope termination attached by zinc or resin. Sockets poured with resin are not approved for towing. See “Poured socket.”

Sound. To measure depth of water at sea or the depth of a liquid in a ship’s tanks. To strike a chain link with a hammer to detect cracks or loose studs.

Spelter socket. See “Poured socket.”

Splay. To unlay and broom the bitter end of a wire rope, usually done preparatory to attaching a socket.

Spliced eye. A wire rope termination formed by inlaying the rope and intertwining the strands to form an eye.

Sponsoring command. The command that requires a tow, and is responsible for preparing the towed vessel for sea.

Spooling. Winding a rope on a reel or drum.

Spring lay rope. A rope combining fiber and wire.

Spring line. See "Spring."

Spring, stretcher. A pendant or grommet used to dampen towline surges.

Stability. Ability of a ship to right itself after being heeled over.

Starboard. The right-hand side of a ship when looking forward. Opposite of "port."

Static load. The force applied by deadweight, often referred to as the "average" or "mean" load.

Steady (or static) towline tension. Resistance of the ship to be towed, the tow hawser, and the vertical component of wire catenary.

Stem. The forward extremity of a ship's hull.

Stern. The rear section of a ship.

Stern planes. The after horizontal control surfaces of submarine normally used to control depth and angles.

Stern rollers. The horizontal and vertical rollers at the stern of a tug used to lead, capture and control the tow hawser.

Stokes stretcher. A wire mesh container used to transfer injured personnel through hatches onboard ship.

Stopper. A short length of line wrapped around a line to stop it from running.

Strongback. A wood or metal bar which is used to hold a patch or shoring in place.

Stud-link. A chain link with a bar fitted across the middle to prevent the chain from kinking.

Strap. A short working wire with a spliced eye at each end.

Strain. To draw or stretch tight; to injure or weaken by force, pressure, etc.; to stretch or force beyone the normal, customary limits; to change the form or size of, by applying external force.

Stream. To extend or increase the scope of the tow hawser.

Submersible pump. Watertight electric pump that can be lowered into a flooded compartment to pump it out.

Suction lift. A measurement in feet of the ability of a pump to raise water or liquid to the intake of the pump that takes into account friction and entrance losses.

Swage. To connect, splice, or terminate wire rope by use of steel fittings installed under extremely high pressure.

Sway. Motion of a ship in which it is displaced laterally, as distinct from rolling. See also "pitch," "roll," and "yaw."

Swivel. A removable anchor chain link fitted to revolve freely and thus keep turns out of a chain.

SWL. See "Safe Working Load."

Synthetic hawser. A line or pendant used for towing, made from any of a group of continuous or synthetic fibers.

Termination. The fitting installed on the end of a wire rope or chain used in towing.

Thimble. A grooved metal buffer fitted snugly into an eye splice.

Tiller (tiller arm). Casting or forging attached to the rudder stock.

Timber packing. Large wooden planks used to reinforce hull plating.

Towing bows. Transversely installed beams or pipe that bridge the caprails on the afterdeck of the tug.

Towing bracket. See "Smit Towing Bracket" or "Tow pad."

Towing chock. Chock designed or dedicated to use during a towing operation.

Towing command. The command that performs the tow.

Towing hawser. Generally, the main towline that is carried by the tug or the principal segment of the towline.

Towing hook. Heavy steel hooks mounted on vertical pins used to hold the eye of a tow hawser.

Towing machine. A towing winch with automatic features.

Towing pad. Large padeye to which a towline may be attached.

Towing rig. Describes the entire system of components that make up the connection between the tug and the tow.

Towing winch. A basic winch used in towing that stores, pays out, and heaves in the towing hawser to compensate for variations in towline tension.

Towline. See "Towing hawser."

Towline fatigue. The weakening of a towline due to cyclic application of load.

Towline strength. The nominal breaking strength of the tow hawser.

Towline tension. The stress imparted to a towline during a towing operation.

Tow point. The point on the tug where the towline exerts its force. This may be the winch, H-bitts, caprail, norman pins, or other points, depending on the towing configuration.

Tow resistance. The total force resisting the movement of the tow.

Tow ship. A vessel specifically designed for ocean towing.

Traction winch. A multi-sheaved device that generates line tension. Tension is generated by friction between the line and traction heads.

Transfer. Distance travelled by a ship at right angles to original course when turning.

Transverse. Lateral dimension or placement.

Tripping. When a frame or padeye experiences transverse loading, it may result in out-of-plane deformation such that it is no longer perpendicular to the deck or hull plating. It has the appearance of having "fallen over" and is said to be tripped. A structure in this condition has significantly reduced strength.

Tucks. In splicing, the insertion of the end of a strand between the strands of a rope.

Turnbuckles. A metal device consisting of a threaded link bolt and a pair of opposite-threaded screws capable of being tightened or loosened and used for setting up standing rigging or stoppers.

Two-blocking. Term describing when the two blocks of a block-and-tackle have been drawn together or tightened so that they touch.

Two valve protection. Consists of either two valves wired shut or one valve and a blank flange.

Ultrasonic inspection. A non-destructive testing method that uses high frequency sound waves to check for material thickness, laminations, and defects or inclusions.

Underrider. The wire rope, chain, or combination used as a pendant heavy enough to pass under a leading tow to a trailing tow at a sufficient depth not to foul on the leading tow.

Veer. To pay out.

Vertical stern rollers. Vertical rolling pins mounted on the caprail of a tug to restrain the tow hawser sweep.

Voith-Schneider propeller. A propeller that generates thrust at right angles to the axis of rotation which, through control of the angle of attack of the vertical propeller blades, can be directed through 360 degrees thus acting as both propeller and rudder.

Wallis brake. A wire brake used for keeping a steady load on a wire rope as it is installed on a drum.

Warping tug. A small boat used to control the heading and speed of a tow during connection of the tow line.

Water brake. A device attached to the stern of a vessel (usually in lieu of a propeller) that provides drag for directional stability.

Wetted surface. The area of the vessel below the waterline which is exposed to the sea.

Williams target sled. The target used most for gunnery exercises.

Winch. An electric, hydraulic, or steam machine aboard ship used for hauling in lines, wire, or chain.

Windward. Toward the wind.

Wire rope. Rope constructed of wire strands twisted together, as distinct from the more common, and weaker, fiber rope.

Wire rope pendant. A length of wire with a termination fitting at each end.

Y-gate. A piping connection with a large inlet section and two smaller outlet sections to permit hookup of two hoses to one pump outlet.

Yard tugs. Vessels that dock/undock, provide standby duty and safety duty services of harbor towing.

Yawing. Failure of a vessel to hold a steady course because of forces of wind, sea, damage to vessel, etc. In towing, yaw angle is the difference between the tow's heading and the tug's heading. Yawing can be manifested by an oscillation of the tow's heading by a small angle to either side of the base course, with the tow remaining on the same track as the tug. See also "sheer," "sway," "pitch," and "roll."

Yield strength. A measure of the maximum stress that can be applied to a material without permanent deformation. This is the value of the stress at the elastic limit for materials for which there is an elastic limit.

YTB class. The largest tugs used for harbor towing.

YTL class. Small size tugs which move small craft and unloaded barges from one berth to another within a harbor.

YTM class. Medium size tugs which move vessels of all sizes from berth to berth within a harbor and assist vessels of all sizes in getting underway and mooring.

Z-drive propulsion. A mode of propulsion that uses a propulsar which can be trained through 360 degrees and can be positioned in the hull during design to provide the optimum propulsion.

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Appendix P

USEFUL INFORMATION

P-1 Introduction

This appendix contains miscellaneous information useful during salvage operations. Ground reaction is measured in long tons. Freeing and lifting forces are measured in short tons.

P-2 Weights and Measures

This section lists general information needed for performing salvage calculations in both metric and English systems. Use this material with salvage formulae found throughout this manual.

Table P-1. System of Metric Measures.

LENGTH	
1 meter (m)	= 10 decimeters (dm)
	= 100 centimeters (cm)
	= 1,000 millimeters (mm)
1,000 meters	= 1 kilometer (km)
AREA	
1 square meter (m2)	= 1,000,000 square millimeters (mm^2)
	= 10,000 square centimeters (cm^2)
	= 100 square decimeters (dm^2)
1 square kilometer	= 1,000,000 square meters
VOLUME	
1 liter (l)	= 10 deciliters (dl)
	= 100 centiliters (cl)
	= 1,000 milliliters (ml)
	= 1 cubic decimeter (dm^3)
1 kiloliter (kl)	= 1,000 liters
	= 1 cubic meter (m^3)
1 milliliter (ml)	= 1 cubic centimeter (cc)
MASS	
1 kilogram (kg)	= 1,000 grams (g)
1 gram (g)	= 1,000,000 micrograms (µg)
	= 1,000 milligrams (mg)
	= 100 centigrams (cg)
1,000 kilograms	= 1 metric ton (tonne)
FORCE	
1 kilogram force (kgf)	= 9.807 newtons (N)
1 newton (N)	= 0.102 kgf
1 kilonewton (kN)	= 1,000 newtons
	= 102 kgf
1 meganewton (MN)	= 1,000,000 newtons
	= 102,000 kgf
	= 102 tonnes force (tonnef)

Table P-2. System of English Measures.

LENGTH	
1,000 mils	= 1 inch (in)
12 inches	= 1 foot (ft)
3 feet	= 1 yard (yd)
6 feet	= 1 fathom (fm)
15 fathoms	= 1 shot of chain= 90 feet
120 fathoms	= 1 cable's length= 720 feet
6,080 feet	= 1 nautical mile (NM)= 2,027 yards
AREA	
144 square inches (in2)	= 1 square foot (ft^2)
VOLUME	
1,728 cubic inches (in3)	= 1 cubic foot (ft^3)
27 cubic feet (ft3)	= 1 cubic yard (yd^3)
231 cubic inches	= 1 U.S. gallon (gal)
277.27 cubic inches	= 1 imperial gallon
42 U.S. gallons	= 1 barrel= 5.615 cubic feet
1 cubic foot	= 7.48 U.S. gallons
	= 6.23 Imperial gallons
BOARD MEASURE	
board feet	= Length in feet x width in feet x thickness in inches: therefore:
12 board feet	= 1 cubic foot
DRY MEASURE	
1 pint	= 0.5 quart = 33.6 in^3
LIQUID MEASURE	
16 ounces	= 1 pint
2 pints	= 1 quart
4 quarts	= 1 gallon
NOTE:English system dry measure and liquid measure quarts and pints are not equivalent volumes. All Imperial liquid measures are therefore larger than the corresponding U.S. measure by a factor of 277/231, or 1.2.	
FORCE AND WEIGHT	
7,000 grains (gr)	= 1 pound (lb)
16 ounces (oz)	= 1 pound
2,000 pounds	= 1 short ton
2,205 pounds	= 1 metric ton (tonne) = 1,000 Kg
2,240 pounds	= 1 long ton

Table P-3. Basic English/Metric Equivalents.

MEASURES OF LENGTH			
1 millimeter	= 0.03937 inch	1 inch	= 25.4 millimeters
1 centimeter	= 0.3937 inch	1 inch	= 2.54 centimeters
1 meter	= 39.37 inches	1 inch	= 0.0254 meter
1 meter	= 3.281 feet	1 foot	= 0.3048 meter
1 kilometer	= 0.62 mile	1 mile	= 1.6 kilometers
1 kilometer	= 0.54 nautical mile	1 NM	= 1.85 kilometers
1 kilometer	= 1,094 yards	1 mile	= 1,609 meters
1 kilometer	= 3,281 feet	1 NM	= 1,853 meters
MEASURES OF AREA			
1 square mm (mm^2)	= 0.00155 square inch	1 square inch	= 645.2 square millimeters
1 square cm (cm^2)	= 0.155 square inch	1 square inch	= 6.452 square centimeters
1 square meter	= 10.76 square feet	1 square foot	= 0.0929 square meter
1 square meter	= 1.196 square yards	1 square yard	= 0.836 square meter
1 square kilometer	= 0.386 square mile	1 square mile	= 2.59 square kilometers
MEASURES OF VOLUME			
1 cc or ml	= 0.061 cubic inch	1 cubic inch (in^3)	= 16.39 cc or ml
1 cubic meter (m^3)	= 35.3 cubic feet	1 cubic foot (ft^3)	= 0.0283 cubic meter
1 cubic meter	= 1.31 cubic yards	1 cubic yard (yd^3)	= 0.764 cubic meter
1 liter	= 61.023 cubic inches	1 cubic foot (ft^3)	= 28.32 liters
1 liter	= 0.0353 cubic foot		
LIQUID MEASURE			
1 liter (l)	= 1.057 U.S. quarts	1 U.S. quart (qt)	= 0.946 liter
1 liter (l)	= 0.264 U. S. gallons	1 U.S. gallon (gal)	= 3.79 liters
1 cubic meter	= 264.17 gallons	1 U.S. gallon	= 0.0038 cubic meter
DRY MEASURE			
1 liter (l)	= 0.908 dry quarts	1 dry quart	= 1.101 liters
MEASURES OF WEIGHT AND MASS			
1 kilogram (kg)	= 2.205 pounds mass	1 pound mass (lbm)	= 0.454 kilograms = 454 grams
1 tonne	= 1.1023 short tons = 2205 pounds	1 short ton	= 0.972 tonne = 907.2 kilograms
1 tonne	= 0.9842 long tons	1 long ton	= 1.016 tonne = 1016 kilograms
1 milligram	= 0.0154 grain		
1 gram	= 15.432 grains	1 grain	= 64.8 milligrams = 0.0648 gram
1 newton	= 0.225 pounds force		
1 meganewton	= 100.4 long tons = 112.4 short tons	1 pound force (lbf)	= 4.448 newtons
		1 long ton	= 0.009964 MN
	= 224,799 pounds	1 short ton	= 0.008896 MN

Table P-4. Circular or Angular Measure.

60 seconds	= 1 minute of arc	
60 minutes	= 1 degree	
90 degrees	= 1 quadrant or right angle	
4 quadrants	= 1 circumference	= 360 degrees
2π radians	= 1 circumference	
1 radian	= 180π	= 57.3 degrees

Table P-5. Common Pressure Conversions

MULTIPLY	BY	TO OBTAIN
Feet of seawater	0.445	psi
Feet of fresh water	0.434	psi
Psi	2.25	feet of seawater
Psi	2.3	feet of fresh water
Inches of mercury	0.49	lb/in^2
Lb/in^2	2.04	inches of mercury
Atmospheres	14.7	lb/in^2
Lb/in^2	0.07	atmospheres
Atmospheres	10.0	meters of seawater

Table P-6. Common Density Conversion

MULTIPLY	BY	TO OBTAIN
Lb/ft^3	16.02	kg/m^3
	0.01602	g/cc
Kg/m^3	0.0624	lb/ft^3
	0.001	g/cc
m^3/tonne	35.87	ft^3/long ton
ft^3/long ton	0.0279	m^3/tonne

Table P-7. General Conversion Factors.

MULTIPLY	BY	TO OBTAIN
Atmospheres	760	mm of mercury (mm Hg)
	76.0	cm of mercury (cm Hg)
	33.9	feet of fresh water (ffw)
	34	approx. ffw
	33.1	feet of seawater (fsw)
	10	approx. meters of seawater
	33	approx. fsw
	29.92	inches of mercury (in Hg)
	1.033	kg/cm^2
	10,332	kg/m^2
	14.7	lb/in^2 (psi)
	1.06	$tons/ft^2$
Barrels	5.615	cubic feet (ft^3)
	42	U.S. gallons (gal)
	0.159	kiloliters, cubic meters
Cubic centimeters	0.0002642	gallons (U.S.)
	0.0338	ounces
Cubic feet	28,320	cubic cm (cc)
	1,728	cubic inches (in^3)
	0.02832	cubic meters (m^3)
	7.48	U.S. gallons (gal)
	28.32	liters
	0.178	barrels (bbl)
Cubic feet/minute	0.02832	cubic meter/min (m^3/min)
	7.48	U.S. gallons/min (gpm)
	1.43	bbl/hour
Cubic inches	16.39	cubic cm (cc)
	0.0005787	cubic feet (ft^3)
	0.00001639	cubic meters (m^3)
	0.004329	U.S. gallons (gal)
	0.01639	liters (l)
Cubic meters	61,023	cubic inches (in^3)
	35.31	cubic feet (ft^3)
	264.2	U.S. gallons (gal)
	6.29	barrels
	1,000	liters (l)
	1	kiloliters (kl)
Cubic meters/minute	35.31	ft^3/min

Table P-7 (Continued). General Conversion Factors.

MULTIPLY	BY	TO OBTAIN
Feet	304.8	millimeters
	30.48	centimeters
	0.3048	meters
	0.0001645	miles (nautical)
Feet of fresh water	0.0295	atmospheres
	0.8827	in Hg
	0.0305	kg/cm^2
	62.4	lb/ft^2
	0.434	lb/in^2
Feet of seawater	0.0303	atmospheres
	0.9048	in Hg
	0.03124	kg/cm^2
	64.0	lb/ft^2
	0.445	lb/in^2 (psi)
Feet/second	30.48	cm/sec
	1.097	km/hour
	0.5921	knots
	0.6818	miles/hour
	0.01136	miles/min
Foot-lbs	1.355	newton-meters
	0.1383	kilogram-meters
	13830	gram-centimeters
Foot-tons (long tons)	3,036.7	newton-meters
	0.00303	meganewton-meters
	0.3	meter-tonne
Foot-tons (short tons)	2,711	newton-meters
	0.00271	meganewton-meters
	0.276	meter-tonne
Gallons (U.S.)	3,785	cubic cm (cc)
	0.1337	cubic feet (ft^3)
	231	cubic inches (in^3)
	1.2	Imperial gallons
	0.0238	barrels (bbl)
Gallons (Imperial)	0.833	U.S. gallons (gal)
Inch-Pounds	0.113	newton-meters
	1153	gram-centimeters
Kilograms	2.205	pounds

Table P-7 (Continued). General Conversion Factors.

MULTIPLY	BY	TO OBTAIN
Kilograms/m2	0.2048	lb/ft^2
	0.00142	lb/in^2 (psi)
Kilograms/m3	0.0624	lb/ft^3
Kilograms/cm2	14.226	lb/in^2 (psi)
Kiloliters	6.29	barrels (bbl)
	264.2	U.S. gallons
	35.31	cubic feet (ft^3)
Kilometers	3,281	feet
	0.54	miles (nautical)
Kilometers/hour	27.78	cm/sec
	0.9113	feet/sec
	0.5396	knots
Knots	6,080.2	feet/hour
	1.8532	kilometers/hour
	0.5148	meters/sec
	1.1516	statute miles/hour
	1.689	feet/sec
Liters	61.02	cubic inches (in^3)
	0.0353	cubic feet (ft^3)
	0.2642	U.S. gallons (gal)
	0.00629	barrels (bbl) (oil)
Meganewtons	100.4	long tons (lton)
	112.4	short tons
	102	tonne
	101,954	kilograms (kg)
	224,809	pounds (lb)
Meganewton-meters	329.4	foot-tons (long tons)
	368.8	foot-tons (short tons)
	102	meter-tonne
Meganewtons/meter	30.6	long ton/ft
	34.3	short tons/ft
	102	tonne/meter

Table P-7 (Continued). General Conversion Factors.

MULTIPLY	BY	TO OBTAIN
Meters	39.37	inches
	3.281	feet
	0.000539	miles (nautical)
	1.094	yards
Meters/second	1.944	knots
	3.281	feet/sec
	3.6	km/hour
	0.03728	miles/min
Miles (nautical)	1,853.15	meters (m)
	1.853	kilometers (km)
	6,080	feet (ft)
	2,027	yards (yd)
	1.1516	miles (statute)
Miles/hour	44.7	cm/sec
	88	feet/min
	1.467	feet/sec
	1.609	km/hour
	0.8684	knots
	0.447	meters/sec
Millimeters	0.03937	inches (in)
Millimeters of mercury	0.00132	atmospheres
	0.00435	feet of seawater (fsw)
	0.00446	feet of fresh water (ffw)
	13.6	kg/m^2
	0.0193	lb/in^2 (psi)
Newtons	0.225	pounds (lb)
Newtons/meter	0.102	kg/m
	1.356	lb/ft
Ounces	0.0625	pounds (lb)
Ounces (fluid)	1.805	cubic inches (in^3)
	0.02957	liters (l)
	0.0313	quarts, liquid (qt)
	0.0078	U.S. gallons (gal)
Pounds	0.454	kilograms
	16	ounces
	4.448	newtons (N)

Table P-7 (Continued). General Conversion Factors.

MULTIPLY	BY	TO OBTAIN
Pounds/ft2	0.0004725	atmospheres
	4.882	kg/m^2
	0.006944	pounds/in^2 (psi)
Pounds/in2	0.068	atmospheres
	2.25	feet of seawater (fsw)
	2.3	feet of freshwater (ffw)
	703.1	kg/m^2
	144	lb/ft^2
	0.0005	short tons/in^2
	0.000446	long tons/in^2
Quarts, U.S. liquid	0.946	liters (l)
	0.0334	cubic ft (ft^3)
	57.75	cubic inches (in^3)
	32	fluid ounces
	4	gallons
Square feet	929	square cm (cm^2)
	0.0929	square meters (m^2)
	144	square inches (in^2)
Square inches	6.452	square cm (cm^2)
	0.006944	square feet (ft^2)
Square kilometers	0.3861	square miles
	0.29155	square nautical miles
Square meters	10.76	square feet (ft^2)
	1.196	square yards (yd^2)
Square miles	2.590	square kilometers
	27,878,400	square feet
Square yards	0.8361	square meters (m^2)
Tons (long)	1,016	kilograms
	2,240	pounds
	1.12	tons (short)
	1.016	tonne (metric)
	0.009964	meganewtons (MN)
Long tons/square inch	2,240	lbs/in^2 (psi)
	1,574,508	kg/m^2
	1,574.5	tonne/m^2
	157.5	kg/cm^2
	15.44	meganewtons/m^2

Table P-7 (Continued). General Conversion Factors.

MULTIPLY	BY	TO OBTAIN
Long tons/foot	1.12	short tons/foot
	3.33	tonne/meter
	3,333.7	kg/m
	32,693.6	newtons/meter (N/m)
	0.0327	Meganewtons/meter (MN/m)
Tons (short)	907.2	kilograms
	2,000	pounds
	0.8929	tons (long)
	0.9072	tonnes (metric)
	0.008897	neganewtons (MN)
Short tons/ square inch	2,000	lb/in^2
	1,406,151	kg/m^2
	1,406.15	$tonne/m^2$
	140.62	kg/cm^2
	13.79	MN/m^2
Short tons/foot	0.8929	long ton/ft
	0.276	tonne/meter
	2,976.5	kg/m
	29,190.6	newton/meter (N/m)
	0.0292	MN/m
Tonne (metric)	0.984	long tons
	1.1023	short tons
	2,205	pounds (lbs)
	1,000	kilograms
	0.009807	meganewtons (MN)
Tonne/meter	0.3	long ton/ft
	0.336	short tons/ft
	672	lb/ft
	9,807	newtons/meter
Yards	91.44	centimeters
	0.9144	meters

Table P-8. Power Conversion.

MULTIPLY	BY	TO OBTAIN
Horsepower	0.746	kilowatts
Kilowatts	1.3404	horsepower
BTU	778.2	foot-pounds
Foot-pounds	0.001285	BTU
BTU	0.0003930	horsepower hours
Horsepower hours	2,554	BTU
BTU	0.0002931	Kilowatt hours
Kilowatt hours	3,412	BTU

Table P-9. Temperature Conversion

$$°F = \frac{9C}{5} + 32$$

$$°C = \frac{5}{9}(F - 32)$$

ABSOLUTE TEMPERATURE
Rankine (R) = Degrees Fahrenheit + 460
Kelvin (K) = Degrees Celsius + 273

Table P-10. Common Flow Rate Conversion.

MULTIPLY	BY	TO OBTAIN
Liters per second (lps)	15.83	gpm
	2.12	cfm
Liters per minute (lpm)	0.26	gpm
	0.0353	cfm
Tons seawater per hour	261.8	gal/hour
	4.36	gpm
	0.583	cfm
	0.276	lps
	0.995	m^3/hour
Tonnes seawater per hour	4.295	gpm
	0.574	cfm
	0.271	lps
	0.976	m^3/hour
Tons fresh water per hour	4.475	gpm
	0.598	cfm
	0.282	lps
	1.016	m^3/hour
M^3/hour	4.4	gpm
	0.588	cfm
	0.278	lps
	1.01	tons seawater/hour
	0.98	tons fresh water/hour
	1.025	tonnes seawater/hour
M^3/sec	15850.2	gpm
	2118	cfm
Ft^3/min (cfm)	7.48	gpm
	0.472	lps
	28.32	lpm
	1.714	tons seawater/hour
	1.671	tons fresh water/hour
	1.741	tonnes seawater/hour
	0.00047	m^3/sec
	1.7	m^3/hour
U.S. gallons per minute (gpm)	0.134	cfm
	0.063	lps
	3.79	lpm
	0.229	tons seawater/hour
	0.223	tons fresh water/hour
	0.233	tonnes seawater/hour
	0.00006	m^3/sec
	0.228	m^3/hour

Appendix Q

HEAVY LIFT SAMPLE CALCULATIONS

Q-1 Introduction

This Appendix demonstrates sample calculations for the procedures outlined in Chapter 8, Heavy Lift Transport. These calculations can be used to actually perform the heavy lift or to check the contractor's calculations. Because the heavy lift of the damaged USS COLE (DDG 67) is not only the most recent, but also the most complex of the heavy lift transport operations undertaken by the US Navy, it has been used to show the calculations involved.

Q-2 Information

On 12 October 2000, while USS COLE was in the port of Aden, Yemen for refueling, terrorists bombed USS COLE using an explosive laden small boat which was deliberately driven into the port side of USS COLE and exploded causing structural damage. It was determined that the best method for returning COLE to a port where the damage could be repaired was to use a heavy lift vessel.

Information relative to USS COLE used in the calculations to follow comes from data on ship's characteristics from the Trim and Stability Booklet and the Docking Drawing updated for observed condition of loading and damage. This information is summarized in Table Q-1.

Using the drafts of 26.5 ft forward, 22 ft aft for the damaged condition the following information can be derived from the DDG 51 Draft Diagram and Functions of Form (Figure Q-1). (This requires extension of the data to cover the area of interest. These extensions are shown as dashed lines on Figure Q-1). This displacement includes the free flooding water in the damaged compartments. This condition was needed to address the drafts to be cleared to get the ship over the blocks.

WARNING
When trim exceeds one foot, especially by the bow, a more rigorous analysis, preferably by a computer program, should be used to obtain the hydrostatic information.

Determine the displacement and other parameters as follows:

Given:	Draft Forward	26 feet 6 Inches
	Draft Aft	22 feet 0 Inches

On the Draft Diagram and Functions of Form (Figure Q-1), draw a straight line connecting these drafts and where it crosses the center of floatation scale, read

Displacement	10,700 Tons
Transverse Metacenter (KM_t)	29.05 feet

Project a line horizontally from this point and where it crosses the other scales, read:

Tons per inch immersion	53.9 Tons/inch
Moment to alter trim one inch	1,532 foot-tons
Longitudinal Center of Buoyancy (LCB)	5.9 feet aft of ⊗

Project a line vertically, where it crosses the scale at the bottom (center of flotation curve) shows the center of flotation

LCF	23 feet aft of ⊗

Using the Displacement & Other Properties Table from the docking drawing or the Curves of Form drawing, you can also get these values at the mean draft. For a damaged ship, especially with a large amount of trim, a computer should be used to check this information. This was also verified by using the POSSE program and the NAVSEA Flooding Casualty Control program (FCCS).

The next step is to determine the Longitudinal Center of Gravity, LCG, as follows:

Determine the trim between drafts:

(Draft aft -Draft fwd) = 26.5 ft - 22 ft = 4.5 ft fwd

Determine the trimming lever (TL)

$$TL = \frac{12 \times (\text{trim}) \times MT1}{\text{Displacement}}$$

$$= \frac{12(4.5)(1532)}{10,700}$$

$$= 7.73 \text{ feet fwd}$$

$$\text{Determine LCG} = TL + LCB$$

$$= 7.73(f) + 5.9(a) = 1.83 \text{ feet fwd } ⊗$$

Estimating the KG requires estimating weight changes from a known condition. For COLE heavy lift, we were given

Full Load Condition:

Dispacement	8,886 Tons
Draft(mean)	21.3 feet
KG	24.28 feet
Vertical Moment (KG x Displacement)	215,752 foot-Tons

This was a good start and was used on COLE because the ship was in the process of refueling to a full load condition. With compensated tanks, the ship would be a little heavier (sea water is heavier than fuel oil) and the KG a little lower than if the tanks were full of fuel. The loads equate to 2,127 Tons at 12.68 feet.

To estimate a KG for the ship at 10,700 Tons

Observed Condition:

Observed Displacement	10,700 Tons
Full Load Displacement	8,886 Tons
Difference is flooding water	1,814 Tons

To estimate the KG, first bracket the range of centers of gravity. First, for a low level we will use the group average of the loads (12.68 feet). For another level, we will use the estimated VCG of the flooding water in the area between the observed drafts and the tank top (14.00 ft).

Estimate the range of KG:

High level.

	8,886 Tons	24.28 feet	215,752 foot-Tons
add	1,814	12.68	23,002
new high	10,700	22.31	238,754

	8,886 Tons	24.28 feet	215,752 foot-Tons
add	1,814	14.00	25,396
new low	10,700	22.54	241,148

For the damaged condition, we also have to estimate the free surface effect of the flooding water. Free surface equates to:

$$FS = \frac{l \times b^3}{12 \times \nabla \times 35\ \text{ft}^3/\text{ton}}$$

$l = 80$ ft (length of flooding between Fr 174-254)

$b = 66.5$ ft (beam of COLE)

$$= 80\ \text{ft} \times (66.5\ \text{ft})^3 / 12 \times 10700 \times 35$$

$$= 5.2\ \text{ft}$$

Therefore the virtual KG (taking into account the free surface effect of the flooding water) could range from:

KG_v low = 22.3 + 5.2= 27.5 feet
KG_v high = 22.54 + 5.2= 27.74 feet

The flooding water in this condition would run out of the ship as it is lifted. Once lifted the displacement of COLE would be essentially the same as that of the ship prior to damage. Items known to be removed would be subtracted for the condition. To this is added, estimated weights for sand bags and equipment on the weather decks and damage material in the overhead or trapped flooding water.

Estimate for USS COLE:

Full Load	8,886 Tons	24.28 feet	215,752 foot-Tons
Removals:			
Fuel	60	10.00 feet	600
Crew and effects	40	50.00	2,000
Additions:			
Trapped Flooding Water	80	10.00 feet	800
Sandbags and Salvage Equipment	20	60.00	1,200
Estimated Condition	8886	24.21	215,152

Note: The new KG is determined by dividing the sum of the moment column by the sum of the weight column (i.e. 215, 152 ÷ 8,886 = 24.21)

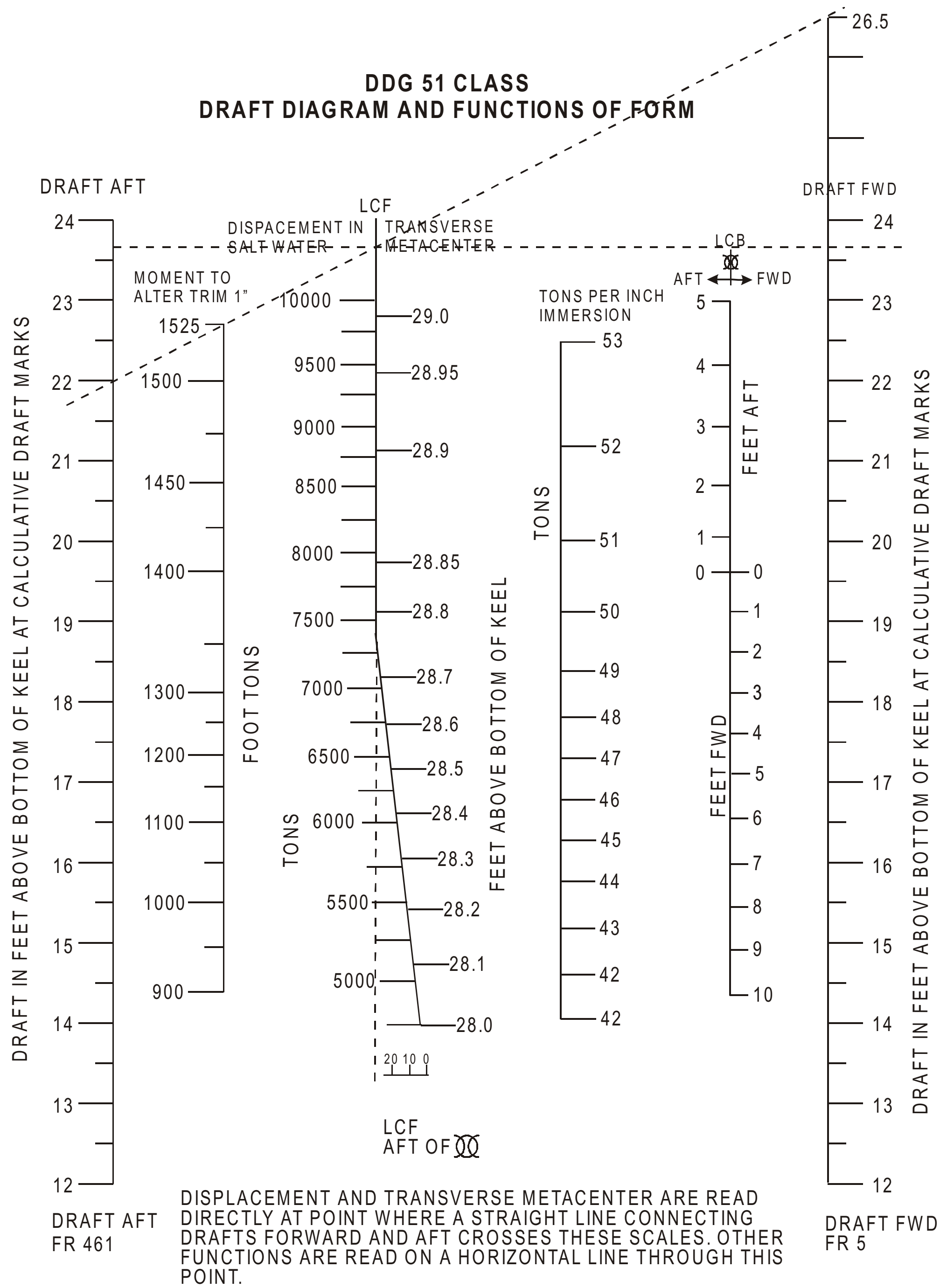


Figure Q-1. DDG 51 Draft Diagram and Functions of Form.

Table Q-1. DDG 67 Information

LOA	504.5 feet	
LBP	465.5 feet	Note: BY DESIGN LBP=466 ft
Beam	66.5 feet	
	Damaged	**Fully Loaded**
Draft Fwd	26.5 feet	
Draft Aft	22.0 feet	
Draft Ꝏ	24.25 feet	21.3 feet
Trim	4.5 feet	
Displacement	10,700 tons	8,886 tons
KG	22.54 feet	24.21 feet
MT1	1,532 ft-ton/in.	1460 ft-ton/in.
TPI	53.9 ton/in.	52.1 ton/in.
LCB	5.9 ft aft Ꝏ	2.80 aft Ꝏ
LCG	1.83 ft fwd Ꝏ	0.62 fwd Ꝏ
LCF	23.00 ft aft Ꝏ	23.00 aft Ꝏ
Underwater Projections		
	Sonar Dome forward	~ 10 feet below the keel
	Propellers	~ 5 feet below the keel
Length of Keel Block System	312 feet	From Docking Drawing
Distance from aft end of knuckle block to Ꝏ	147.26 feet	From Docking Drawing
Distance from aft end of knuckle block to LCG	147.88 feet	Calculated
Distance from aft end of knuckle block to LCF	124.26 feet	Calculated

Q-3 Draft-at-Instability

This section demonstrates the calculations to determine the draft-at-instability for the COLE landing on the blocks of BLUE MARLIN. If COLE is not leaning against the guide posts and landed on the keel and side blocks before the draft-at-instability is reached, the ship will roll off the blocks. See Section 8-5.2.3 for more information on these calculations. The following equation represents the balance of the buoyancy moment and the displacement moment. The draft at which these two are equal will be the draft-at-instability.

$$KM(\Delta - R_{kn}) = \Delta KG_o$$

Table Q-2 shows the information required to perform this calculation. The displacement moment is a constant: Δ x KG = 8886 tons x 24.21 feet = 21.5 x 10^4 ft-tons. For the damaged condition the displacement moment is 10,700 tons x 27.5 feet = 29.4 x 10^4 ft-tons.

The bouyancy moment is found for a range of drafts. Table Q-3 displays the results of this calculation. Figure Q-2 shows these results graphically. Both KM and the residual buoyancy can be found from the draft diagram (Figure Q-1). In Figure Q-2, the intersection of the buoyancy moment line and the displacement moment line represents the draft-at-instability for the example provided. The draft-at-instability for this example is 19.1 feet, for COLE after the flooding water runs out. However, the draft-at-instability during landing could be as much as 23.8 feet. The drafts of COLE in the damaged condition were 26.5 ft fwd and 22 ft aft with a mean draft of 24.25 feet. COLE could go unstable if it was picked up on one end. For this reason, BLUE MARLIN matched the trim and list of COLE in the damaged condition for loading the ship.

Table Q-2. Draft at Instability Information.

Required Information	Source
Draft	Assume a series of drafts (19’ - 24’)
Residual Buoyancy (Δ-R_{kn}) at Assumed Drafts	Draft Diagram (see Figure Q-1)
Height of Metacenter (KM) at Assumed Drafts	Draft Diagram (see Figure Q-1)
Original KG (KG_o)	Table Q-1
Displacement (Δ)	Table Q-1
Displacement Moment (lifted condition)	21.5 x 10^4 ft-tons
(flooded condition)	29.4 x 10^4 ft-tons

Table Q-3. Draft at Instability Results.

Draft ft.	Residual Buoyancy $\Delta - R_{kn}$ (tons)	Height of Metacenter above Keel, KM (ft)	Residual Buoyancy Moment $KM \cdot (\Delta - R_{kn})$ (ft-tons)
19	7481	28.72	21.4×10^4
20	8090	28.80	23.3×10^4
21	8703	28.85	25.1×10^4
22	9330	28.91	26.9×10^4
23	9965	28.97	28.8×10^4
24	10,600	29.1	30.8×10^4

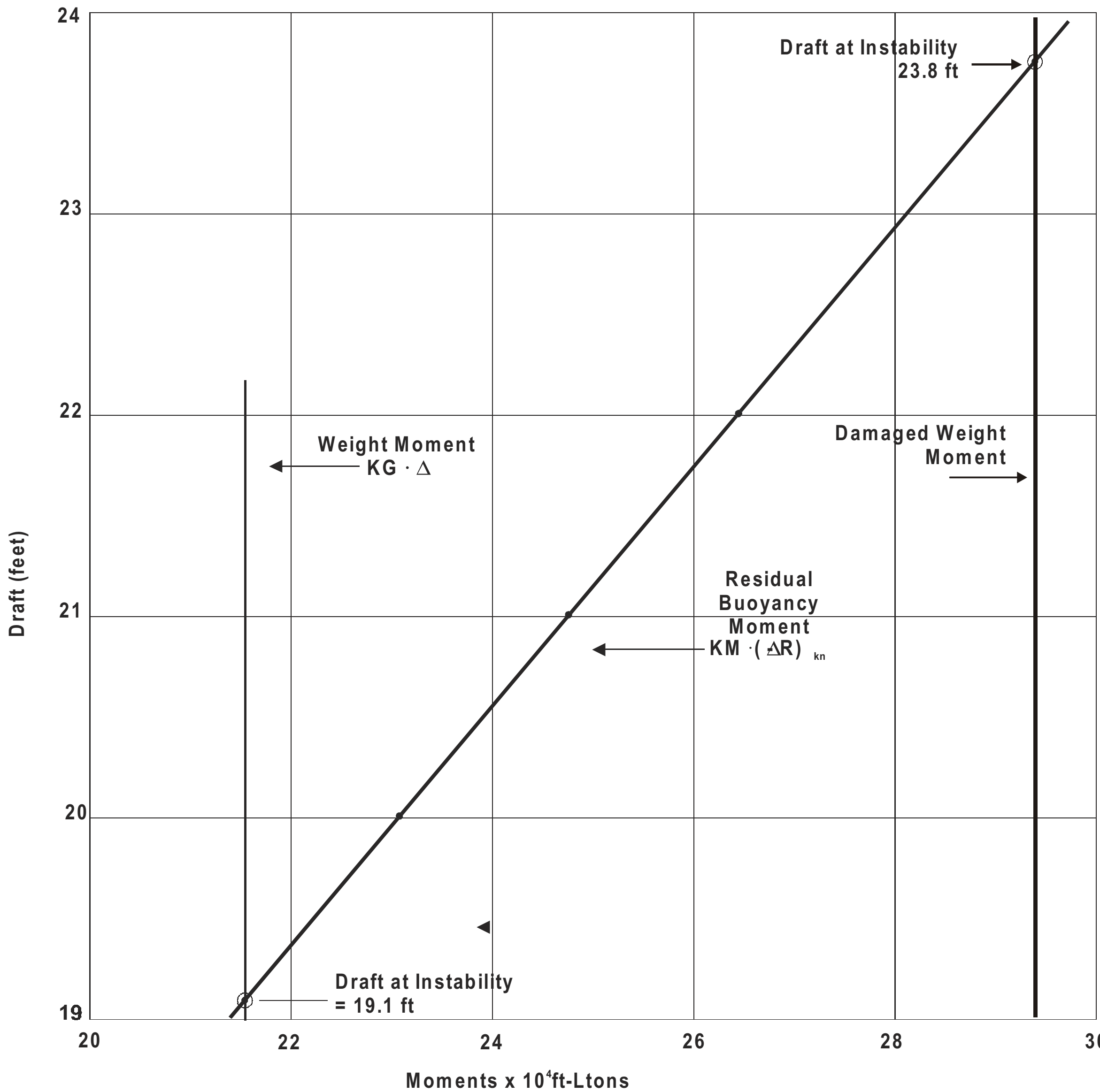


Figure Q-2. Draft at Instability Results.

Q-4 Draft-at-Landing Fore and Aft

This section demonstrates the calculations to determine the draft at landing for the COLE landing on the blocks of the BLUE MARLIN. The draft-at-landing acceleration takes into account a ship with trim pivoting around the knuckle block. When the two moments are equal, the trim will be removed and the ship will be landed fore and aft. See Section 8-5.2.3 for more information on these calculations. Figure 8-9 depicts the relationship of LCB and LCG to the reaction of the COLE landing on the knuckle block. The moments created by the buoyancy force (acting through LCB) and the displacement force (acting through LCG) must be equal for the COLE to land fore and aft. These two moments are calculated and graphed to determine the draft at which this occurs. Table Q-4 shows the information necessary to make the calculations.

WARNING
When trim exceeds one foot, especially by the bow, a more rigorous analysis, preferably by a computer program, should be used to obtain the hydrostatic information.

Two conditions will be considered. The first is for the ship in the flooded condition. The second is for the ship in the lifted condition with the flooding water drained out.

For the first condition LCG is located 1.83 feet forward of amidships (see Table Q-1) which equals a distance of 149.09 feet from the aft end of the knuckle block. The displacement moment about the knuckle block is a constant 10,700 tons times 149.09 feet which equals 15.95×10^5 ft-tons. In Figure Q-3 this is a vertical line. The buoyancy moment is found for a range of drafts (Table Q-5) and is plotted as a line in Figure Q-3. The intersection of the two lines represents a draft at landing of 25.2 feet for the flooded condition.

For the second condition, LCG is located 0.62 feet forward of amidships (see Table Q-1) which equals a distance of 147.88 feet from the aft end of the knuckle block. The displacement moment about the knuckle block is a constant 8,886 tons times 147.88 feet which equals $13.14\ 10^5$ ft-tons. In Figure Q-3 this is a vertical line. The buoyancy moments are the same as those plotted in the previous paragraph. The intersection of the two line represents a draft at landing of 21.7 feet for the dewatered condition.

For COLE, BLUE MARLIN was trimmed to match the trim of COLE so that COLE landed level fore and aft to minimize the loading on the knuckle block and on the end of the skeg of COLE. This approach was taken due to the uncertainty in the longitudinal strength of COLE.

Table Q-4. Draft-at-Landing Fore and Aft Information	
Information	**Source**
Draft	Drafts from 19 ft - 23 ft
Residual Buoyancy (Δ - R_{kn}) at Assumed Drafts	Figure Q-1
LCB at Assumed Drafts	Figure Q-1
LCG	Table Q-1
Displacement (Δ)	Table Q-1
Distance from aft end of knuckle block to LCG	Table Q-1
Displacement Moment (lifted condition)	13.14 x 10^5 ft-tons
(flooded condition)	15.95 x 10^5 ft-tons

Table Q-5. Draft-at-Landing Fore and Aft Results.					
Draft	**Dist. ⦶ to Knuckle Block (ft)**	**Dist LCB to ⦶ (ft)**	**Dist LCB to Knuckle Block (ft)**	**Residual Buoyancy Δ - R_{kn} (tons)**	**Residual Buoyancy Moment (ft-tons)**
19	147.26	1.2 fwd	148.46	7481	11.11 x 10^5
20	147.26	0.9 aft	146.36	8090	11.84 x 10^5
21	147.26	2.2 aft	145.06	8703	12.62 x 10^5
22	147.26	3.8 aft	143.46	9330	13.38 x 10^5
23	147.26	5.0 aft	142.26	9965	14.18 x 10^5
24	147.26	6.0 aft	141.26	10600	14.97 x 10^5

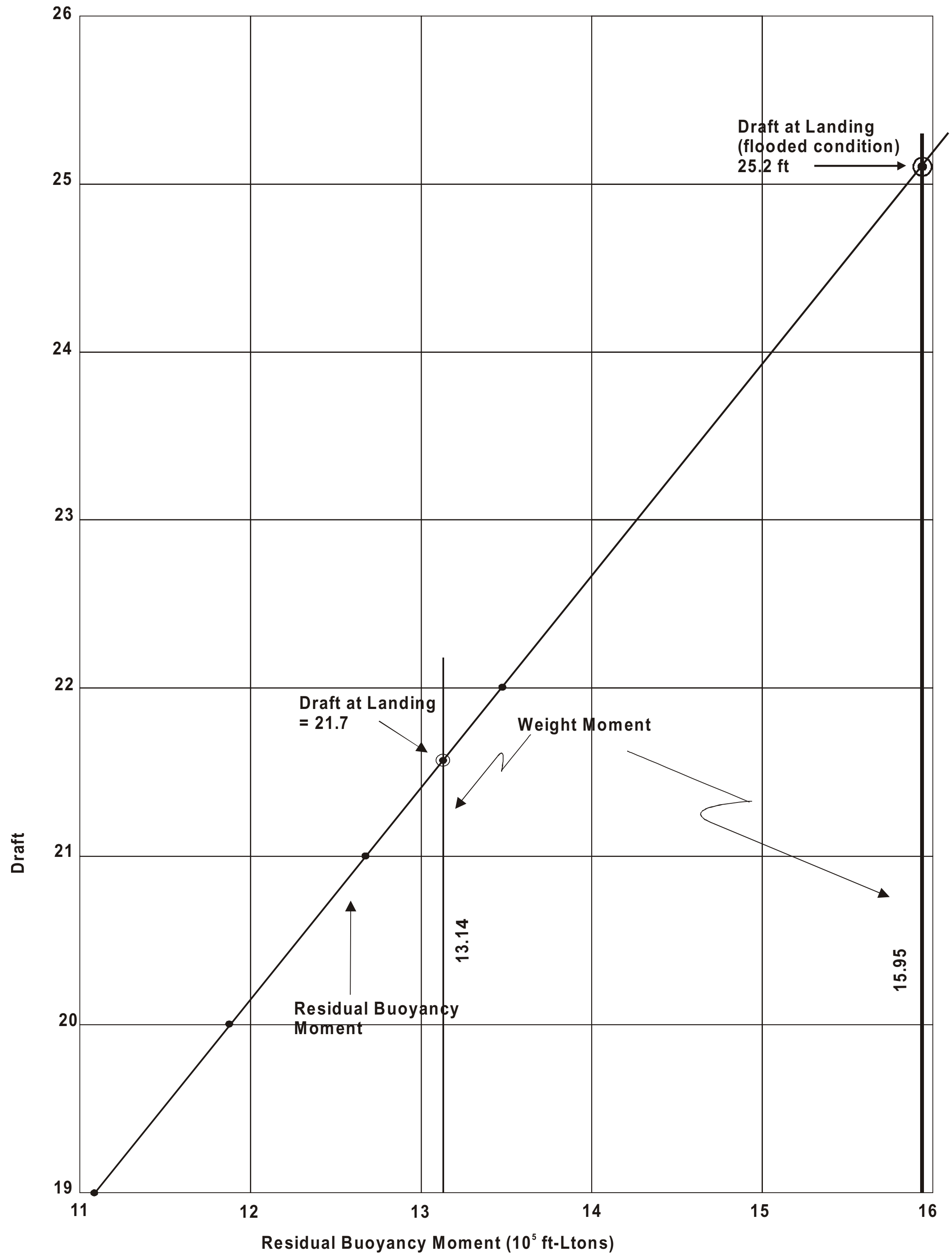


Figure Q-3. Draft-at-Landing Fore and Aft.

Q-5 Keel Block Build and Loading

The height of the keel block row should be as low as possible to improve stability, minimize the required submergence depth for onloading, and minimize the complexity of build of the keel and side blocks. It should be high enough to provide at least one foot of clearance under any hull appendage, protrusion, or penetration. For COLE, propeller pits were cut in the deck of BLUE MARLIN so that a keel block height of 16 inches could be used.

It is necessary to evaluate the stress on the keel blocks to ensure that they are strong enough to survive the expected loading conditions of the transit. The stress on the blocks will be affected by the loading condition of the asset and the dynamic motions of the heavy lift ship. To determine the stress on the blocks, it is necessary to look at these motions. Tables 8-4, 8-5, and 8-6 are used to evaluate the ship motions for the heavy lift ship and the validity of the contractor's Ship Motion Analysis. Sea State 7 (7m significant wave height) was the expected maximum condition for the transit of the COLE. Expected ship motions as predicted by Ship Motion analysis are also presented for comparison in Table Q-6.

Table Q-6. Heavy Lift Ship (HLS) Blue Marlin Characteristics and Motions

Item	Value		Source
LOA	712 ft		Load Manual
LBP	677 ft		Load Manual
Beam	137.8 ft		Load Manual
Draft	28.7		Load Manual
Maximum Submerged Depth of Cargo Deck	32.8 ft		
Maximum Cargo Deck Load	27.5 $\frac{mT}{m^2}$		
Displacement (Δ)	65177 ton		Load Manual
KG with DDG 67	39.08 ft		Load Manual
LCG with DDG 67	349.25 ft fwd AP		Load Manual
TCG with DDG 67	0.01 ft Port		Load Manual
Gm with DDG 67	31.4 ft		Load Manual
(z) Distance between DDG 67 KG and HLS KG = 30.17 feet aft (x) Distance between DDG 67 LCG and HLS LCG = 39.85 feet (y) Distance between DDG 67 TCG and HLS TCG = 17.0 feet			

Table Q-6. Heavy Lift Ship (HLS) Blue Marlin Characteristics and Motions (Continued)

Item	Value from Table	Table	Value from Ship Motion Analysis
Heave Acceleration	0.2 g	8-4	-
*Pitch Angle (P)	4^o	8-5	4.38^o
*Pitch Period (T_P)	7 sec	8-5	5.47 sec
*Roll Angle (R)	20^o	8-6	16.7^o
*Roll Period (T_R)	9.8	8-6(see below)	8.25 sec

* For Sea State 7

The roll period of the heavy lift ship can be estimated using

$$T_r = \frac{(C_C \times B)}{\sqrt{GM}}$$

$$C_C = 0.40 \frac{\text{sec}}{\sqrt{\text{ft}}}$$, Table 8-6, Note 3

B = 137.8 ft

GM = 31.4 ft for HLS with DDG 67 loaded

$$T_r = \frac{\left(0.40 \frac{\text{sec}}{\sqrt{\text{ft}}} \times 137.8 \text{ ft}\right)}{\sqrt{31.4 \text{ ft}}}$$

$$T_r = 9.84 \text{ sec}$$

Ship motion analysis gave $T_r = 8.25$ sec and 16.7^o roll

Once the motions for the ship are determined, the acceleration factors that result from these motions can be determined. Use the equations from Section 8-6.2.1 to determine these acceleration factors.

$$a_z = 1 + h + \frac{0.0214 \text{ Px}}{T_p^{\ 2}} + \frac{0.0214 \text{ Ry}}{T_r^{\ 2}}$$

$$a_z = 1 + 0.2 + \frac{0.0214(4 \text{ deg})(39.85 \text{ ft})}{(7)^2} + \frac{0.0214(20 \text{ deg})\ (17.0 \text{ ft})}{\left(9.84^2\right)}$$

$$a_z = 1 + 0.2 + 0.07 + 0.8$$

$$a_z = 1.35$$

Ship Motion Analysis gave

$a_z = 1.214$ which will be used in the following computations.

The hand calculations confirm that the ship motion analysis results are reasonable. They are also within the commercial rule of 20^o roll with a 10 second period and 10^o pitch in a 10 second period.

Use this vertical acceleration factor to determine the loading on the keel blocks, DL_k.

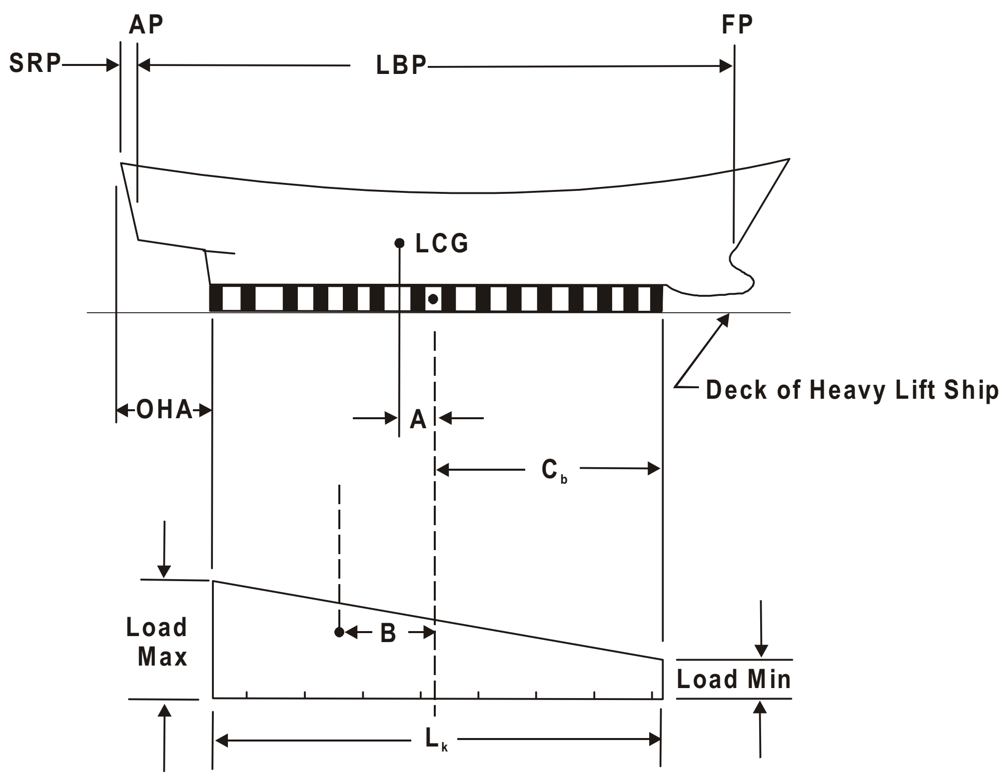
$$DL_K = wa_z$$

$$DL_K = 8,886 \text{ tons} \times 1.214$$

DL_K = 10,788 tons (Note: This is sufficient to encompass the flooded condition of COLE at 10,700 tons at loading)

Since the loading of the keel block row is relatively continuous for its length and uniform for its width, we will use the trapezoidal approximation method described in Section 8-6.2.5 to determine the distribution. Figure 8-9 shows the geometric relation of the components of these calculations. This figure is repeated as Figure Q-4 to show the specific relationships for the DDG 67. These dimensions are taken from the DDG 67 Docking Drawing. For the purposes of these calculations, it is assumed that the continuous row of keel blocks will extend from roughly the aftermost part of the DDG 67 skeg to the after limit of the sonar dome. The keel is 36 inches wide for the majority of its length but narrows to 18 inches wide at the end of the skeg. Some exclusions for items such as the Prairie-Masker belts and hull penetrations/sea chests are also assumed. These exclusions will not affect the length of keel blocking (L_k) but must be considered when evaluating the total effective contact area. Since these exclusions will not occur in the area of LoadMax, they will not be included in those calculations. Note: If you consider that a normal docking block of 48” wide by 40” long and that one or 2 blocks can be left out without appreciably affecting the keel block loading, the assumption that the keel block row is continuous can be used unless 3 or more keel blocks are left out, especially near one end.

The maximum (LoadMax) and minimum (LoadMin) loads will be determined from this approximation. The concern is the overall load carrying capacity of the keel block row, the maximum ex-



FP = Forward Perpendicular = 0

AP = After Perpendicular = 465.5 ft

LBP = Length between perpendiculars of asset = 465.5 ft

SRP = Distance from AP to point from which distance to keel blocks is measured = 4.5'

LCG = Asset's longitudinal center of gravity = 237.82 ft fwd of SRP

OHA = Distance from SRP to keel block = 90'

L_k = Length of keel blocking = 312'

$C_b = \frac{L_k}{2}$ = Center of blocking = 156'

$B = \frac{L_k}{6}$ = Approximate Center of Trapezoid = 52'

A = Distance from asset's LCG (center of Gravity) to C_b (center of Blocking)
(($OHA + C_b$) – LCG)
($OHA + C_b$) - LCG = 90 + 156 - 237.82 = 8.18 ft aft

Figure Q-4. Load Distribution.

pected local stress on the keel blocks, and the load carrying capacity of the cargo deck of the heavy lift ship. The equation for LoadMax returns a value in tons per foot.

$$\text{LoadMax} = \frac{DL_K}{L_K}\left(1 + \frac{A}{B}\right)$$

$$\text{LoadMax} = \frac{10788 \text{ tons}}{312 \text{ ft}}\left(1 + \frac{8.18 \text{ ft}}{52 \text{ ft}}\right)$$

$$\text{LoadMax} = 40.01 \text{ tons/ft}$$

$$\text{LoadMin} = \frac{DL_K}{L_K}\left(1 - \frac{A}{B}\right)$$

$$\frac{10788 \text{ tons}}{312 \text{ ft}}\left(1 - \frac{8.18 \text{ ft}}{52 \text{ ft}}\right)$$

$$\text{LoadMin} = 29.13 \text{ tons/ft}$$

In a normal dry-docking, this would be used to evaluate the stress on the last block in the line. Since heavy lifts are often done with a continuous row of keel blocks, the last foot of blocking will be evaluated. To determine the maximum stress on the last section of keel blocking, use LoadMax and the equation from Section 8-6.2.5.

$$S = \frac{\text{LoadMax}}{A_e} \times \frac{2240 \text{ lb}}{\text{ton}}$$

$$S = \frac{40.01 \text{ tons/ft} \times 1 \text{ ft} \times 2240 \text{ lb/ton}}{36 \text{ in} \times 12 \text{ in}}$$

$$S = 207.5 \text{ psi}$$

The stress of 207.5 psi is acceptable for the entire keel block row as it is below the compressive limit for Douglas Fir (370 psi). Recalculating for an 18-inch wide keelblock, the stress of 415 psi exceeds the 370 psi limit. It should be noted that this stress is above the limit set for a 18-inch keel block at the end of the skeg when looking at knuckle loading. To spread the load over the block, a 1-inch thick steel plate was installed on top of the knuckle block under the skeg. Since the keel block loading was so high (40.01 tons/ft), it was checked against the load carrying capacity of BLUE MARLIN's cargo deck which is 27.5 mT/m^2. The location was changed so that the end of the skeg landed over a transverse bulkhead and spreader beams were placed under the keel blocks in these areas to spread the load.

It should be noted that this calculation assumes that the keel blocks will bear the entire deadweight and dynamic load of COLE. In reality, the side blocks will provide a significant contribution to supporting the load of COLE.

Q-6 Side Blocks

The number of side blocks required will be calculated in a two step process. Step 1 will determine the minimum number of side blocks required for loading of the asset and deballasting of the heavy lift ship. Step 2 will determine the number required for the transit.

Step 1. To calculate the number of side blocks needed for loading, refer to the equations in Section 8-7.2. The first consideration is to support the dead (or static) load. The two components of this loading are the assumed sharing of the vertical load (estimated at 15 percent) and the increase in this load when the BLUE MARLIN heels or rolls during loading. Sea State 4 will be the maximum observed during the loading and blocking operation and the numbers for roll amplitude (R) and period (T_r) are assumed for this condition. From Table 8-6, BLUE MARLIN would roll approximately 5 degrees in Sea State 4. Due to the damage the COLE was listed 2 degrees. Therefore, a reasonable angle for the loading operation was 7 degrees. The number of blocks needed for one side for this weight and assumed keel angle is found by:

$$N_d = \frac{DL_s + DL_r}{S_p \times A_e}$$

Where $DL_s = 0.5 \text{ x } 0.15 \text{ x } w = 0.5 \text{ x } 0.15 \text{ x } 8886 = 666$ tons per side
$DL_r = w\mathrm{Sin}R = 8886 \sin 7^o = 1083$ tons per side
S_p = 800 psi for Douglas Fir
A_e = 24 in x 36 in = 864 in^2

$$N_d = \frac{666 + 1083 \times 2240}{800 \ \times 864} = 5.67 \text{ or 6 blocks per side}$$

As noted in Section 8-7.3, this number of side blocks is only for the loading operation. Special consideration should be given to selecting the locations for the initial side blocks for landing. The locations should be taken from the side block locations on the docking drawing for the best possibility of correct fit. The lowest side block with the least curvature should be selected to minimize the height. Areas of damage should be avoided due to uncertainty of the shape or strength of the hull. On past heavy lifts, use of wedge material or air bags was required at loading because the asset landed out of position or the side blocks did not fit well to the hull. These blocks may need to be replaced or not counted in the final total of required side blocks.

Step 2. To determine the final side blocking and seafastening, the number of additional side blocks that need to be added, both wind loading and dynamic loads from ship motions for the transit must be considered. The magnitude of these forces will depend on the expected conditions. If the blocking build will take place at a site other than the load site, the conditions for the transit to the building site must also be evaluated. If the build is to take place in an exposed area, the conditions at that site must be considered. The conditions for the complete transit to the final destination must also be evaluated. However, the expected conditions for all phases of the operation must be evaluated to ensure a safe transit. For these example calculations, the transit conditions will be used.

To complete Step 2, first, the moment from wind forces is found using the recommended winds from section 8-5.1.1. This wind (86.8 knots) must be multiplied by a gust factor of 1.21 which equals 105 knots. It is also necessary to know the area upon which this wind will act, assuming a beam wind. The area for the DDG 67 above the waterline is published in various sources, and an estimate of the below waterline area is made or an estimate of the entire sail area can be made.

A_s of superstructure = 40 x 190 = 7600 ft^2

A_s above the water line = 22 x 506 = 11132 ft^2

A_s below the water line = 22 x 466 ft = 10252 ft^2

A_s = 28984 ft^2

This area is used in the equations found in Section 8-7.2.5 to find the number of side blocks required to resist the wind forces. The value, L_3 is an approximation of the moment arm from the deck of the heavy lift ship to the center of the projected area. The factor, 0.004, in the moment equation accounts for the conversion in units (using feet and knots).

$L_3 = 35$ ft

$$M_w = 0.004\, A_s L_3 V^2$$

For a 25 knot wind speed

$$M_w = 0.004 \times 28984 \times 35 \times 25^2 = 25.4 \times 10^5 \text{ ft} - \text{lbs}$$

For the 86.8 knot wind speed

$$M_w = 0.004 \times 28984 \times 35 \times 105^2 = 44.7 \times 10^6 \text{ ft} - \text{lbs}$$

$$N_w = \frac{M_w}{A_e S_p L_2}$$

Where L_2 =11.25 ft for the inner row and 17 ft for the outer row

For the 25 knot wind speed

$$N_w = \frac{25.4 \times 10^5}{36 \times 18 \times 800 \times 11.5}$$

$$N_w = 0.319 \text{ side blocks}$$

This can be accounted for within the initial 6 side blocks.
For the higher wind speed (105 kts)

$$N_w = \frac{44.7 \times 10^5 \text{ft} - \text{lbs}}{36 \times 18 \times 800 \times 17}$$

$$N_w = 3.8 \text{ side blocks}$$

The outer row of side blocks was chosen because they are easier and quicker to install. On the COLE heavy lift, these blocks were installed first and immediately after loading in case the weather became worse during the period of final side blocking and seafastening. Next, the amount of additional side blocking for ship's motion during transit must be computed. Using Tables 8-4, 8-5, and 8-6 and some historical weather data, the motions of the heavy lift ship with the asset aboard are determined. For this example, sea state 7 is used as the maximum expected condition. The factors listed in Table Q-6 will be used to find the accelerations associated with rolling.

$$a_y = \text{Sin R} + \frac{0.0107 \text{ Px}}{T_p^2} + \frac{0.0002 \text{ R}^2 y}{T_r^2} + \frac{0.0214 \text{ Rz}}{T_r^2}$$

$$a_y = \text{Sin}(20^o) + \left(\frac{0.0107(4°)(39.85 \text{ ft})}{(7)^2} + \frac{0.0002(20°)^2(17.0)}{(9.8)^2} + \frac{0.0214(20°)(30.2 \text{ ft})}{(9.8)^2}\right)$$

$$a_y = 0.342 + 0.035 + 0.014 + 0.135$$

$$a_y = 0.526$$

Ship Motion Analysis gave a roll of 16.7^o and $a_y = 0.435$

These accelerations can then be used to find the moment associated with rolling.

$$M_r = W \times a_y \times (KG) \times 2240$$

$$= 8886 \text{ tons} \times 0.435 \times 24.21 \text{ ft} \times 2240 \text{ lbs/ft}$$

$$= 209.62 \times 10^6 \text{ ft-lbs}$$

Once the moment is known, the number of sideblocks that are required to resist that moment can be found. In this equation, L_2 represents the distance from the centerline of the ship to the center-of the side block. This is the location through which the resultant force will act. While this number will be different for every block, the value of 17.5 represents an average or a typical block. This information comes from the docking drawing.

$$N_r = \frac{Mr}{A_e S_p L_2}$$

$$N_r = \frac{209.62 \times 10^6 \text{ ft-lbs}}{36 \text{ in} \times 24 \text{ in} \times 800 \text{ lb/in}^2 \times 17.5 \text{ ft}}$$

$$N_r = 17.3 \text{ per side}$$

Therefore, the combined total number of side blocks could be determined by combining step 1, total side blocks for loading ($T_{SB1} = N_d + N_w = 5.67 + 0.32 = 6$) and step 2, total side blocks for transit loadings ($T_{SB2} = N_w + N_r$)

$$\text{Final total side blocks} = N_d + N_w + N_r$$

$$= 5.67 + 3.8 + 17.3$$

$$= 26.77 \text{ or } 27 \text{ side blocks on each side}$$

The DDG 67 docking drawing indicates that 15 to 21 side blocks are required in a normal docking. This means that there will be insufficient room to install 27 side blocks and that spur shores will have to be used to resist the higher roll angles and dynamic overturning moments.

To determine the number of shores required, we will reassess the number of side blocks required for ship's motion (N_w). We will start with determining the assumed number of side blocks to support the static angle of roll.

The position of the side blocks on the docking drawing are designed to resist angles of roll up to 15 degrees. The assessment used should reflect the angle of roll under consideration (maximum static angle of roll from the ship's motion analysis, i.e. 16.7.) The first term in the equation for A_y is SinR where R is maximum roll angle. The equation for DL_r can be reworked using the maximum angle of roll for R.

DL_r = w SinR

= 8886 (sin 16.7°)

= 2553.5 tons

$$N_r = \frac{2553.5 \times 2240}{800 \times 24 \times 36} = 8.3 \text{ sideblocks}$$

Spur shores must resist all angles above 15 degrees and should be spaced accordingly. The number of shores required to resist dynamic loading during transit is then determined from the number of side blocks and the maximum allowable reaction of the shores. The position of the shores and the side blocks is also a factor in considering how many shores are required.

Then the number of shores can be reworked for the remainder of the dynamic load. This methodology will give a reasonable idea of how the spur shores should be distributed. See Section 8-7.4 for more information.

$$N_s = \frac{M_r - DL_r \cdot L_2}{\sigma_s L_3}$$

L_2 is the average distance off centerline for the side blocks for ship motions. For COLE we used side blocks in the outer row, L_2 = 17.5 feet.

L_3 is the average distance off centerline for shore spur locations against the hull of the COLE = 21 feet

$$= \frac{209.62 \times 10^6 - 2553.5 \times 2240 \times 17.5}{195 \times 2240 \times 21}$$

$$= 12 \text{ shores per side}$$

Therefore the total side blocking would consist of side blocks and spur shores. Side blocks equal to $N_d + N_w + N_r = 5.67 + 3.8 + 8.3 = 17.33$ or 18 per side. To this is added 12 spur shores per side.

Now that we know how many shores we needed, we need to determine how to make the shores.

To start, it is necessary to determine the maximum allowable stress of the shores. This is based both on material and geometry.

For USS COLE, heavy, steel I-beams were chosen for the spur shores. These were designed for a loading of 195 tons/shore to be installed under the intersections of the transverse and longitudinal back up structure to the shell plating as specified by NAVSEA O5P. The spur shores were capped with a steel spreader plate and 1” thick dense rubber.

To ensure that the spur shore could develop its full compressive yield strength (σ_y) without column buckling, its $\frac{L}{r}$ was limited to 40.

<u>Column strength</u>

$$\sigma_{cr} = \text{Compressive yield strength } \frac{P}{A} \left(\text{if slenderness ratio, } \frac{L}{r} \le 40\right)$$

Noting that

$\sigma_y = 32$ Ksi for mild steel

$P = 195$ tons

Therefore the minimum cross sectional area of the shore would be

$$A = \frac{P}{\sigma_{cr}} = \frac{195 \text{Ton} \times 2240 \frac{\text{lb}}{\text{Ton}}}{32000 \text{ psi}} = 13.65 \text{ in}^2$$

Chosen I – beams were 300mm × 300mm × 11mm × 19mm

		$A(mm^2)$
Flange	300 x II	3,300
Web	(300-22) x 19	5,282
Flange	300 x 11	3,300
		11,882

$$\frac{11,882}{(25.4)^2} = 18.417 \text{ in}^2$$

Buckling strength To ensure adequate buckling strength, the slenderness ratio, $\frac{L}{r}$ must be less than 40.

L = unsupported length of spur shore b = flange width

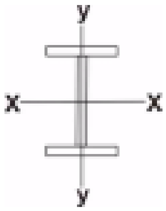
r = least radius of gyration of the section d = depth of web

$$r = \sqrt{\frac{I}{A}}$$

where I = moment of Inertia

A = cross sectional area of the shore

Properties of the I-beam



For x axis	$A(mm^2)$	X(mm)	$M = AX(mm^3)$	$I_x = MX(mm^4)$	$I_y = \frac{bd^3}{12}(mm^4)$
Upper flange	300 x 11 = 3300	$300 - \frac{11}{2} = 294.5$	971850	286209825	33275
Web	(300-22) x 19 = 5282	$\frac{300}{2} = 150$	792300	118845000	34017841
Lower flange	300 x 11 = 3300	$\frac{11}{2} = 5.5$	18150	99825	33275
	11,882		1782300	405154650	34084391

$$I_N = I_x + I_y - \frac{M^2}{A} = 405154650 + 34084391 - \frac{(1782300)^2}{11882}$$

$$= 171894041 \text{ mm}^4$$

$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{171894041}{11882}} = 120.27 \text{ mm (minmum radius of gyration)}$$

For y Axis	A	Y	M	I_x	I_y
300 x 11	3300	150	495000	74250000	24750000
(300 - 22) x 19	5282	150	792300	118845000	158900
300 x 11	8300	150	495000	74250000	24750000
	11882		1782300	267345000	49658900

$$I_N = I_x + I_y - \frac{M^2}{A}$$

$$= 267345000 + 49658900 - \frac{(1782300)^2}{11882}$$

$$= 267345000 + 49658900 - 2634500$$

$$= 49658900$$

$$r = \sqrt{\frac{I}{A}} = 64.65 \text{ mm (minimum radius of gyration)}$$

$$\frac{L}{r} \le 40$$

Therefore $L \le 40r$

Using the minimum radius of gyration:

$$\le 40(64.65\text{mm}) = \frac{2586\text{mm}}{25.4\frac{\text{mm}}{\text{in}}}$$

$$= \frac{101.8 \text{ inches}}{12 \text{ in/ft}}$$

$$= 8.48 \text{ ft}$$

Therefore, shores have to be less than 8.48 ft in length or they have to be braced such that no unsupported length is greater that 8.48 ft. That is, spur shores cannot be longer than 17 ft if supported or 8.5 ft if unsupported. They are welded at the base to the cargo deck of the heavy lift ship.

Q-7 POSITIONING OF SPUR SHORES

Once the number of spur shores is determined, the locations and orientation of the spur shores needs to be assessed. The locations are determined as to how high on the ship's hull they need to be to overcome the overturning moment, M_o. An estimated starting point is with the shore at the turn of the bilge. Under the turn of the bilge, the hull is relatively flat, the shores have to be perpendicular to the local hull curvature, and the shores will be at too great an angle, more than 45°. At angles greater than 45° the shores provide very little resultant force in the transverse direction and will tend to trip out. If the shores are too high above the turn of the bilge, they become too long and will not support the column strength. If the point has to be high on the hull to overcome the overturning moments, towers may have to be used.

M_o is created by the transverse dynamic force working through the ship's (i.e. COLE) center of gravity. (See Figure Q-5)

M_o = (displacement) (a_y)(L_o)

Where displacement = 8,886 tons

a_y = 0.435 from motion analysis

L_o = distance between the ship's CG and the position of the shores on the hull in the vertical direction. = (ship's CG above its keel (KG) + Keel block height (H_{kb})) - shore average height (H_s) = 15.54'

M_o = (8,886) (0.435)(15.54) = 60,068 ft-tons

The righting moment is developed by the resultant force that the spur shores can create in the transverse direction against the hull. From the motion analysis, in a dynamic environment, the weight of the ship is more when the heavy lift ship pitches up and less when the heavy lift ship pitches down. An example of this is when the heavy lift ship pitches down and rolls off the top of a wave into a trough. The dynamic load factor in the vertical direction is a_z. When the heavy lift ship pitches up, a_z increases the loading on the blocking system, (displacement x a_z). When the heavy lift ship pitches down, a_z decreases the loading on the blocking (displacement x (2-a_z). The resultant of this force in the transverse direction is the loading on the blocking times the cosine of the angle of roll.

The lever arm L_r is the distance between the line of action of the downward force through the CG of the ship and the position of the shore on the hull in the transverse direction.

L_r = 20.5' - (sin 16.8°)((24.21' + 1.33') - 10')))

M_r = (displacement) (2-a_z) (cos 16.8°) L_r

M_r = (8886)(2-1.214)(cos 16.8°)(20.5 - 15.54 sin 16.8°) = 107,047 ft-tons

The righting moment is greater than the overturning moment, therefore this is an acceptable shore height. Next you look at the ship's structure to make sure that where the shores are positioned on the hull aligns with back up structure such as a bulkhead, a web frame or a deck. When these positions are met, the final consideration determines the orientation of the shore. As noted in the first paragraph above, the shore has to be perpendicular to the local hull curvature. Where the shore is located on the hull curvature to the cargo deck determines the angle of the shore. A good mix of angles between 20° and 45° is recommended with at least two at each angle.

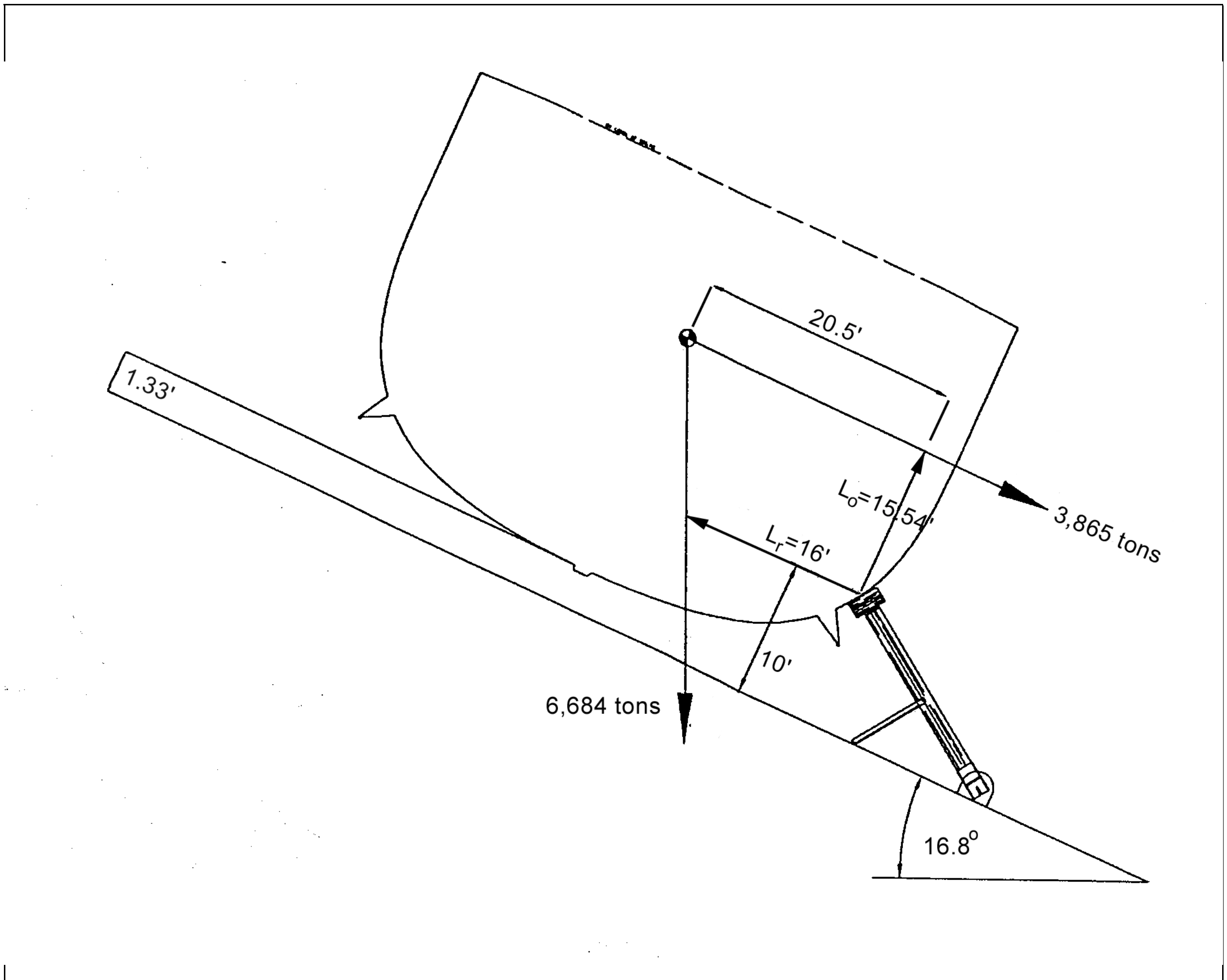


Figure Q-5. Overturning Moment.

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Appendix R

CHECKLIST FOR PREPARING AN ASSET FOR HEAVY LIFT

The following checklist is designed to help the crew of a ship or other preparing activity prepare a vessel to be heavy lifted. It lists general requirements, most of which must be completed before the asset is delivered to the float-on site. If the preparing activity has questions concerning this checklist or preparations required to ready the asset for heavy lift, it should communicate these concerns as early as possible to ensure a timely departure. The preparing activity should fully complete this checklist in time for the preloading conference. Items that are not applicable or cannot be accomplished must be cleared through the Loadmaster and Docking Observer.

The Docking Observer should conduct a preliminary inspection as soon as possible (prior to the float-on date) to preclude misunderstandings and rework. In special situations, the standards reflected in this checklist can be "relaxed" if operational factors dictate that greater risk is acceptable and if all parties agree. Any deviations from this checklist must be accompanied by an appropriate justification from the preparing activity.

The Docking Observer should conduct a final inspection of the asset, accompanied by a representative of the preparing activity or the asset as well as the Loadmaster and Independent Marine Surveyor. Upon satisfactory completion of this inspection, condition ZEBRA should be set on the asset.

NOTE
For more information on preparing a vessel for heavy lift, refer to Chapter 8.

ASSET INSPECTION CHECKLIST

Asset Name ________________________ Hull Number ________________________

Owner ________________________ P.O.C. and 24 Hour # ________________________

Departure Port ________________________ Arrival Port ________________________

Receiving Activity Port ________________________ P.O.C. and 24 Hour # ________________________

Heavy Lift Vessel Name ________________________ P.O.C. and 24 Hour # ________________________

Asset Characteristics Upon Arrival at Float-On Site

Length:	Beam:	Displacement:
Draft fwd:	Draft aft:	Mean draft:
Freeboard fwd:	Freeboard aft:	Freeboard mid:
MTI:	TPI:	KG:
GM:	Maximum Ht above WL:	
Maximum Navigational Draft (include underwater appendages; i.e., sonar domes, propellers, etc.):		

Has the asset been prepared and is it authorized to be heavy lifted in accordance with requirements set forth in this manual?

Provide rationale for accepting asset with items not accomplished________________________

____

____

____

____

____

Use separate sheet if additional space is needed.

The asset described above is seaworthy in all respects. The material condition is noted.

Representative of command having prepared the asset for lift ***Date***

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1. SHIP INFORMATION

		Reference	N/A	Yes	No
a.	Is the booklet of general plans available? If yes, provide location:				
b.	Is damage control book, curves of forms, or other stability data available? If yes, provide location:				
c.	Are liquid load diagrams and damage control flooding plates available on board? If yes, provide location:				
d.	Are instructions posted in after steering for lining up hydraulic steering systems to hand pump?				
e.	Are plans and date of the last drydocking available? If yes, provide location: Date of last drydocking: ***Note**: A copy should be provided to the heavy lift ship as early as possible. An extra copy should be brought to the preloading conference.*				
f.	Has a list of equipage been prepared? ***Note:** The preparing activity is responsible for providing a list of equipage assigned to the craft that is pilferable and must be on board at destination. Provide list on separate sheet.*				
g.	List remaining HAZMAT on board (include all fuel and ammo):				

2. RIDING CREW

		Reference	N/A	Yes	No
a.	Will a riding crew be employed? If so, attach a copy of the directive (message, letter, etc.) and proceed with the following checks.				
b.	Authority that authorized a riding crew:				
c.	Number of crew members:___________________				
d.	Has a list of the riding crew been provided to the heavy lift vessel? ***Note:** A list of the riding crew is entered in towing ship's diary (name, rate, SSN, and NOK; address and phone number of rider and NOK for civilians).*				
e.	Are enough life rafts on board the heavy lift ship with emergency rations and water for the riding crew in the event that they have to abandon ship? Location of life rafts:				
f.	Date life rafts were last tested/inspected:				

		Reference	N/A	Yes	No
g.	Are a sufficient quantity of life jackets and life rings on board? Number, type, and location:				
h.	Means of communication between the docked asset: and the heavy lift ship: ***Note:*** *Must be provided if riding crew is to live aboard asset.*				
i.	Has the riding crew been trained in damage control and support systems? ***Note:*** *The preparing activity is normally responsible for such training.*				
j.	Is habitability and sustenance sufficient from on-board the heavy lift ship or asset? ***Note:*** *Habitability and sustenance should be available on the asset if the riding crew is to live aboard.*				

3. SEAWORTHINESS

		Reference	N/A	Yes	No
a.	Draft after craft is in proper trim: Forward: __________________ Aft: ______________________ Max. navigational draft:	*8-5.2.2* *8-3.6.1*			
b.	GM after craft is in proper trim:				
c.	KG after craft is in proper trim:				
d.	If GM is not known, “sally ship” to establish period of roll: Normally T = $2\sqrt{\text{Beam(ft)}}$ T (observed):	*5-7.3*			
e.	Displacement:				
f.	Provide a list of all tank soundings.				
g.	Has any temporary ballast been installed? Type and location of ballast:	*8-3.6.1*			
h.	If not, will craft require additional ballast?	*8-3.6.1*			
i.	Type of ballast required:				
j.	Describe where ballast will be placed and how much:				

		Reference	N/A	Yes	No
k.	Is condition ZEBRA set throughout the tow? If the answer is Unsatisfactory, list exceptions on separate sheet.				
l.	Are all sea valves secured and tagged out?	*8-3.6*			
m.	Is a list of sea valves attached?	*8-3.6*			
n.	Are all sounding tubes capped?	*8-3.6*			
o.	Is there a list of all sounding tubes attached? (Required)	*8-3.6*			
p.	Are all between-tank sluice valves closed?	*8-3.6*			
q.	Are all normally dry compartments dry?	*8-3.6*			
r.	Are all bilges free of oil and water?	*8-3.6*			
s.	Have all compartments been inspected for loose equipment?	*8-3.6*			
t.	Has steel wire or cable been used to secure all equipment to prevent any movement in heavy weather? ***Note:*** *All moveable equipment must be secured in place with wire or by welding. No fiber rope or line will be accepted.*	*8-3.6* *5-7*			
u.	Are all rudders secured? ***Note:*** *The rudders should be secured to ensure that there will be no movement during rolling on the heavy lift ship.*	*8-3.6*			
v.	Type of securing device used:				
w.	Are all portholes secured for heavy weather?				
x.	Are all watertight boundaries secured?	*8-3.6*			
y.	Are all hatches, scuttles, doors, and other watertight closures provided with pliable gaskets?	*8-3.6* *5-7.9*			
z.	Have weather decks and main transverse bulkhead watertight closures been chalk tested?				
aa.	Are all dogs on watertight closures operable and functioning as designed?				
bb.	For LST-type assets, all of the following must be answered Satisfactory, or the vessel ***will not be accepted for lift***:				
	i. Do the bow doors have hydraulic rams connected?				
	ii. Are mud flaps at the bottom of the doors secured?				
	iii. Are all dogs, heavy weather shackles, ratchet-type turnbuckles and strongbacks in place, tight and secure so that they cannot work free?				
	iv. Are bow ramp operating instructions posted in the hydraulic control room?				
cc.	If asset is equipped with a bow or stern ramp, all normal securing devices (i.e., ramp chains, dogs, and turnbuckles) must be in place and in good mechanical order.				
dd.	Are all lifelines in place and in good condition?				

		Reference	N/A	Yes	No
ee.	Are there two means of egress for the asset? ***Note:*** *One egress must be a well constructed stair-type access. The second egress may be a temporary access such as a jacob's ladder.*	*8-4.5*			
ff.	Are damage control inspection routes marked by paint/diagrams and/or reflective tape?	*5-8.4*			
gg.	Is interior access sufficiently marked for DC teams?				

4. ELECTRICAL POWER

		Reference	N/A	Yes	No
a.	If power is to be supplied by the heavy lift ship, has the power cable connection been inspected to ensure compatibility? ***Note:*** *To ensure an adequate connection, a visual inspection should be conducted.*				
b.	If the assets generators are to be run have the following items been accomplished?				
c.	Has provisions for cooling water been made?				
d.	Have cooling water pumps been demonstrated to have sufficient suction lift and discharge head?				
e.	Is sufficient fuel available on board the asset for the entire transit?				
f.	Is there sufficient ventilation for the riding crew to run the generators?				
g.	Has the free surface of the partially filled fuel tank (due to fuel expended during voyage) been included in the stability calculations (also check calculations in Transport Manual)?				

5. FIRE FIGHTING

		Reference	N/A	Yes	No
a.	Has adequate fire fighting capability been provided?				
b.	If provided from the asset:				
c.	Have pumps been demonstrated to have sufficient suction lift and discharge head?	*5-8.2*			
d.	Are at least two P-100s or operating fire pumps and all other necessary fire fighting equipment on board?	*5-8.2*			
e.	Is there enough P-100 fuel on board?	*5-8.2*			
f.	Are there sufficient starting cartridge spares? ***Note:*** *4 recommended.*	*5-8.2*			
g.	Is means for storage of fuel adequate?	*5-8.2*			
h.	If provided from the heavy lift ship:				

		Reference	N/A	Yes	No
i.	Has the connection on board the heavy lift vessel been inspected and been shown to be compatible? ***Note:*** *To ensure an adequate connection, a visual inspection should be conducted.*	*8-9.6*			
j.	Is adeqaute fire hose available to reach from the proposed connection point to the asset's connection point?				
k.	Is all hose protected against chafing?				
l.	Is all hose secured for heavy weather?				

6. NAVIGATION

		Reference	N/A	Yes	No
a.	Have all required navigation lights been installed? ***Note:*** *Previous lifts have required a mast light due to increased height.*				
b.	Is each light rigged with two bulbs, so that if one burns out the craft still complies with the *COLREGS*?	*5-7.7*			
c.	Is all wiring well-secured and protected from damage by the elements?	*5-7.7*			
d.	Is the light equipped with a solar switch or time switch?				
e.	Are the batteries secured for heavy weather? ***Note:*** *If topside, batteries must be in a watertight box. The location should be carefully selected and secured from heavy seas. If possible, batteries should be inside the asset.*				
f.	Is battery ventilation adequate?				
g.	Are the batteries charged with sufficient amperage available to keep the lights burning brightly for the duration of the trip?	*5-7.7*			
h.	Total ampere capacity of the bank: Sufficient amperage must be calculated and available to cover the following: (1) Wattage of the bulbs serviced (2) Distance of bulbs from battery source (wiring losses) (3) Duration of transit (taking into consideration the solar/time switch and length of the period of darkness).	*Table 5-4*			
i.	Are day shapes rigged in accordance with *COLREGS*?				

7. CARGO

		Reference	N/A	Yes	No
a.	Is any ship equipment to be included as separate cargo on board the deck of the heavy lift ship?				
b.	If so, has a list of this equipment been prepared? Is this list attached?				
c.	Is this cargo properly stowed for sea in it's container?				

		Reference	N/A	Yes	No
d.	Has the removal of this equipment been included in all weight and stability calculations?				

8. OTHER CONSIDERATIONS

		Reference	N/A	Yes	No
a.	Are safety nets provided around access brows?				
b.	Are sufficient mooring lines available for tug operations?				
c.	Is sufficient fendering available for tug operations and for contact with alignment columns?	*8-4.1*			
d.	Have provisions been made to extend scuppers and overboard discharges to beyond the deck of the heavy lift vessel (gray water, CHT, etc.)				

9. REMARKS:

SAMPLE CERTIFICATE OF DELIVERY LETTER

FIRST ENDORSEMENT

1. Upon inspection of the asset described above, the following unsatisfactory conditions were found, which render the asset not ready for heavy lift (if none, so state).

   a.

   b.

   c.

   d.

2. (Cross out the statement which is not applicable).

   a. I find the asset described above in a condition satisfactory for heavy lift, and hereby assume responsibility for delivery to the port of destination prescribed in my sailing orders.

   b. I find the asset described above in an unsatisfactory condition and will not accept the vessel for heavy lift until these discrepancies are corrected.

Representative of command having Cognizance of lifted asset.	Date

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