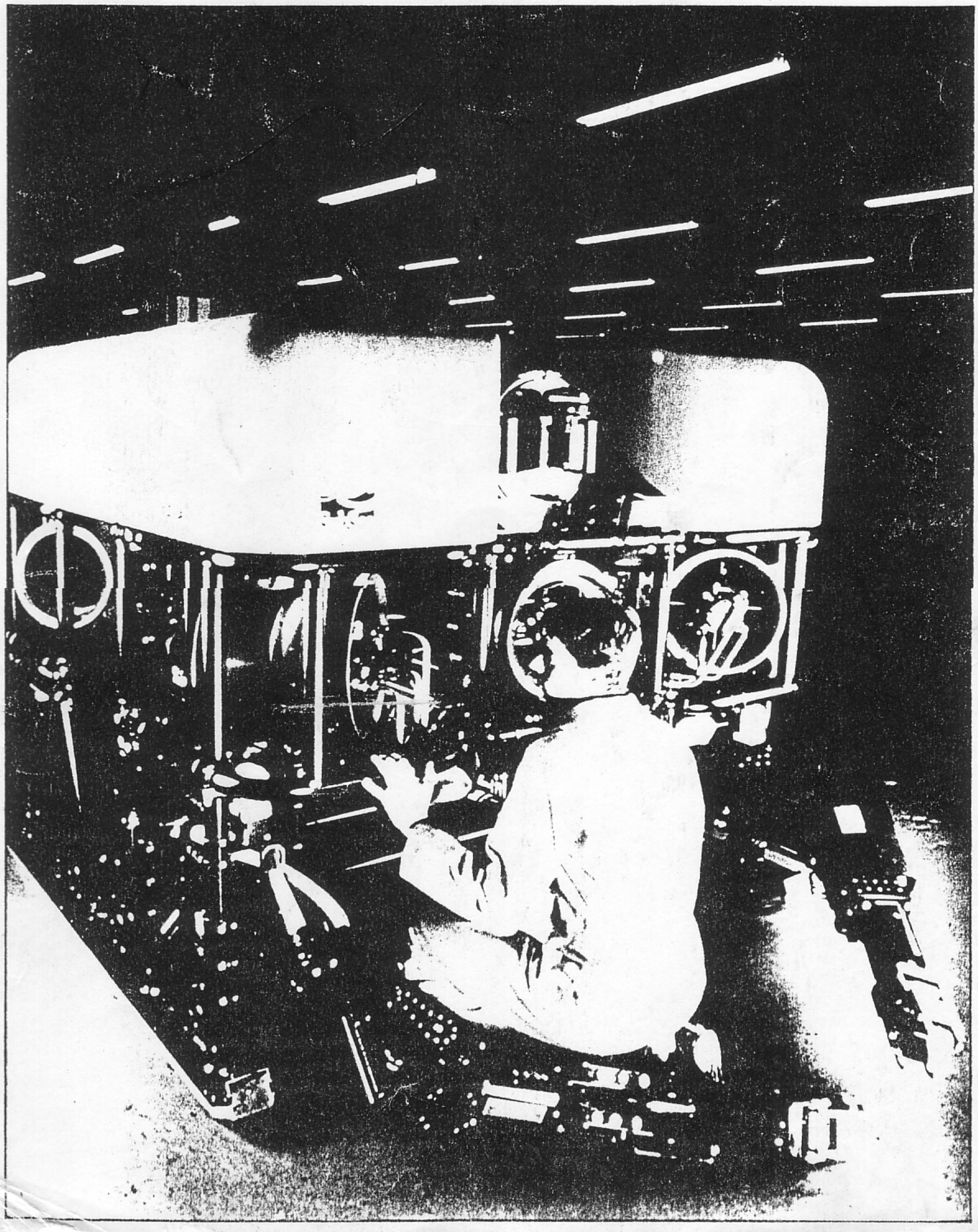
HANDBOOK FOR ROV PILOT/TECHNICIANS

Revised [redacted]

By Chris Bell, Mel Bayliss
and Richard Warburton



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Foreword

Over the last 20 years or so, ROV Pilots and Technicians have had to master more and more trades and skills. In these days of small operations teams, working with ever more complex systems, usually far from home and 'the beach', they are expected to keep all of their equipment at 100% availability as well as use their special skills in navigating their vehicles safely and surely around all the hazards of the sea.

All ROV businesses have been built upon the professionalism of their Pilots and Technicians. As new successful operations generate new skills, this in turn prompts advances in vehicle technology, and this continuous cycle of change makes the life demanding and challenging. If there were any limits to the progress of ROV activities they would be, in the end, set by the people who actually know and drive them.

In this refreshing handbook, the authors have skilfully brought together a great wealth of practical knowledge and experience of ROV operations, addressing all of the technical, operational and management disciplines in a clear and comprehensive manner, as well as including plenty of 'hard to find' technical reference data. No matter whether you are a shore-based manager, operations supervisor, system designer, interested bystander or actually at the sharp end "hands on the sticks", it should be kept close by.

About Marcus Cardew

Marcus Cardew spent 9 years at sea as a Navigator. He then spent 2 years working with manned submersibles then 8 years as technical and operations director of Sub Sea Surveys before moving to Slingsby Engineering as technical director. For the past 10 years he has been running his own business 'System Technologies' in Ulverston, designing and manufacturing a range of underwater and vehicle systems.

About The Authors

Chris Bell is a Chartered Engineer with twelve years experience as an ROV superintendent. He has been responsible for the development of the presently recognised ROV training schemes.

Richard Warburton is specialist in ROV Electronics and Hydraulic systems with extensive offshore experience.

Mel Bayliss is a Member of the Institute of Non-destructive Testing with extensive experience in inspection diving in addition to ROV inspection. He teaches on CSWIP Phase 7 approved courses at all levels.

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Pipeline Rules of Thumb Handbook	E W McAllister Gulf Publishing Co ISBN 0-88415-094-1
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MTS Operational Guidelines for ROVs

HANDBOOK FOR ROV PILOT/TECHNICIANS

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CHAPTER 1 INTRODUCTION

1.0.0 Introduction

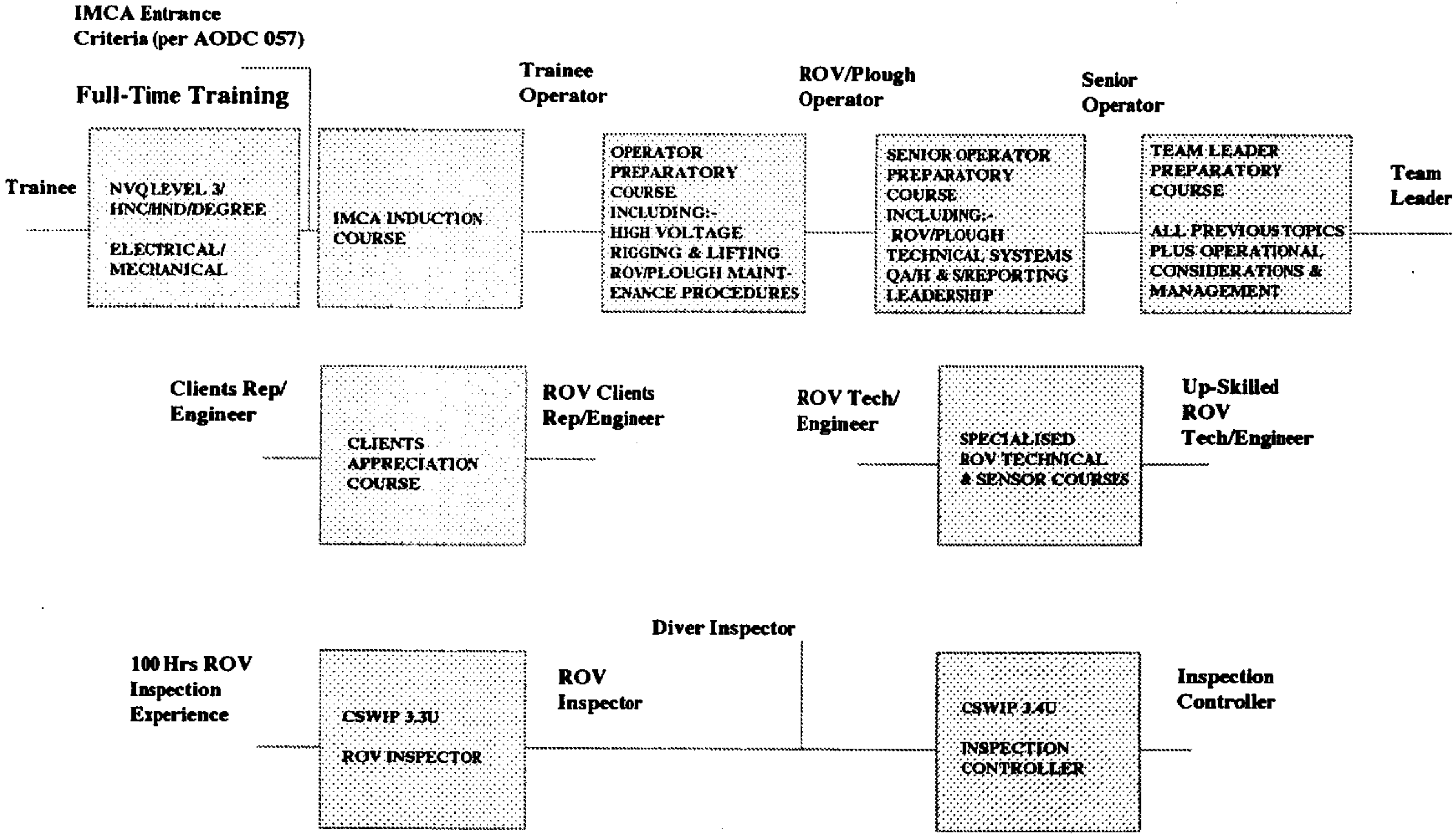
This ROV Pilot/Technician Handbook has been written to compliment the International Marine Contractors ROV Pilot/Technician Induction course, and is the product of several years experience running such courses. It is intended to be the first in a series by the same authors to include Handbooks for: ROV Inspectors, ROV Systems/Survey Engineers and ROV Superintendents. In addition to being required reading for these now well established courses, this handbook is likely to become a reference book for ROV Systems Operators offshore and others such as Sub Sea Engineers and Manufacturers who may have an interest in the work of an ROV Pilot/Technician. The aim of this handbook is to present concisely the essential information required by ROV Pilot/Technicians in their everyday work that enables them to work both safely and effectively in the offshore industries, in particular, the petroleum and cable laying industries, but also the growth industries of mine counter measures (MCM), anti-terrorism and drug intervention. Much of the technology of ROV design is common to all types, which is reflected in this handbook by the use of generic examples rather than specific ROV types as appropriate. These examples emphasise common features and enabling technologies. Practical exercises are included to allow the reader to practice the methods described in circumstances where suitable equipment and supervision are available. This enables the handbook to also be used for the structured training of personnel who started working in this industry prior to the establishment of the present training programme.

1.0.1 Training Programmes

A typical programme of training modules and assessment is now being established and is clearly shown in Figure 1. The first hurdle that must be negotiated is for the prospective ROV operator to become a Technician or Engineer with abilities in Electrical Engineering, Electronics, Mechanics and Hydraulics. It is not normal in the UK for students to receive this breadth of training and it is therefore more usual for them to have specific skills and to rely on 'in-house' training once employed to introduce them to the essentials of the other disciplines. Thorough cross training is then achieved through experience and attendance of further modules of training as careers progress. It must be emphasised that with the introduction of the Health and Safety at Work Act to the offshore environment that training is considered absolutely essential as employers must be able to show that their personnel are competent to undertake <u>all</u> the activities asked of them. To this end larger employers have introduced training schemes along the lines shown here to ensure that their personnel reach the highest levels of competence. It is recommended that suitable experience and assessment in the work environment take place alongside this programme of training to ensure these competencies.
There are a number of recognised routes to becoming a Technician or Engineer and full details should be sought from the Engineering Council or other recognised body, but they include the following technical qualifications:- Degrees, HNC or HND, City and Guilds and National Vocational Qualifications at level 3 or above. Complimentary practical experience, such as apprenticeships, may be required in addition to these qualifications but where sufficient relevant experience has been obtained, this alone may be acceptable to enrol for the ROV Pilot/Technician Induction Course, which is the first step to competency and to which this Handbook applies.

1.0.2 Aims of this handbook

Typical ROV Training Course Structure (Courtesy of Subserv)



* MAINTENANCE/QA/H & S/LEADERSHIP/ HIGH VOLTAGE/RIGGING & LIFTING COURSES CAN BE AVAILABLE AS SEPERATE MODULES

FIGURE 1

The aims of the ROV Pilot/Technician Induction and skills course and this book are similar and are to ensure that the Trainee Pilot/Technician has the essential knowledge and skills to enable him to work both safely and effectively from his very first offshore tour of duty. This is essential in the modern ROV industry as the requirement for lower costs has reduced the crew sizes to the minimum, often only two or three, and there is rarely an opportunity for extra-numerary trainees to be included. In addition we lay the foundations for future learning by explaining the principles of the enabling technologies such as; 'O' rings, video cameras, telemetry and hydraulics. Our industry is practically based and in this respect this Handbook acts as a guide to practical exercises and an identification of the skills required, these exercise should be adapted to the training environment and equipment available.

1.0.3 Scope of this handbook

The subjects that this handbook cover are wide ranging and diverse making it necessary for the reader to have a grasp of scientific fundamentals such as electricity, hydraulics, and photography prior to reading it. There are many books available explaining these fundamentals and the reader is recommended to familiarise himself with these before taking up this course of study.

1.0.4 Technical Levels

The technical levels described are equivalent to the National Vocational Qualification (NVQ) at level 3. The specific qualification recommended is the Engineering Training Authority (EnTra) NVQ Level 3 in Engineering Maintenance, Electro-mechanical option, (or the Marine and Engineering Training Association equivalent) adapted for ROV equipment. In addition to technical information, this handbook contains valuable information on offshore safety, ROVs and their applications, quality assurance systems, photography, seamanship and many other subjects essential for successful ROV operations.

1.1.0 Background to the industry

As early as 1953 in the USA, the development of a diver propulsion vehicle by a company called Rebikoff produced an ROV called Poodle which was used to locate shipwrecks. In 1966 CURV a US Navy vehicle assisted with the recovery of a number of hydrogen bombs inadvertently dropped by the Americans into the Atlantic off Spain. The potential of these systems was dramatically demonstrated in 1973 when CURV 3 assisted in the rescue of a Pisces class manned submersible in 1575 ft of water off Ireland. The years 1973 to 1978 where dominated by fully autonomous battery powered manned submersibles operating in either diver lock-out or observation mode. In observation mode these manned submersibles where used for general intervention work and surveys much as ROVs are today, and in diver lock-out mode they where used as a means of carrying and supporting divers in saturation. The years 1973 to 1977 saw a tremendous development of computer systems and technologies enabling the boom in ROV manufacture and use after 1977. The TROV (ISE) and as a result of US Navy backing the SCORPIO (AMETEK) and RCV 225 were introduced to the commercial sectors. The SCORPIO was initially intended as a mine recovery vehicle and the RCV 225 was designed to be 21 inches in diameter so that it could be deployed though a torpedo tube. The 'classic' configuration of these vehicles has since been reproduced with less expensive alternatives such as the Hydrovision Diablo and Hyball ROV systems. There were around 20 ROVs in operation by 1974, mainly in military or scientific applications, this had risen to 100 by 1978 and is estimated to be over 2000 in 1994 with over 150 different types available from over 60 different manufacturers. The

SI 971	The Offshore Installations (Safety Representatives and Safety Committees) Regulations 1989
SI 978	Included Apparatus or Works
SI 996	Diving Operations at Work (Amendment)
SI 1019	The Offshore Installations (Operational Safety, Health and Welfare)Regulations 1976
SI 1106	Prevention of Oil Pollution
SI 1232	The Health and Safety at Work etc. Act 1974 (Application outside Great Britain) Order 1989. Fully applicable in the UKCS from March 1995
SI 1331	Safety Zones
SI 1333	Ionising Radiations
SI 1398	Prevention of Pollution
SI 1513	Submarine Pipelines Safety
SI 1531	Control of Explosives
SI 1542	The Offshore Installations (Logbooks and Registration of Death) Regulations 1972 (Amended by SI 679)
SI 1542	The Offshore Installations (Emergency Procedures) Regulations 1976
SI 1671	The Offshore Installations and Pipeline Works (First-Aid) Regulations 1989
SI 1672	Operational Safety, Health and Welfare and Life-Saving Appliances
SI 1823	Offshore Safety (Repeals and Modifications) Regulations 1993
SI 1842	The Offshore Installations (Inspectors and Casualties) Regulations 1973 (Amended by SI 679)
SI 1890	Freight Containers (Safety Convention)
SI 1985	Submarine Pipelines Safety (Amendment)
SI 2002	The Merchant Shipping (Prevention of Oil Pollution) (Amendment) Order
SI 2040	The Merchant Shipping (Prevention of Oil Pollution) (Amendment) Regulations
SI 2051	The Management of Health and Safety at Work Regulations 1992
SI 2292	The Merchant Shipping (Prevention of Pollution by Garbage) Regulations
SI 2379	The Ionising Radiation (Outside Workers) Regulations 1993
SI 2406	The Offshore Safety Act (Commencement No 1) Order 1993
SI 2605	Dangerous Goods and Marine Pollutants
SI 2792	The Health and Safety (Display Screen Equipment) Regulations 1992
SI 2793	The Manual Handling Operations Regulations 1992
SI 2885	The Offshore Installations (Safety Case) Regulations 1992
SI 2932	The Provision & Use of Work Equipment Regulations 1992
SI 2966	The Personal Protective Equipment at Work Regulations 1992
SI 3246	The Control of Substances Hazardous to Health Regulations 1994 (COSHH)

Copies of these will be available on the installation and it is important to become familiar with the most relevant ones as soon as possible. Guidance on this should be sought from your Supervisor who is required to have an in-depth knowledge of health and safety matters. SI 1232 and SI 1019 specifically refer to fixed installations and apply on or within 500m of these, the COSHH and Manual Handling Statutory Instruments are also worthy of special note. The other regulations and Codes of Practice should be used as guidelines and although not in themselves legal requirements failure to follow an approved code could be construed by a court as failure to meet the requirements of the HSAWA. Operations outside the UK will be governed by the laws of that country which may not be the same as UK law. If in doubt British Standards, Codes of Practice and UK legislation are a good guide to safe working practice.

AODC Guidance Notes:

The AODC has now changed its name to IMCA (the International Marine Contractors Association) but these guidelines are presently still known by their AODC number.

AODC 018	Crane Hooks
AODC 032 /REV 1	Remotely Operated Vehicle intervention during diving operations
AODC 036 /REV 1	ROV Handling Systems (UK)
AODC 033	Responsibility for Underwater Inspection
AODC 051	Guidance Note on the Safe and Efficient Operation of Remotely Operated Vehicles
AODC 057	Basic Induction Course for ROV Personnel
AODC 060	Safety Procedures for Working on High Voltage Equipment
AODC 061	Bell Ballast Release Systems and Buoyant Ascent in Offshore Diving Operations
AODC 062	Use of Battery Operated Equipment in Hyperbaric Conditions
AODC 063	Underwater Air Lift Bags
AODC 064	Ingress of Water into Underwater Cylinders Charged by Means of a Manifold System

Code of Practice for the Safe Use of Electricity Under Water

DMAC 06	Recommendations The Effect of Sonar Transmission on Commercial Diving Activities
Safety Notice 2/93	Crane Sling Hooks Used to Deploy Equipment Sub Sea

IMCA/DMAC Publications may be obtained from:

IMCA,
177A High Street,
Beckenham,
Kent,
UK,
BR3 1AH

Government legislation and Statutory Instruments from:

HMSO Her Majesty's Stationary Office

There are some excellent publications explaining the application of the various H & S legislation available from:-

HSE Books
PO Box 1999
SUDBURY
Suffolk CO10 6FS

Also in this series; 'The Handbook for ROV Supervisors' contains a more detailed explanation of H & S legislation as it particularly applies to the ROV industry.

2.0.2 Medical Fitness

The Offshore operators require their personnel to be medically examined by an approved doctor. There is a prescribed form to the medical and it is valid for:-

5 years for workers under 40 years of age.
3 years for workers 40 to 50 years of age.
1 year for workers over 50 years of age.

The medical includes a dental fitness inspection.

2.0.3 Offshore Survival Courses

There are various approved offshore survival centres which are authorised to issue survival certificates. The centres offer 3 1/2 and 4 1/2 day survival courses designed to teach offshore personnel the basics of fire fighting, survival in the sea, helicopter safety and evacuation and general first aid including EAR and CCM. The certificate is valid for 5 years the 4 1/2 day course being required to work in Norwegian waters. There are also refresher courses which lasts for 3 or 4 years depending on the individual operator's requirements.

Addresses of UK Centres:

For general information:

Central Training Register,
Offshore Petroleum Industry Training Board,
Forties Road,
Montrose,
Angus,
DD10 9 ET.

RGIT,
Survival Centre Ltd.,
Aberdeen

Courses also available in Newcastle, Fleetwood and Great Yarmouth

2.1 Responsibilities

Under the Health and Safety at Work Act(HSAWA) and the Offshore Installations (Operational Safety, Health and Welfare Regulations); Statutory Instruments (SI) 1019, the **employer** has a responsibility to ensure the health, safety and welfare of his employees and to provide "...such information, instruction, training and supervision as are necessary..." to ensure these responsibilities are properly discharged. The employer must provide a written statement of his safety policies and procedures which must be freely available to employees. This statement is usually known as the Safety Manual. Employers also have a duty to protect persons not in their employment and self-employed persons who may be affected by their operations. The Control of Substances Hazardous to Health Regulations 1988 (COSHH) requires employers to take the steps necessary to minimise the risks arising from the use of dangerous substances. These regulations also place a duty on the **employee** to look after the health, safety and welfare of himself and others he may be working with and to make "...full and proper use of any control measure, personal protective equipment or other thing of facility provided pursuant to these regulations and if he discovers any defects therein, he shall report it forthwith to his employer...". The responsibility of the employee for safety is considered to be of paramount importance and evidence of the employee's awareness of this must be demonstrated during the trainee's period of primary training.

2.2 Attitudes

Poor attitudes towards safety usually come from a belief that accidents will only happen to other people and not to oneself. Experienced operators who have witnessed accidents, or near accidents offshore are aware that accidents can and do happen and adjust their attitudes to minimise the risk of accidents to themselves. A trainee must imagine being in the same situation and be particularly careful to allow for any inexperience, asking where necessary for assistance or instructions. The trainee must imagine the worst case scenario in all situations, for example, posing the question, "What happens if that lifting wire parts?" and then taking appropriate safe action.

2.3 Operational Safety

Many factors combine when operating ROVs which make the potential for accidents greater than for most other forms of employment. The major ones are listed below.

2.3.1 Electrical Safety.

2.3.2 Explosive Environments (Hazardous Areas).

2.3.3 Explosives, Radioactive Sources and COSHH.

2.3.4 Mechanical Devices.

2.3.5 High Pressure Hydraulic Systems.

2.3.6 Lifting and Deploying the ROV and Manual Handling in general.

2.3.7 Welding.

2.3.8 Gas Cylinders.

2.3.9 Restricted Areas.

2.3.10 Helicopter Operations.

2.3.11 Protective Clothing.

2.3.12 Use of Tools.

2.3.13 Requirement for Good Housekeeping.

2.3.14 Working with Divers.

2.3.15 The Nature of the Sea Itself.

2.3.16 Requirement for Emergency Procedures.

These factors will be examined in more detail in the following sections:

2.4. Electrical Safety

ROVs usually operate with high voltages to reduce the current through the umbilical and hence the umbilical size. This fact coupled with the nature of the offshore work environment dictates close scrutiny of materials used in electrical installations in order to avoid possible toxic effects in confined spaces should an electrical fire occur. The harsh conditions require that a high degree of skill and safe working practices go into these installations. It is obvious that if we are to operate with high voltages in a wet environment there is a very real risk of electric shock and that precautions against this must be taken. These precautions fall into three categories: personal precautions passive protection and active protection. Personal precautions consist of applying good work practices, good housekeeping methods, using correct protective clothing and the correst tools and parts for the job in hand. Passive protection can be provided in a number of ways such as insulation and active protection may be provided by either a Residual Current Device (RCD) or a line insulation monitor (LIM).

2.4.1 Personal Precautions

1. Only work on electrical systems if you are sure you know what you are doing. High Voltage courses are available to ensure competence. Work in pairs.
2. Be absolutely sure that the ground connection is made through the umbilical to the ROV, ie the ROV frame is earthed if conductive.
3. Connect an additional external ground strap when the ROV is on deck during maintenance.
4. Wear rubber gloves if handling the umbilical or ROV frame when power is on.
5. Make sure that inexperienced personnel stand well clear during operational and maintenance procedures.
6. Do not allow personnel and tools to become disorganised during maintenance and repair procedures or take short cuts due to operational pressures.
7. Stand on a rubber mat when working in the vacinity of High Voltages.
8. Know the first aid for shock treatment and the medical evacuation procedures of the vessel.
9. All meters must be suitably rated *e.g.* 1000 V a.c. or 5000 V a.c. as required.
10. Know where mains isolating switches are and ensure that LIMs and RCDs are operational.

2.4.2 Passive Protection

This form of protection is provided by the use of adequate insulation to provide a fixed barrier. Using protective clothing, shielding and suitable earthing also provide passive protection.

2.4.2.1 Insulation

The primary means of providing passive protection against shock is by insulation of the power system and the appliance it serves. Insulation may be less effective underwater than on dry land because a defect at any point would allow current to flow through the water. The effectiveness of insulation as a means of protection may be improved by using two layers of insulation with a conducting screen in between. Two defects are then needed to constitute a risk. The first defect can be detected by continuously monitoring the insulation level between the conducting screen and the load, and between the screen and the outer casing or armour. Entry of water could however cause simultaneous failure of both sections of insulation therefore sealing arrangements such as 'O' rings and pressure balance terminations should be incorporated if double insulation is to be more effective than single insulation. See Figure 2.1

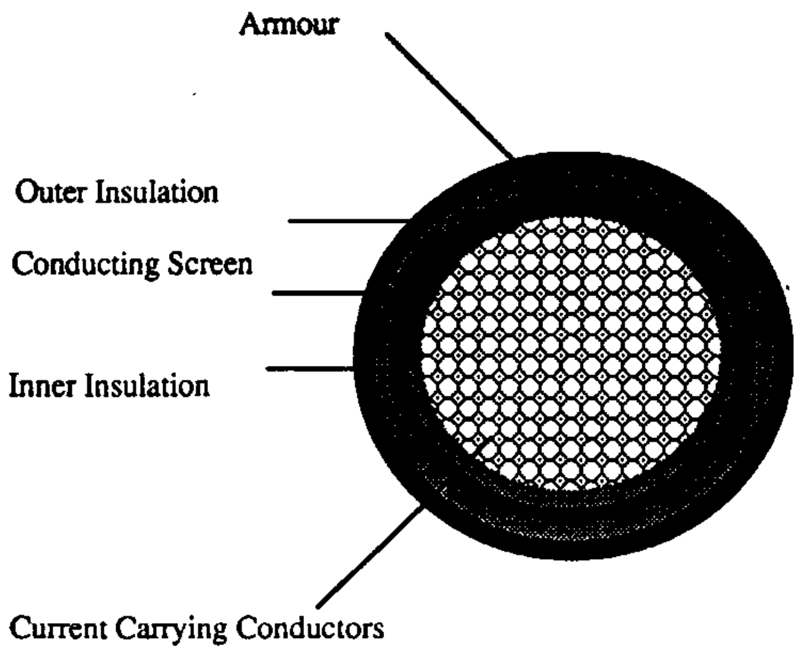


Figure 2.1
Double Insulation With a Conducting Screen

Insulation should be further improved by supplying the load via an isolating transformer (see Figure 2.2). This electrical device isolates the supply current from the load. The whole of the electrical system including the transformer secondary winding and all the appliances are thus insulated from earth. It is then possible to make contact with any point on the secondary circuit without receiving a shock. This prevents, for example, contact with a crane wire from the surface, the leg of a steel platform or a ship's hull from forming an earth return path and thereby creating a hazard. If a first defect is not rectified, contact with the circuit or the occurrence of a second defect may cause current to flow through either the ROV or a diver. This can be avoided by incorporating an active protection device for detecting the first defect. The whole of the circuit: transformer; secondary winding; connected cable and the load should have a high insulation resistance to earth.

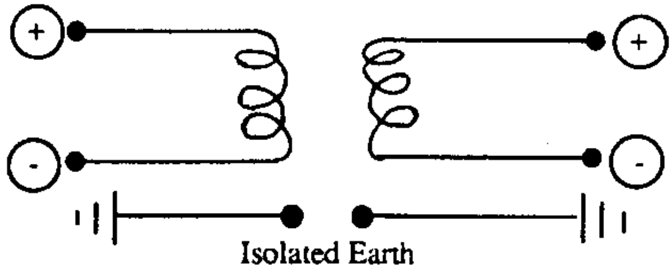


Figure 2.2
Isolating Transformer

2.4.2.2 Fixed Barrier

When electrical equipment requires direct contact with sea water to function correctly *e.g.* an impressed current anode a fixed barrier can be installed to keep the ROV or diver a specific safe distance away from it. This barrier should be non-metallic and non-conducting if possible. In addition to such equipment, high-power fixed installations *e.g.* cables and motors can feed large currents into the water if a fault occurs. Again fixed barriers can be used to keep the ROV or a diver at a safe distance. The safe distance can be reduced by incorporating an impedance in the star point to earth line of the supply to limit the fault current. Care should be taken to ensure that all protective devices will function at the low level. A fault current limit of 1 amp is recommended by the AODC Code of Practice for the Safe Use of Electricity Underwater.

2.4.2.3 Protective Clothing

Any practice which limits the flow of current through the body is beneficial. Rubber gloves should be worn when handling the ROV or umbilical and these should have a cuff to give the wrist area some degree of protection.

2.4.2.4 Shielding

The electrical equipment may be enclosed within a conducting shield to prevent current from flowing into the water. Where a shield is fitted it should be suitably connected to earth, to prevent a dangerous voltage by an internal fault. Protective screens should be constructed from high conductivity material and have low resistance joints, otherwise a fault current flowing in the screen can produce a dangerous voltage gradient over its external surface. However, this deficiency can be greatly reduced by the use of a double screen. The conducting screen, the external screen in double screened systems should also be in contact with the water to restrict the voltage difference between the screen and the surrounding water.

2.4.2.5 Suitability of Earthing

On any unit which operates at a voltage which is higher than the unprotected safe limit (30V dc or 7.5V ac) the conductive structure or frame should be connected to earth to dissipate any fault current. The connection should have a low impedance to minimise any rise of voltage on the conductive structure or frame, and sufficient mechanical strength to prevent accidental breakage when the equipment is operated within the stated limits. The connection should be through purpose designed conductors in the power cables. The earth return path can be augmented by an area of bare metal, even corroded steel will do, in contact with the water such an arrangement can be many times more effective than normal earth leads.

2.4.3 Active Protection

This form of protection incorporates devices into the circuit which cut off the supply would a short circuit situation occur.

2.4.3.1 Residual Current Devices (RCDs)

Commonly used RCDs have a typical operating time of 15 to 25 ms. The trip currents of RCDs should be selected to be as low as possible consistent with freedom from accidental tripping which is inconvenient and can be dangerous. A trip current of 30 mA at 20 ms has been found to be suitable.

Any imbalance in the currents flowing in the positive and neutral windings trips the breaker. In a real device there is often only one turn as shown. The breaker is held 'on' by magnetic forces. The magnetic circuit is designed so that only a small current is needed to divert the flux to an alternative path and release the armature. These are shown in Fugures 2.3 & 2.4 where the the latter works in a similar manner to that described but illustrates the situation where an earth is included.

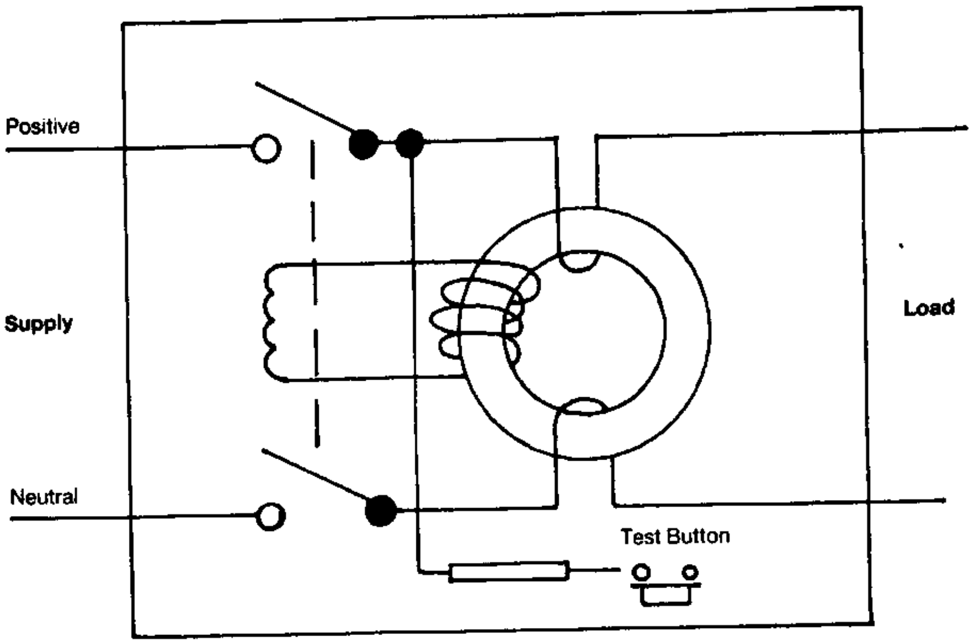


Figure 2.3 Residual Current Circuit Breaker

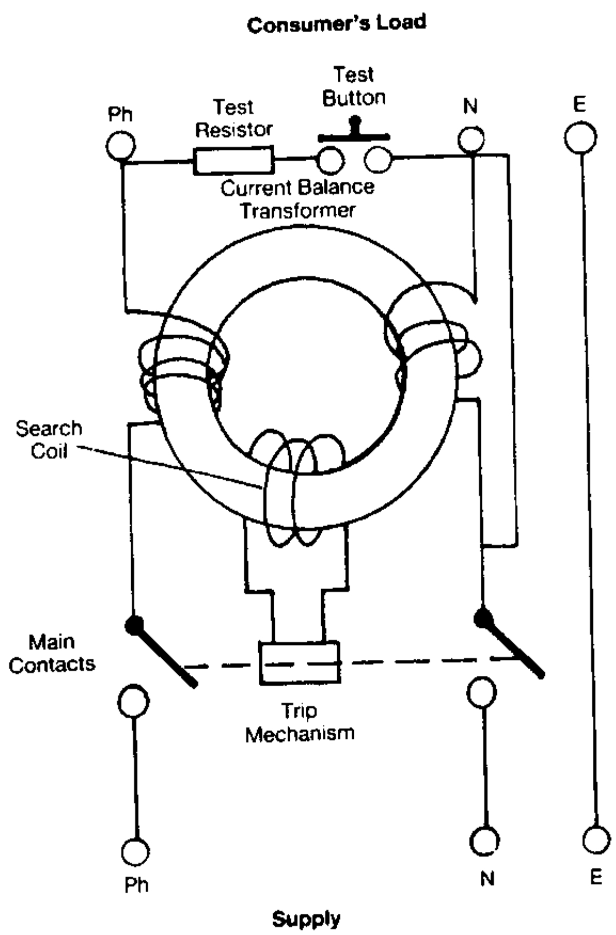


Figure 2.4 Residual Current Circuit Breaker Type 2

2.4.3.2 Line Insulation Monitors (LIMs)

A line insulation monitor (LIM) may be used to monitor the insulation level of an umbilical cable as it enters or leaves the water and any developing electrical leakage will be detected. A read out of insulation level should be provided with warnings of low levels if appropriate. In order to use an LIM as part of an active protection device it should be connected to a circuit breaker to give suitable overall system operating characteristics. Ideally the line insulation should be infinity but a typical acceptable level for an ROV system may be greater than 10 M Ohms. LIMs are particularly useful as water ingress can often be detected at an early stage before damage or an equipment shut down is necessitated. If the subsytem can be isolated at this stage a total system failure can be avoided.

2.5 Installation Practice

To maintain the integrity of all forms of protection, portable and fixed electrical equipment should be regularly inspected by competent staff. Only such staff should carry out installation or rewiring, and any temporary electrical equipment used should be to industry standards. Contractors responsible for underwater electrical equipment should authorise staff in writing as competent for specific functions. Competent staff should be familiar with proper installation procedures and be aware of the hazards and problems particular to underwater work. Frequent inspections should be made for signs of mechanical damage on cables and for any general deterioration of equipment. These inspections can be incorporated with the 6 monthly insulation test of the umbilical which is usually completed to fulfil insurance requirements.

2.6 Batteries

In the past batteries have usually been considered to be electrically 'safe'. As in many cases they are not used as a primary power source, but rather as a reserve or back-up, they are frequently omitted from electrical safety assessments. In practice batteries can present very real hazards and considerable care should be taken when using them. Primary cells (non-rechargeable batteries) have a limited life and when discharged are notorious for producing corrosion products. Short-circuiting of primary cells can be potentially hazardous and adequate short-circuit protection should be provided. Secondary cells (rechargeable batteries) are normally of higher power than primary cells, so the same basic recommendations apply. In addition, however, there is an explosive hazard from hydrogen gases produced during discharge and recharging. Secondary cells should normally be recharged on the surface in a properly ventilated area.

2.7 Explosive Environments

In UK waters, the handling systems of ROV's employed offshore should comply with the Offshore Installations (Operational Safety, Health and Welfare) Regulations 1976 SI 1019 which apply to any activity (as defined) from, by means of, or on, an offshore installation or within a radius of 500m. This relates to equipment located in hazardous areas defined as; "...any part of the installation in which there is likely to be danger of fire or explosion from the ignition of gas, vapour of volatile liquid...".
The Pilot/Technician must therefore be aware if he is working in a hazardous area and suitable precautions must be taken which might include the following:

- No smoking or naked flames.

- Cold Work, Hot/Electrical Work or Red Hot Work Permit may be required when working on the ROV or ancilliary equipment.

• Control and workshop containers may need to be approved for electrically hazardous location by being configured to meet the requirements for purged enclosures. Alternatively explosion proof components and intrinsically safe devices can be used inside these containers, but the former is preferred. For further information on the requirements of purged containers refer to the AODC Operational Guidelines for ROV's page 126.

• Winch slip ring, junction boxes and terminations may need the following modifications:

i) explosion proof boxes, rigid metal conduit.
ii) pressurise the electrical system with safe gas.
iii) fill the existing system with oil.

• Use explosion proof electric motors for winches and cranes.

• Deck cables may not meet the requirements for steel armouring therefore a cage deployed system may be required, alternatively the vehicle may only be operated when a hot work permit has been issued.

2.8 Explosive Handling

Explosives are used extensively during some ROV operations. It is imperative that the personal safety precautions for handling explosives are adhered to. The work itself will be under the direct control of a qualified explosives technician who will follow a written procedure and apply safe working practices. The role of the ROV must be fully understood and the work itself must be detailed in writing. A common safety requirement for this type of work is to impose a radio silence as it is possible for radio transmissions to trigger some types of detonator.

2.9 Mechanical Devices

Thrusters and manipulators on ROVs can be very powerful and may not behave as expected. An electrical fault, for example can cause a normally placid manipulator to oscillate violently due to a phenomena known as positive feedback, causing immense damage. It is important to stand clear of these during pre/post dive checks or whenever the vehicle is operated on deck. For example it is important to be sure that the system is powered down before putting a hand into thrusters to clear obstructions or for any other work of this nature.

2.10 Hydraulic Systems.

ROV hydraulic systems operate typically at 200 Bar (3000 p.s.i.) and, should a loose fitting cause a leak for example, serious injuries may be caused. It is important therefore that all personnel working on the hydraulic system should be qualified and have attended the relevant safety seminars, and that non-essential personnel stand well clear of ROVs whenever the hydraulic system is under pressure. The work area should be isolated with signs in letters at least 5 cm high stating; "DANGER HIGH PRESSURE TESTING".

2.11. Lifting and Deploying the ROV

Many ROV Pilot/Technicians have no experience at sea nor of lifting heavy loads with cranes or tuggers prior to going offshore for the first time. The procedures of lifting and deploying the ROV are crucial to the success of the operation and can represent a very great safety hazard if not implemented correctly and conscientiously. Procedures for lifting equipment and ROV deployment methods are covered in the seamanship section of this handbook. The objective here is to make the pilot/technician aware of the risks that are inherent during launch/recovery procedures to enables him to assist with these procedures safely without exposing himself or others to danger. At the time of writing studies are underway by relevant authorities to determine the most suitable deployment system test procedures. Current practise as laid out in AODC 036 (Rev 1) "The Initial and Periodic Examination, Testing and Certification of ROV Handling Systems" is:

a Initial and period examination and test of ROV launch and recovery systems.

i) **As New/Installed:**

1. Manufacture to a recognised Code of Standard or Build to Manufacturer's Standard Specification. and Verify compliance with National Regulations.
2. Static load brake test at 1.5 x SWL.
3. Function test at 1.25 x SWL.
4. Both tests to include additional equipment which may be fitted to the ROV. NDT to be carried out on critical items.

ii) **In Service:**

1. Visual examination and function test at SWL.
2. Static load brake test at 1.5 x the weight at be lifted in air. NDT to be carried out on critical items.

b. Initial and Period Examination and Test of ROV Lifting Cable/Wire Rope and Terminations.

i) **As New/Installed:**

1. Verify compliance with National Regulations.
2. Load test to 1.5 x SWL.

ii) **In Service:**

1. Function test at SWL as an integral part of the Lifting System and visual examination
2. Static load test at 1.5 x SWL.
3. Electro-mechanical umbilicals should be tested as above and re-terminated at least once every 12 months.

SWL is that of the load to be lifted, not the rated SWL of the lifting appliance and should not be exceeded at any time. Function tests and visual examinations are valid for 6 months other tests are valid for 12 months. Pennant wires or lifting wires that enter the water are subject to stringent annual NDT tests and are often discarded in preference.

These should be verified with the relevant authorities (DnV, Lloyds etc.) on each mobilisation as standards vary.

2.11.1 Precautions

i) Be aware of rigging safety in general and wear the appropriate safety clothing *i.e.* safety boots and hard hats.

ii) Do not stand behind tuggers *etc*. There have been many nasty accidents offshore whereby the wires have parted and personnel have caught the whiplash. Always fit guards to tuggers.

iii) Practice launch/recovery procedures from a fixed platform before attempting them at sea and make sure that all the personnel involved are fully aware of their roles.

iv) ROV's can weigh typically around 1 Tonne. When this weight is lifted from a moving platform it represents a significant hazard therefore; keep the lifting pennant as short as possible, do not stand between the ROV and any fixed structure, and handle the ROV, only when necessary, at arms length or preferably with tag lines to avoid it trapping any part of the person if the lifting mechanism should break or slip.

v) Do not lean over the side of the ship without a safety line and be aware of the location of life saving equipment. It is wise to practice the man overboard procedure in fine weather conditions.

vi) Tie all the equipment down and stow it correctly during periods of heavy weather.

2.11.2 Manual Handling

Around 25% of all reported industrial accidents in the UK are due to improper lifting/handling of loads. On a moving vessel the risks are even greater. Always avoid lifting manually. Wherever possible use a crane or other lifting device. If loads must be lifted manually make sure you lift only what you are capable of with a straight back and bent legs.

2.12 Diver Observation

ROV's have sufficient power to crush divers or to drag them from their worksite should the umbilicals become entangled. Therefore the following precautions must be taken when working with divers.

2.12.1 Precautions

i) Establish communications with the diving supervisor and be prepared to turn off the ROV power immediately on his instruction.

ii) Fit guards to the thrusters.

iii) Wherever possible work down current of the diver and take care to keep the umbilicals apart. Never lift a diver or his umbilical.

iv) Use minimal thruster controls.

Reference: AODC 32 Guidance Note Remotely Operated Vehicle/Diver Involvement.

2.13 The Nature of the Sea

The hazards of the sea are covered in the chapter on seamanship so suffice it to say here:- do not underestimate the inherent dangers of wind, waves and tides.

2.14 COSHH Control of Substances Hazardous to Health

All substances that may be hazardous to health must be clearly marked and kept under lock and key. In addition PPE (Personal Protective Equipment) and RPE (Respiratory Protective Equipment must be available but is only acceptable as a last resort in addition to other means if these alone cannot provide adequate control. If in doubt about any substance - ask your supervisor.

2.15 Use of Tools

All hand tools and machine tools must be used correctly and only for the task they were intended. In addition use all protective equipment such as goggles and guards. It is expected that Pilot/Technicians will have learnt a trade prior to entering the ROV industry. Use only the tools that you are competent to use and be particularly careful with welders and grinders. Be sure to gain the correct work permit prior to using any tools on deck and use 115V tools in preference to 240V.

2.16 Display Screen Equipment Work

Whilst the Health and Safety (Display Screen Equipment) Regulations 1992 may not strictly apply to the operation of ROVs on board ships or platforms it is sensible to take precautions to minimise the damage that could be caused by the prolonged use of display screen (VDU) equipment. Precaution should include:-

- i) Care of eyes through eyesight tests and use of VDU glasses
- ii) Use of correct seating and posture
- iii) Frequent breaks from VDU monitoring activities.

2.17 Care With Buoys

Plastic air filled fishing floats (Grimsby Buoys) are frequently used to add buoyancy to ROVs and Umbilicals. Theses are often submerged to great depths. If a very small hole exists in the buoy water can enter and the buoy can become pressurised. During recovery the buoy may not equalise to atmospheric pressure and is in danger of exploding. This problem can be exacerbated if the plastic is cold and brittle and the buoy is subject to impact with the deck on recovery. All buoys should therefore only be used if in good condition and then only to their rated depth. Care should be taken on recovery not to subject them to impact and if any buoys are heard to be hissing personnel should leave the area until the hissing stops.

2.18 Use of VHF Radios

On many installations the use of radios is restricted, due to the possibility of interference with other equipment. Ensure that you have permission to use radios before their operation.

2.19 Temporary Structures/Welding

Any structures fabricated offshore, such as walkways, must be fabricated to HSE specifications and must be assumed to be accessible to all personnel rather than just the ROV crew. These structures must safe for the use of all personnel. Any welding of structures or load bearing attachments must be performed by a competent welder, and in the case of launch/recovery gear, must be tested before use.

2.20 Stress

Stress is a factor in many accidents. Stress offshore can be caused by: Long shift hours, being away from home, cold and claustrophobic working environment, and interpersonal disputes ('wind-ups') and other factors. Personnel should be aware of the stressful nature of the work environment and take additional care to compensate.

2.20 Competence

Competence is the key word regarding safety. To be competent you must have skills, knowledge and relevant experience of the task in hand. If you are unsure of your competence to undertake any particular task; do not do it without first consulting your supervisor. Remember you are part of a team: 'Teamwork' is essential to safety and you must be prepared to seek assistance wherever you deem it to be necessary.

2.21 Scope of this Chapter

This chapter is intended as a guide to the essentials of Health and Safety as it pertains to offshore working for ROV Pilot/Technicians. It is important, however, that you become familiar with the particular rules and regulations, and company procedures that affect your operation. REMEMBER:- 'IF IN DOUBT - ASK'.

CHAPTER 3 TYPES OF ROV

3.0.0 Introduction

3.0.1

For the purpose of this book the term ROV shall mean an unmanned vehicle with a communication and power link to the surface by means of a tether or umbilical. ROVs are classified in the "Guidance note on the safe and efficient operation of remotely operated vehicles" (AODC 051 February 1989) into five classes:- Class 1 Pure Observation Vehicles, Class 2 Observation with Payload option Vehicles, Class 3 Work class vehicles, Class 4 Towed or bottom crawling vehicles, and class 5 Prototype or Development vehicles. In fact ROVs are a continuum of types and capabilities from simple video cameras to 'flying bedsteads' with any number of options, highly sophisticated work and survey vehicles, bottom crawling vehicles and special one-offs. Any attempt to classify all these possibilities leads to confusion at the boundaries however, in this chapter we will list and describe some well known examples within these AODC classifications. Due to the ever growing number of types and manufacturers this list is by no means exhaustive but serves to demonstrate the range that is available.

3.0.2

Figure 3.1 shows the system components for a RCV 225 system. The basic system components will vary in their physical dimensions but are common to all ROV systems. They are; the Power Pack or Power Distribution Unit (PDU), the control consul or Operator Control Unit (OCU), the Sonar Control Unit (SCU), the Winch and Handling System ('A' Frame), the launcher, Garage, or Tether Management System (TMS), and the vehicle itself.

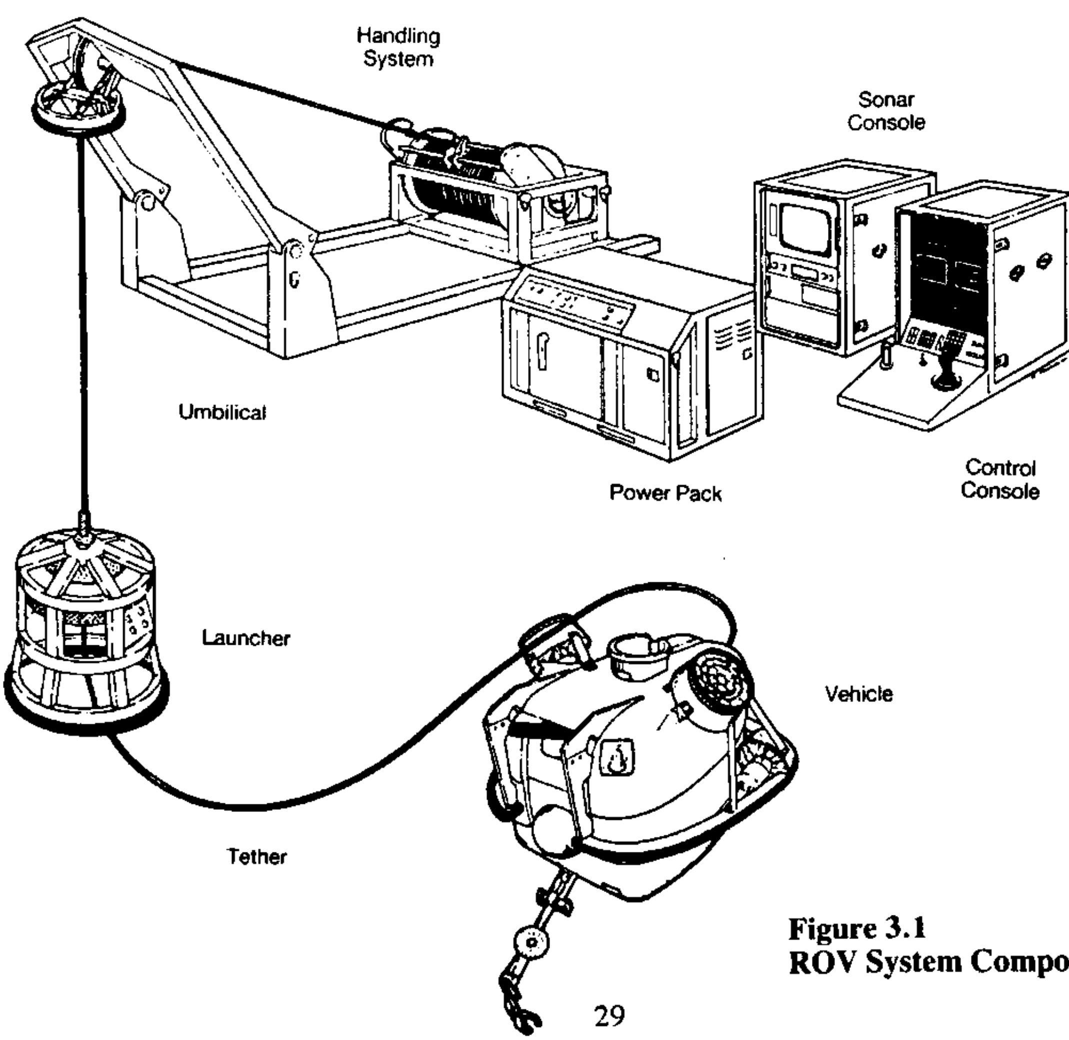


Figure 3.1
ROV System Components

Figure 3.1 ROV System Components

3.1.0 Class 1 Pure Observation vehicles include: The Deep Ocean Engineering Phantom and the Benthos MiniROVER. These are theoretically physically limited to pure video observation tasks although they have more recently been modified with the fitment of grabbers to accomplish retrieval tasks or carry Cathodic Protection (CP) probes. *Figure 3.2 shows a MiniROVER and Figure 3.3 a Phantom 300.*

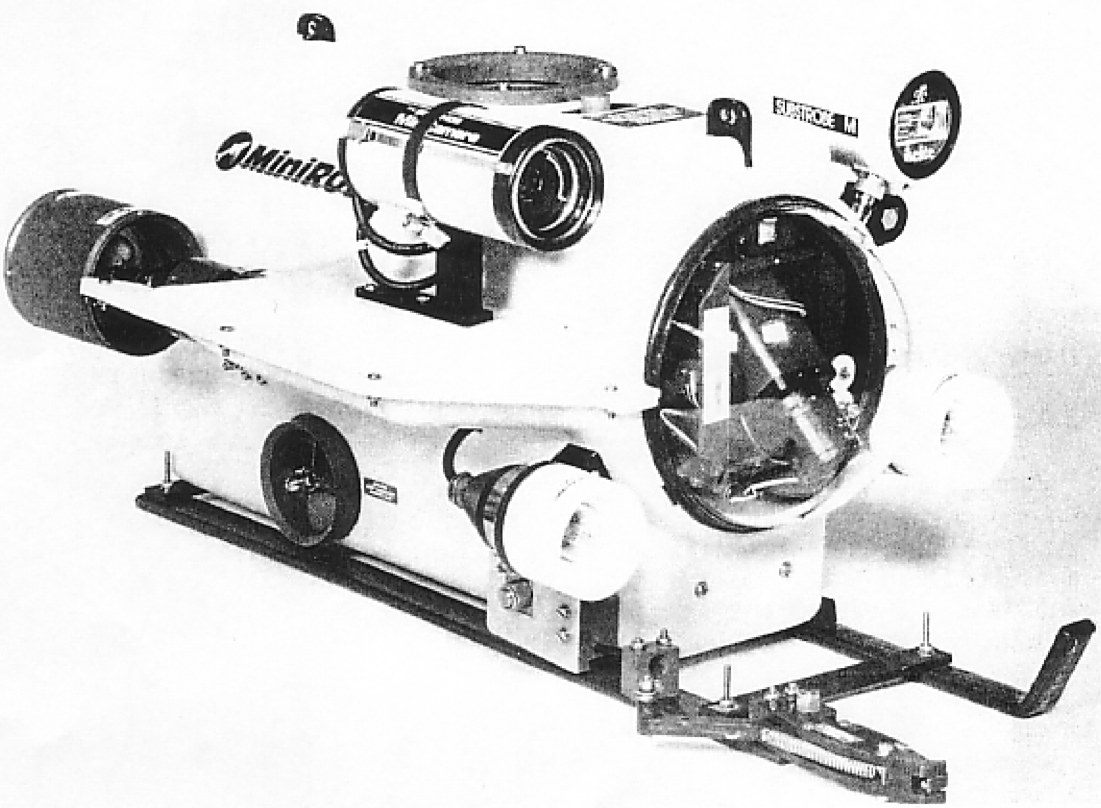


Figure 3.2 Benthos, MiniROVER Mk II

Figure 3.3 Deep Ocean Engineering, Phantom 300

3.2.0

Class 2 Observation Vehicles with a Payload Option include: the Hydrovision Offshore Hyball, the Seaeye Surveyor, the Perry Tritech Sprint, and the Bofors Underwater Systems/Sutec Sea Owl. These are vehicles capable of carrying additional sensors such as stills cameras, cathodic protection (CP) measurement systems, additional video cameras, sonar systems and wall thickness or flooded member detection system. A class 2 system should be capable of operating without loss of its original function when carrying at least two additional sensors. Figure 3.4 shows an Offshore Hyball and Figure 3.5 shows a Seaeye Surveyor.

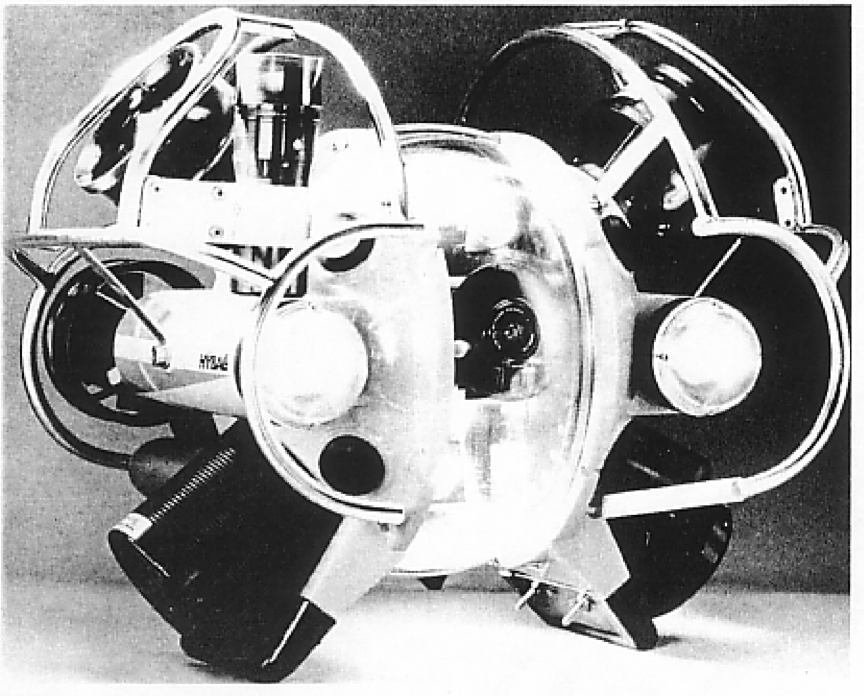


Figure 3.4 Hydrovision, Hyball

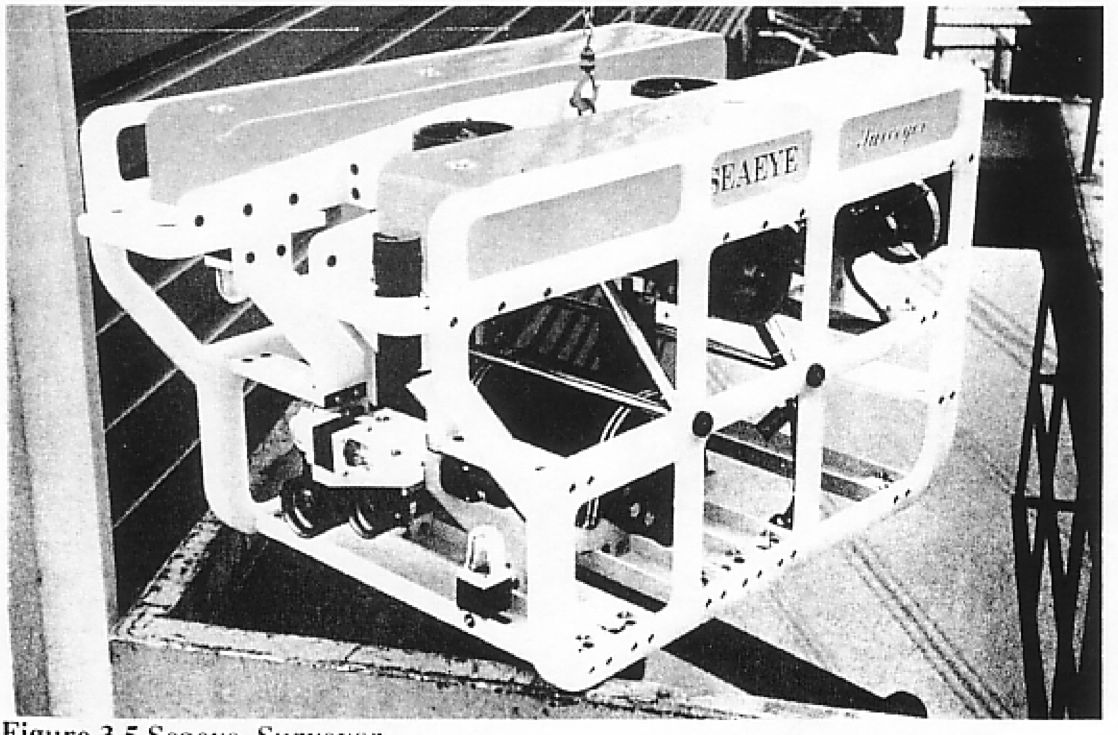


Figure 3.5 Seaeye, Surveyor

3.3.0

Class 3 Workclass Vehicles include: the Hydrovision Diablo, the Perry Tritech Super Scorpio, SubSea Offshore's Pioneer and Examiner, and Slingsby Engineering's Trojan and Multi Role Vehicle (MRV). These vehicles are large enough to be fitted with additional sensors and/or special tools for intervention and manipulative tasks. Class 3 vehicles will have a multiplexing capability allowing additional sensors and tools to be operated through the vehicle system. The umbilical will also have spare conductors to allow operation of payload equipment. Workclass vehicles have sufficient propulsive power (typically at least 50 HP) to operate at least one thruster in each of the longitudinal, lateral and vertical directions whilst carrying additional tooling packages. Figure 3.6 shows a Diablo, Figures 3.7 & 3.8 show the Super Scorpio including the pilots consul, Figures 3.10 & 3.11 show the Trojan including a detailed drawing, Figure 3.12 shows the Pioneer and Figure 3.13 shows the MRV.

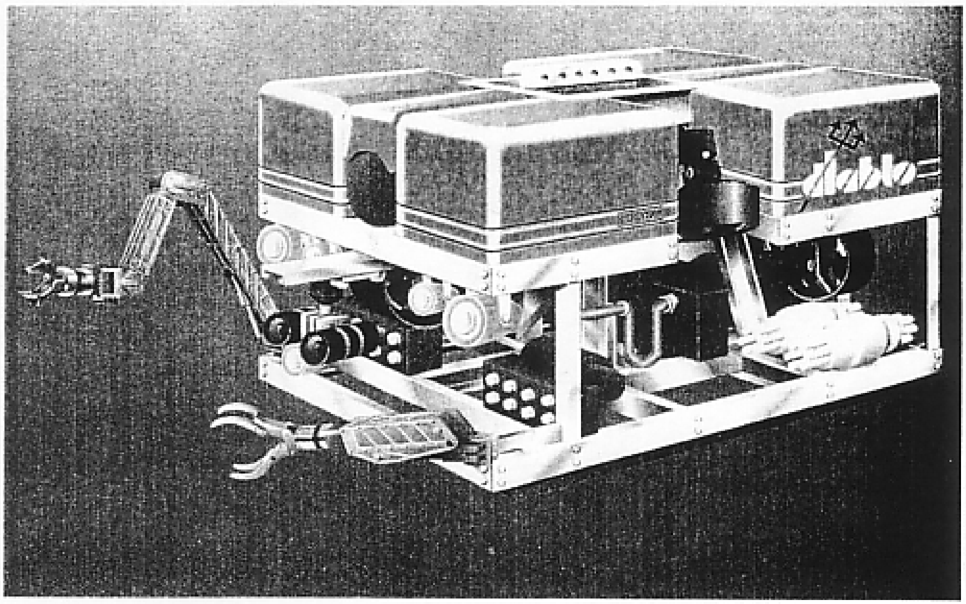


Figure 3.6 Hydrovision, Diablo

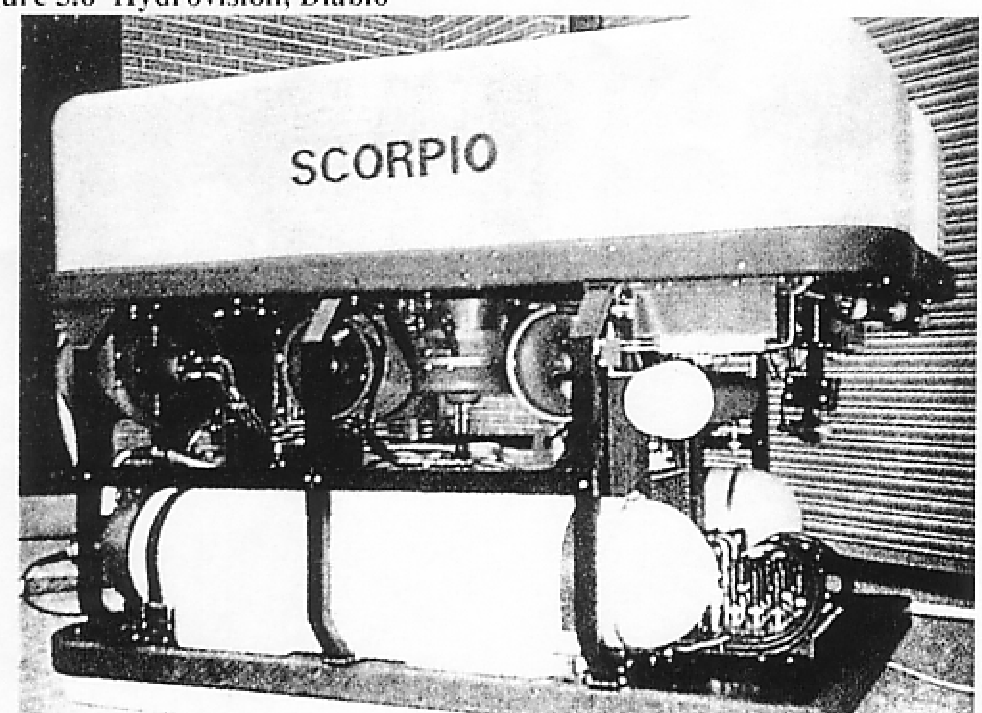


Figure 3.7 Perry Tritech Inc, Super Scorpio

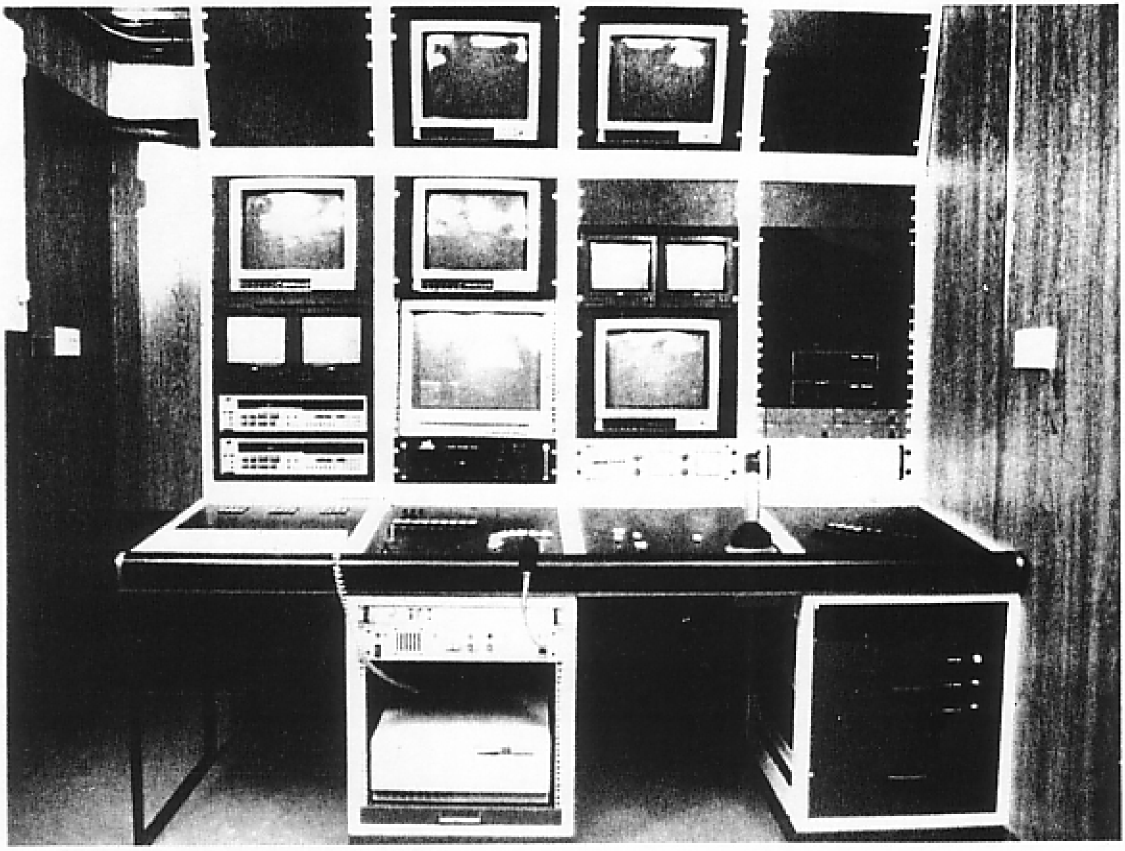


Figure 3.8 Perry Tritech Inc, Super Scorpio Pilots Consul

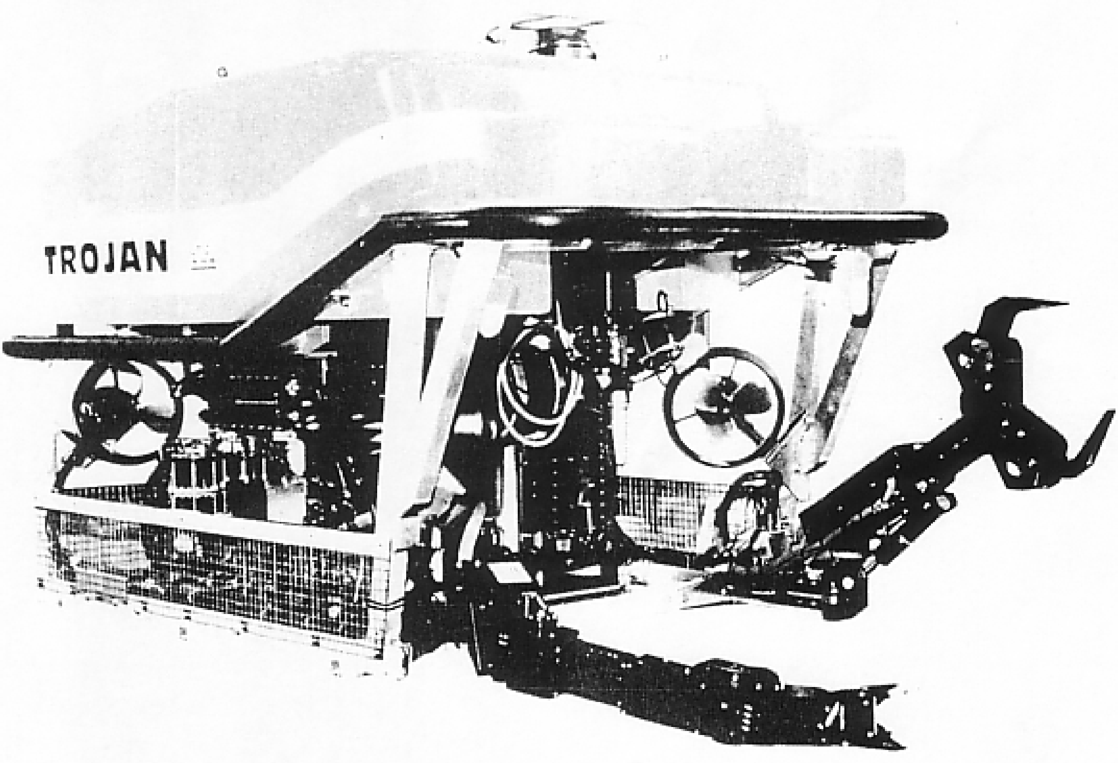


Figure 3.9 Slingsby Engineering, Trojan

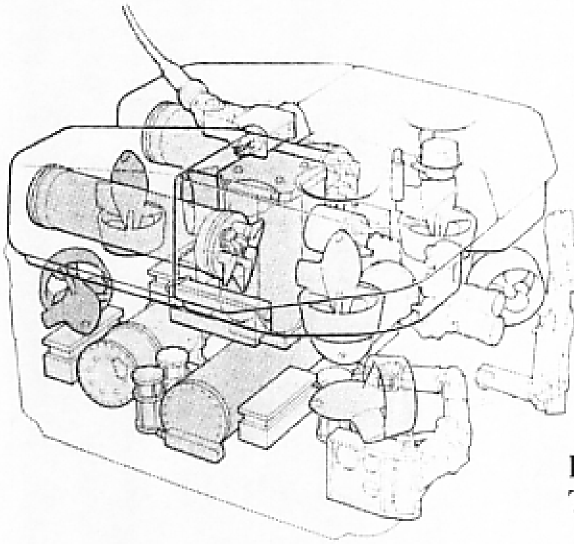


Figure 3.10 Slingsby Engineering Ltd, Trojan Detailed Schematic

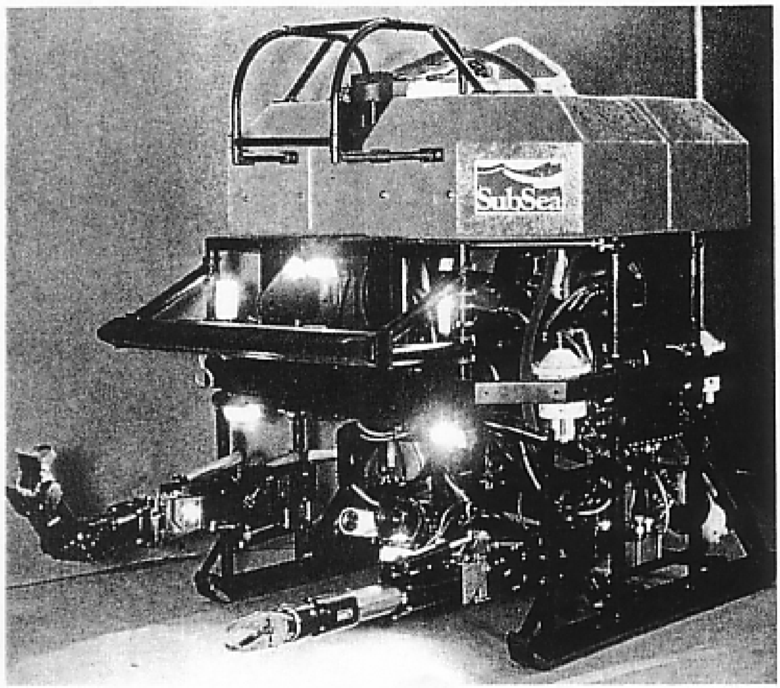


Figure 3.11 Subsea Offshore Ltd, Pioneer

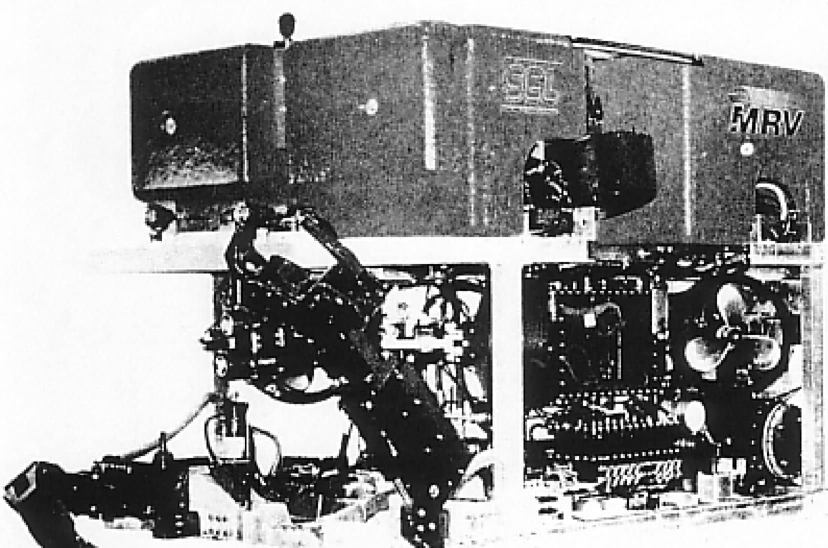


Figure 3.12 Slingsby Engineering, Multi Role Vehicle (MRV)

3.4.0

Class 4 Towed or Bottom Crawling Vehicles include; Soil Machine Dynamics (SMD) Eureka Tracked Vehicle, Slingsby Engineering's ROV 128 and SMD's Modular Plough. Towed Vehicles have no or little propulsive power off the seabed and are generally capable of limited manoeuvrability. They travel through the water by the hauling action of a surface craft or winch. Bottom crawling vehicles move primarily by exerting traction forces on the sea floor via a wheel or track system although some may be able to 'swim' limited distances. Figure 3.13 shows the Eureka, Figure 3.14 shows the ROV 128.

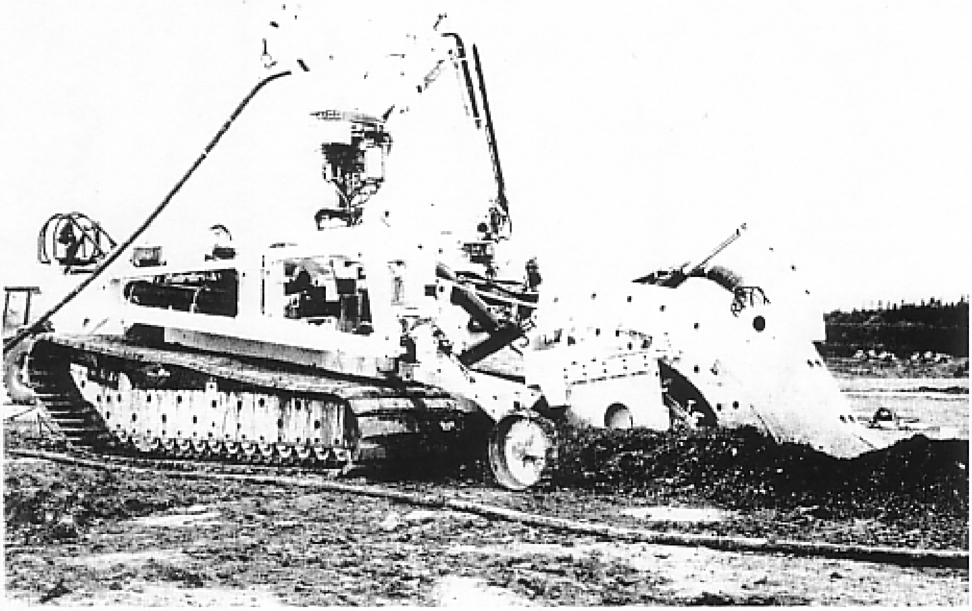


Figure 3.13 Soil Machine Dynamics Ltd, Bottom Crawling Cable Burial ROV

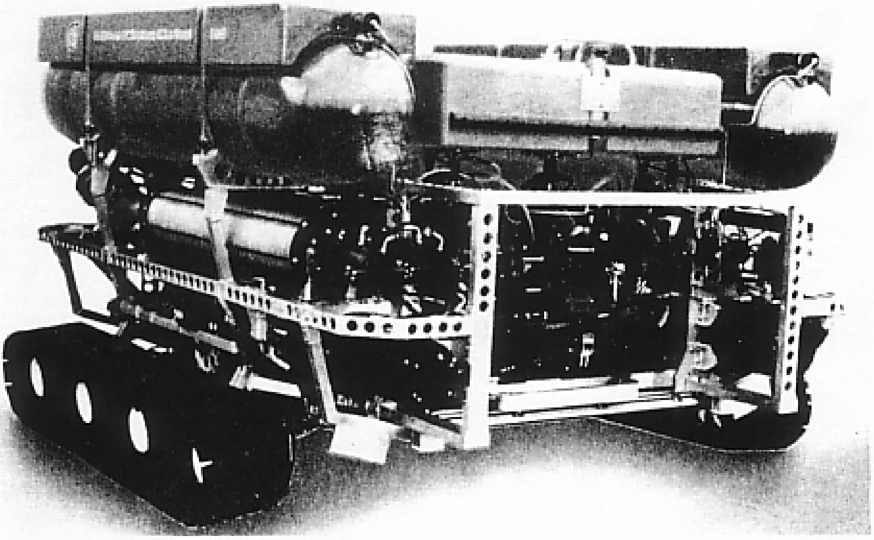


Figure 3.14 Slingsby Engineering, ROV 128 Cable Burial/Retrieval System

3.5.0

Class 5 Prototype or Development vehicles are not featured here as they are beyond the scope of his book. The reader is recommended to read 'Remotely Operated Vehicles of the World' (OPL) for a full listing and description of availlable ROV's.

CHAPTER 4 OFFSHORE STRUCTURES

4.0 Introduction

Offshore oil and gas are the most important natural resources to be discovered in Britain this century. They are a vital commodity providing energy and chemicals to industry and providing revenue to the exchequer. There has been an enormous financial incentive for the oil companies to venture offshore, accepting the high risks involved, in order to exploit these reserves. Since the first licences for North Sea exploration were issued in 1964 over 112 production platforms have been installed; which demonstrates the growth of the industry in this geographical region. World-wide there has been similar growth in regions which have similar deposits of oil and gas.

4.0.1 Exploitation of Reserves

In the search for oil the usual procedure follows a set pattern. Initial surveys are undertaken using seismic techniques which produce data for interpretation by expert geologists. When a likely area is pinpointed wildcat exploration rigs are dispatched to the area to test if there are any reserves by drilling deep into the sea bed. If oil or gas reserves are found further pre-production drilling is undertaken to determine the extent of the reserves and prove whether full production is viable. Once commercial viability is proven production facilities are designed and installed along with all the infrastructure that goes with offshore oil field development such as, for example, sub-sea pipelines, underwater manifold centres and offshore loading facilities.

4.1 Offshore Structures

Structures offshore come in a variety of shapes and sizes and in a variety of materials. Production platforms can be of steel construction or of concrete and some of the steel platforms float and are tethered in place by cables. There are underwater constructions such as wellheads, manifold centres, emergency shut down valve igloos and linear block manifolds. There are many hundreds of kilometres of sub-sea pipelines.

4.1.1 Steel Platforms

It should be remembered that offshore work is expensive and therefore production platforms are designed with a view to doing all the fabrication ashore and minimising the work involved in installation and repair and maintenance. In the main, production platforms are of steel construction and are designed to be easily installed and maintained. There are several variations of design for this type of installation but the majority are of the piled structural type. Some of the variations are; tensioned leg platforms (TLP), jack-up platforms and semi-submersible anchored production facilities.

4.1.1.1 Piled Steel Production Platforms

An example of this type of structure is the Brent A Platform in Shell Expro's Brent Field. Some facts about the platform are of interest.

a) Substructure

Water depth.	14m
Production capacity	100,00 b/d oil and 200mmscfd gas
Jacket type	Self floating steel construction
Number of legs	6
Number of piles	32 skirt piles
Weight of jacket	14,225 tonnes

Weight of piles	7,316 tonnes	

b) Superstructure

Height of deck above sea level		21.7m
Deck area		$2{,}300m^2$
Deck construction		Plate girder
Weights:	Deck	1,507 tonnes
	Facilities on deck	2,354 tonnes
	Modules and equip.	14,762 tonnes.

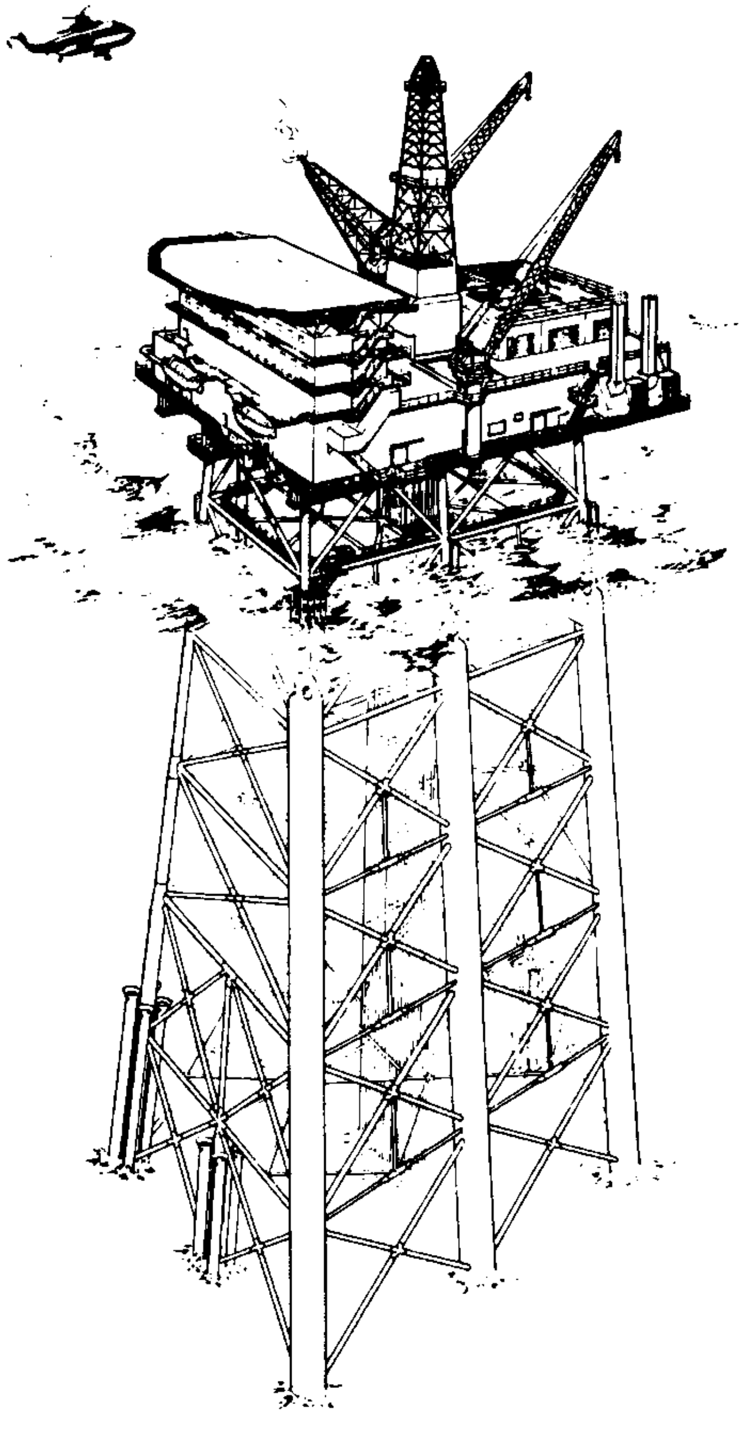


Figure 4.1
Brent A

4.1.2 Concrete Gravity Platforms

An example of this type of platform is Cormorant A in Shell Expro's Cormorant field. These structures are more massive than the steel platforms and are not piled into the sea bed. Hence the generic term " gravity" for this type of structure. Again some facts are of interest.

a) Substructure

Water depth	150m
Production capacity	60,000 b/d oil and 30 mmscfd gas
Storage capacity	1,000,000 bbls
Caisson shape	Square
Caisson height	57m
Number of legs	4
Weight in air	294,655 tonnes

b) Superstructure

Height of deck above water	23m
Area of deck	4,200m 2
Deck construction	Box girder
Weights: Deck	5,834 tonnes
Equipment within deck	3,593 tonnes
Modules and equip.	19,011 tonnes

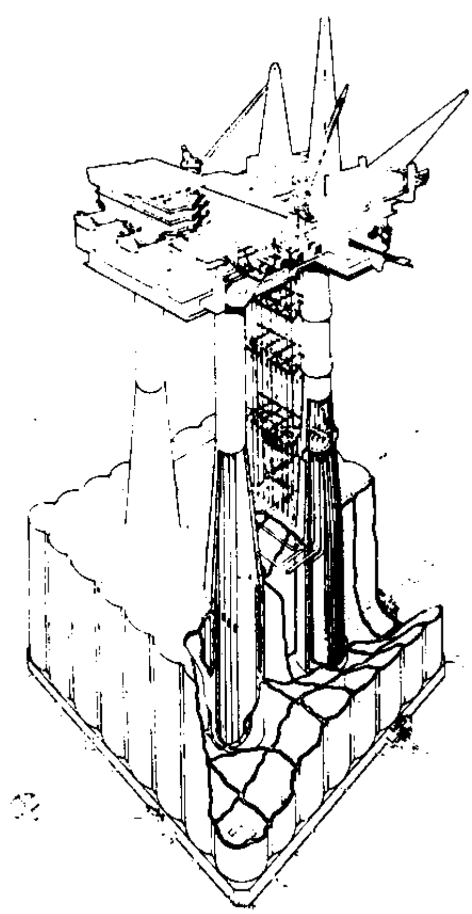


Figure 4.2
Cormorant A

4.1.3 Single Buoy Moorings

World-wide there are a number of different variations on this type of loading facility. An example of an offshore SBM which was initially used by Shell Expro in the Auk oil field was the ELSBM (Exposed Location Single Buoy Mooring) and when in use it was located approximately 1 nautical mile from the Auk A platform. It was kept in place by 8 anchors, each weighing 15 tonnes placed in a 3000 foot diameter circle. The anchor cable was 3" stud chain. The mooring hawsers and the hoses which carried the oil to the tankers were carried on large reels in the superstructure of the buoy.

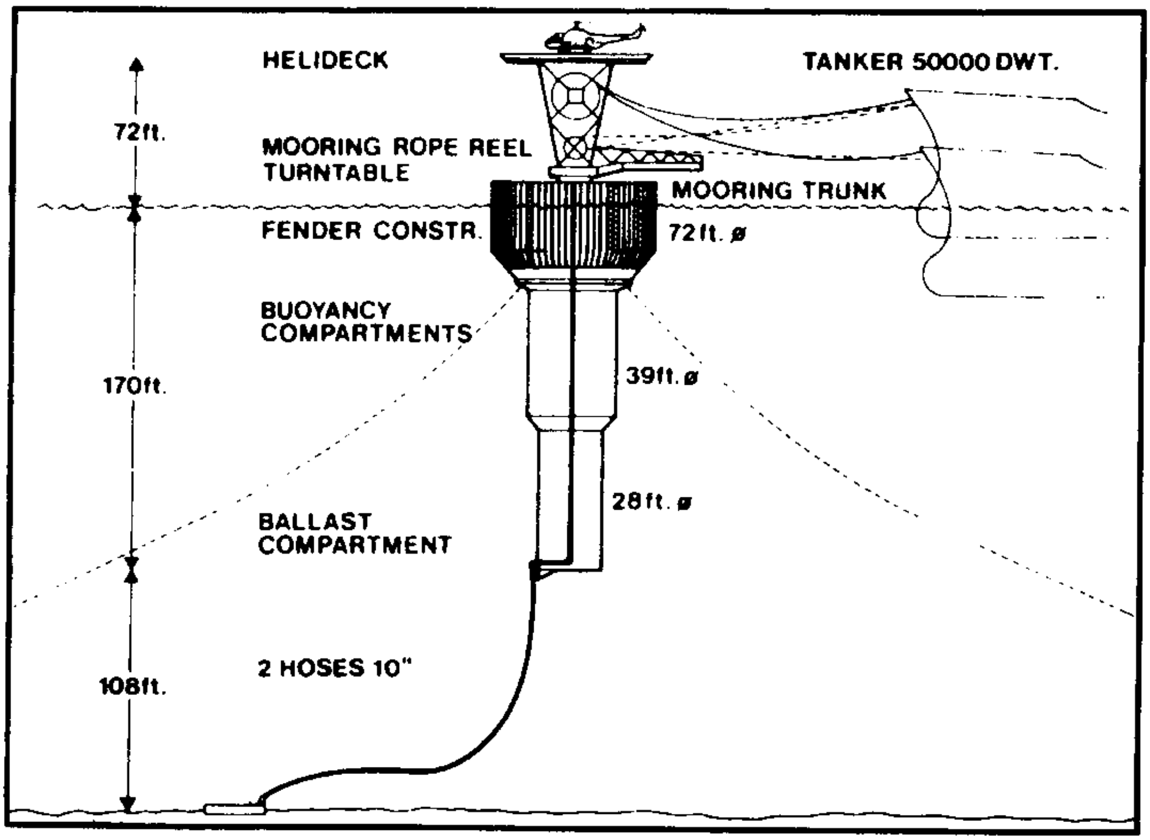


Figure 4.3
Auk Field ELSBM

4.1.4 Pipelines

There are thousands of kilometres of pipeline laid on the sea bed world-wide and although at first glance these structures appear to be simple they are in fact just as carefully designed as all other types of offshore structure as the diagram, fig 4.4, of a typical field joint indicates.

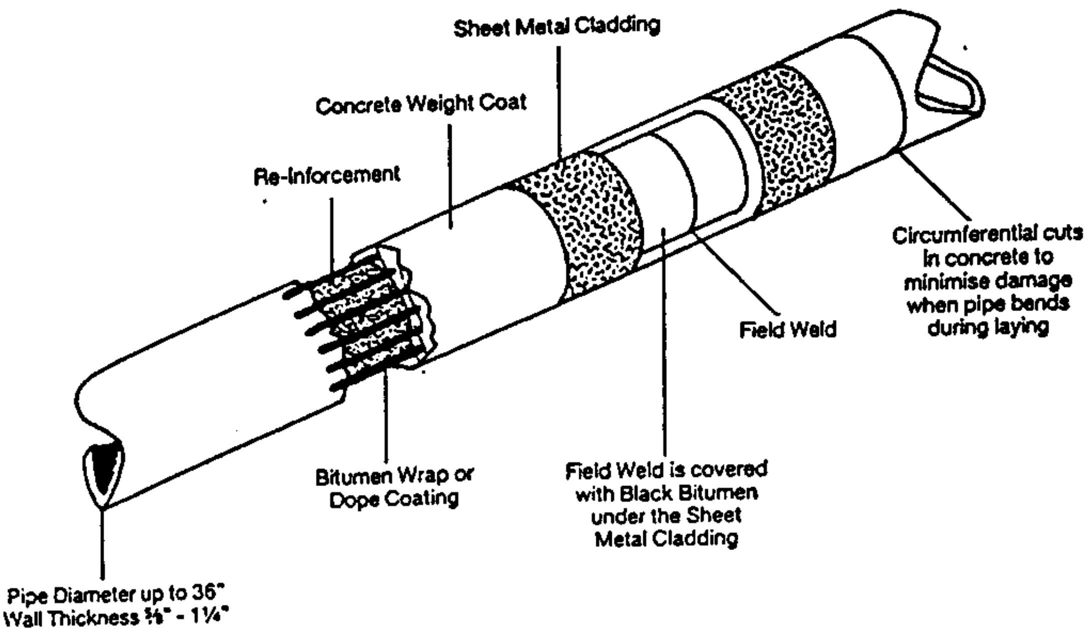


Fig 4.4
Typical Pipe Joint

4.1.4.1 Pipeline Construction

The typical construction of the pipeline is illustrated in figure 4.4.
It can be seen that the pipe is made up in sections that are welded together on the construction barge as the laydown process is under way. The steel sections are protected by a layer of reinforced concrete known as weight coat.

4.1.4.2 Field Joints and Anodes

The welded joint between sections are known as field joints. The field joint is wrapped in a layer of bitumen which is encased in a sheet of steel cladding, this in turn is secured by metal straps.
Corrosion is minimised by zinc anodes that are placed around the pipe at regular intervals. These anodes are typically known as bracelet anodes as they are in contact with the entire circumference of the pipeline.
Anodes that are completely wasted are sometimes replaced by anodes that lay alongside the pipe and are attached by a bonding strap, these are known as retrofit anodes and they behave in exactly the same way as a standard bracelet anode.

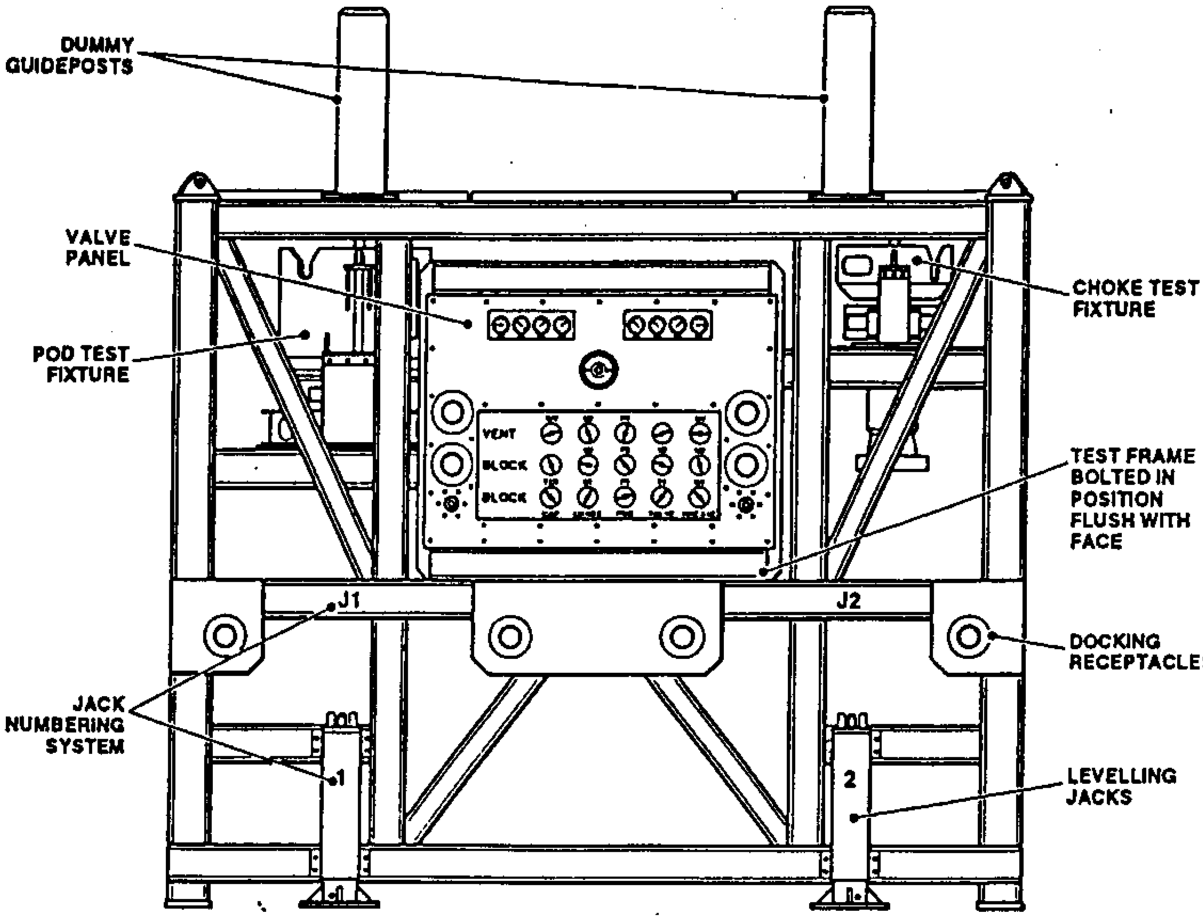


Fig 4.5
Subsea Intervention Frame

4.2 Subsea Structures

Figure 4.5 illustrates a typical subsea intervention frame that is deigned to be operated by ROV as oppose to divers.
The unit consists of two docking latches which enable the ROV to be 'locked ' in position whilst the operations are being carried out.
In practice the ROV is fitted with a dedicated tooling package that is equipped with all the necessary tools to carryout the following tasks:

a. Operation of needle valves during pressure testing

b. Operation of manual override valves when the remote valves are inoperable.

c. Hot Stab for pressure testing and greasing when the well head is operational.

4.2.1 Hot Stabs

Hot Stabs consist of probes that extend in to mating receptacles and provide a flow path for injected fluids.
On engagement of the docking latches by the ROV the Stab in probes can be engaged in to receivers. Once engaged the task can be carried out, these tasks may include the pumping of grease or water or monitoring of operating pressure.

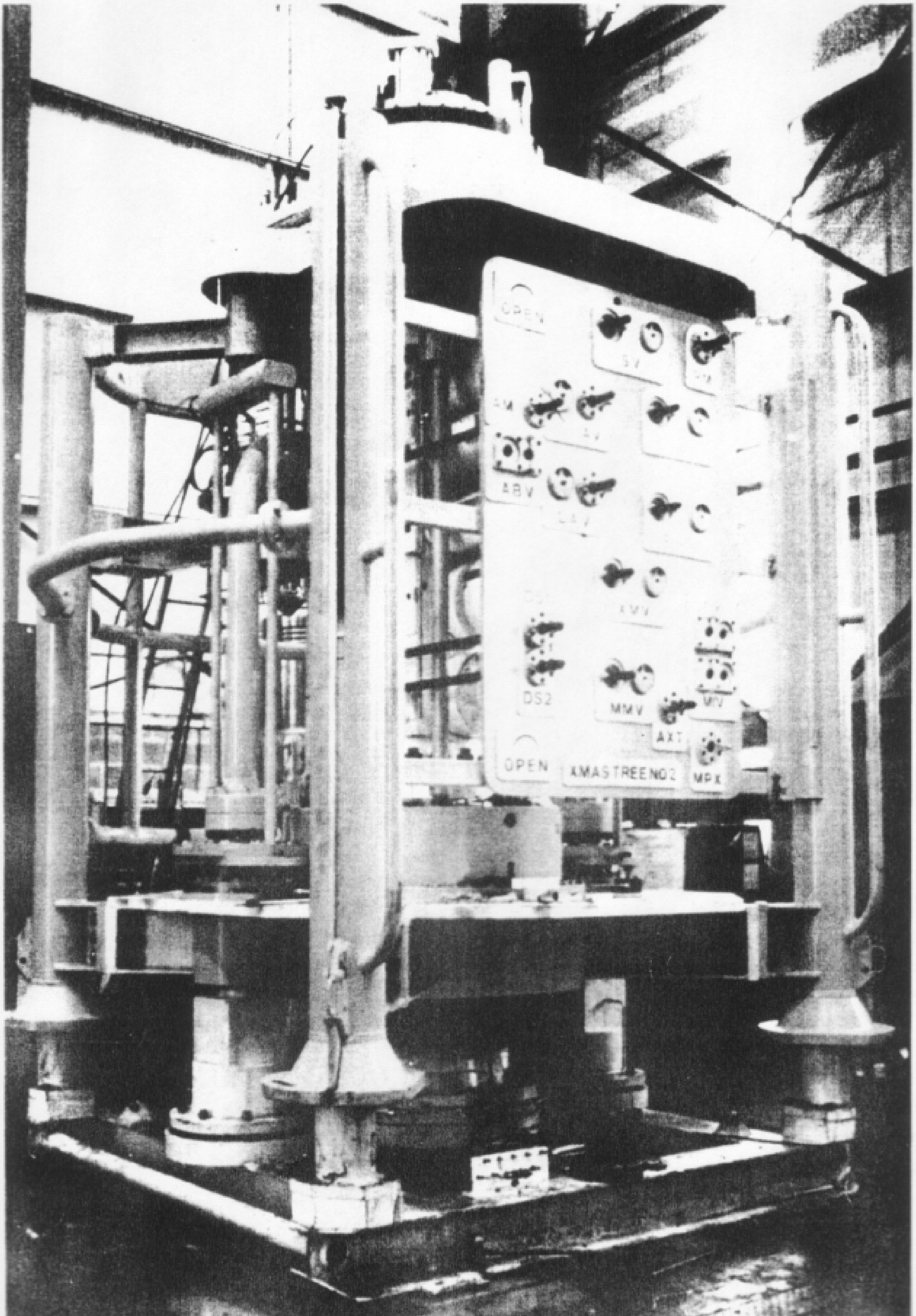


Figure 4.6
Typical Xmas Tree Intervention System

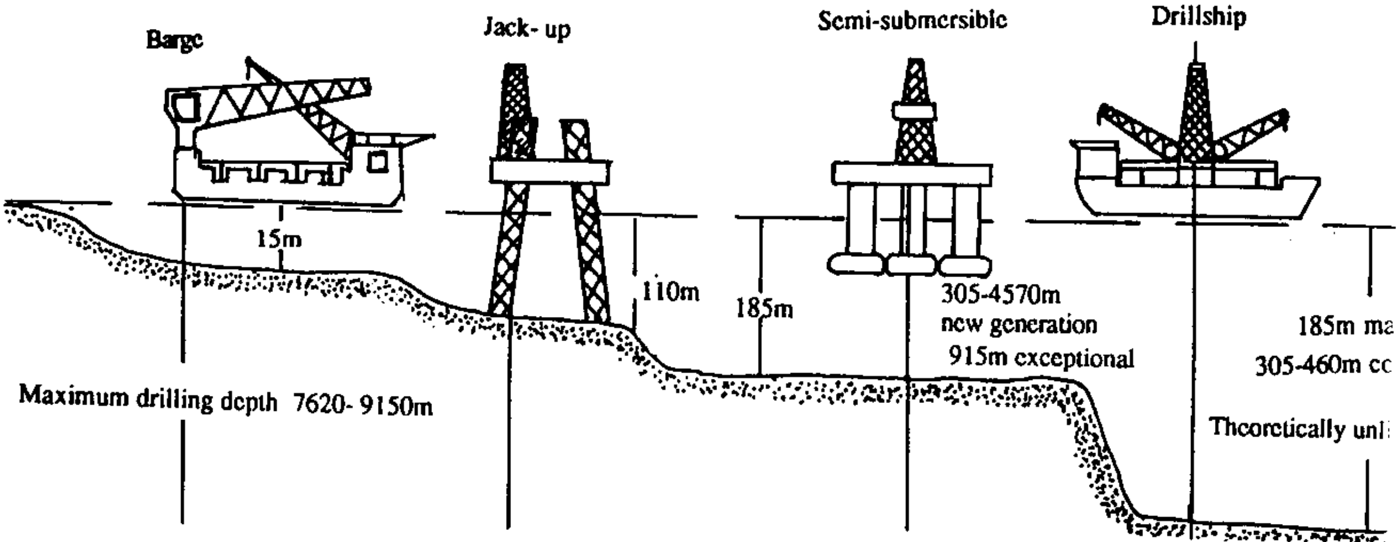


Figure 4.7
Operational Profile of drilling operations

4.3 Summary

The following is a summary of the typical offshore structures.

4.3.1 Barge

Typically used during installation of fixed platforms where heavy lifting is required. Barges may be anchored but are capable of moving under there own power.
There are two types of barge commonly available.They are Lay barges used during pipe laying operations and Derrick Barges used during platform construction.

4.3.2 Jack Up

A flexible and easily mobilised platform capable of working in depths up to approximately 110m. Normally this structure has three legs but a fourth leg is sometime used to fix on a pre-installed template in order to commence production.

4.3.3 Semi Submersible

Floating structures used in marginal fields in medium and deep water. They are anchored to the seabed but also have azimuth thrusters which provide limited manoeuvrability.

4.3.4 Drillships

Designed to produce an integrated production facility for deep water fields.
They may be used for test drilling prior to installing a fixed structure or they can be deployed over existing wellheads to assist in production, this will normally require the assistance of a shuttle tanker.

CHAPTER 5 ROV APPLICATIONS

5.0.1 Introduction

The last ten years have witnessed a slow demise in the offshore diving industry brought about, at least in part, because of the research and development put into making safer, more reliable, better tooled and cost effective Remote Operated Vehicles (ROVs). Currently ROVs are employed on many sub-sea tasks which were formally undertaken by divers, such as general platform inspections and sea bed scour surveys. Reducing human intervention on many underwater tasks also reduces risk of injury or worse to personnel this is a further compelling reason for reducing the number of divers offshore and countries such as Norway have a government policy to legislate against all diving on new projects without dispensation. It is the intention of this chapter to discuss the most common tasks carried out by ROV's these include:-

Pipeline Inspection

Drill Support

Platform Inspection

Intervention

Cable Laying

Construction

ROTV

Mine Counter Measures

Anti-terrorism/Drug enforcement

5.1.0 Pipeline Inspection

The annual inspection of pipelines in the North Sea forms the bulk of ROV operations during the summer months. Currently ROVs operate for periods of up to 70 hours virtually non-stop and the latest acoustic technology records details of the pipeline's integrity with great accuracy. These factors, along with improvements in sub sea video cameras mean that ROVs are the prime pipeline survey method.

5.1.1 Normal Vehicle Fitment

A standard 'Work class' ROV will normally have the following equipment and sensors:

Thrusters

Front and Back SIT Cameras

Lights

Ranging Sonar

Manipulator

Pan and Tilt Mechanism

Emergency Acoustic Transponder

Emergency High Intensity Flashing Light

Gyro Compass

Power, Control, Instrumentation

Hydraulic Power Pack

Vehicle Depth Sensors

Vehicle Altimeter

5.1.2 Additional Fitment Specific to Pipeline Survey

In addition to the above a 'survey package' will be fitted specifically to enable the vehicle to meet the specification requirements of a Pipeline survey contract. This package will usually include:

Twin booms with full colour video and additional lighting

Still camera

Possibly stereo/photogrammetic camera

Strobe lights for still cameras

Side scan Sonar

Pipetracker

Sub Bottom Profiler

Current Density Meter/Contact CP Probe

Temperature and Salinity Sensors

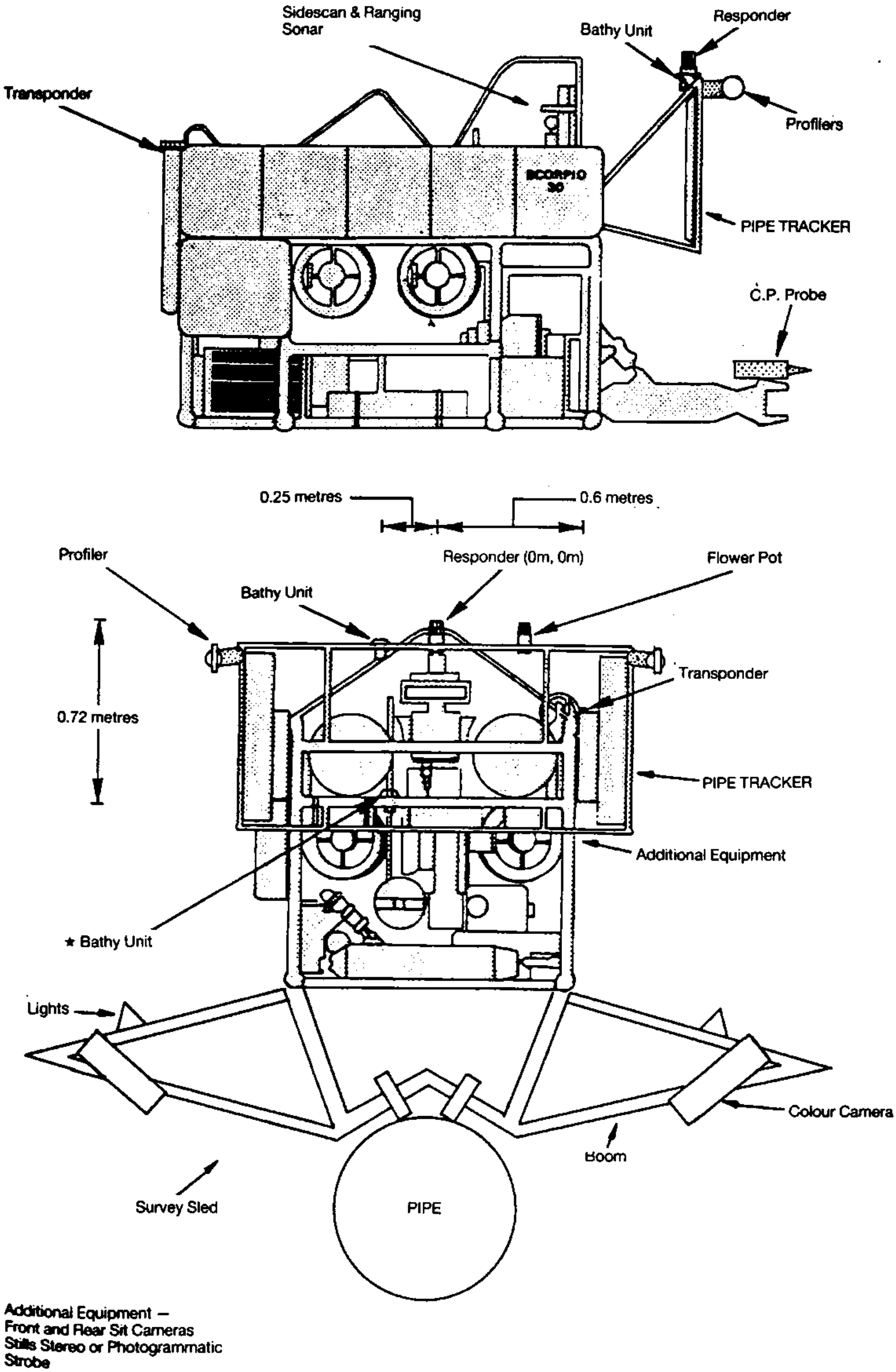
Acoustic Responder

Odometer

This survey equipment is explained in the following paragraphs.

5.2.1 Twin Booms

Prior to undertaking pipeline survey work an ROV will be fitted with twin booms, these are fitted to each side of the vehicle. These booms are deployed and adjusted, usually hydraulically, once the vehicle is at the worksite and on the pipeline. Colour video cameras and the associated lights will be attached to each boom. These can be individually positioned to achieve the best view of each side of the pipe. The type and model of video camera will vary and these are described in Chapter 15 Underwater Video. The lights will be of variable intensity. The maximum power will depend on a number of factors which are outlined in Chapter 15 also. As a guide, however, at least 1000 Watts of power output will normally be required to obtain the correct lighting from a distance of 1 meter from the pipe.



Sidescan & Ranging
Sonar
Bathy Unit
Responder
Transponder
Profilers
SCORPIO
30
PIPE TRACKER
C.P. Probe
0.25 metres
0.6 metres
Profiler
Responder (0m, 0m)
Flower Pot
Bathy Unit
Transponder
0.72 metres
PIPE TRACKER
Additional Equipment
★ Bathy Unit
Lights
Colour Camera
Boom
Survey Sled
PIPE
Additional Equipment —
Front and Rear Sit Cameras
Stills Stereo or Photogrammatic
Strobe

Figure 5.1

D.H.S.S. PROFILER

DIVE	001	**START ANGLE**	035 DEG
DATE	1-1-92	**STOP ANGLE**	145 DEG
TIME	59-59-23	**STEP SIZE**	1.8 DEG
SOUND VELOCITY	1430 M/S	**AUTOMATIC**	00 SEC
HORIZ SEP	1.2M	**PORT HEAD**	ON
VERT SEP	.05M	**STBD HEAD**	ON
STBD HEAD	HIGHER	**LOGGING**	OFF

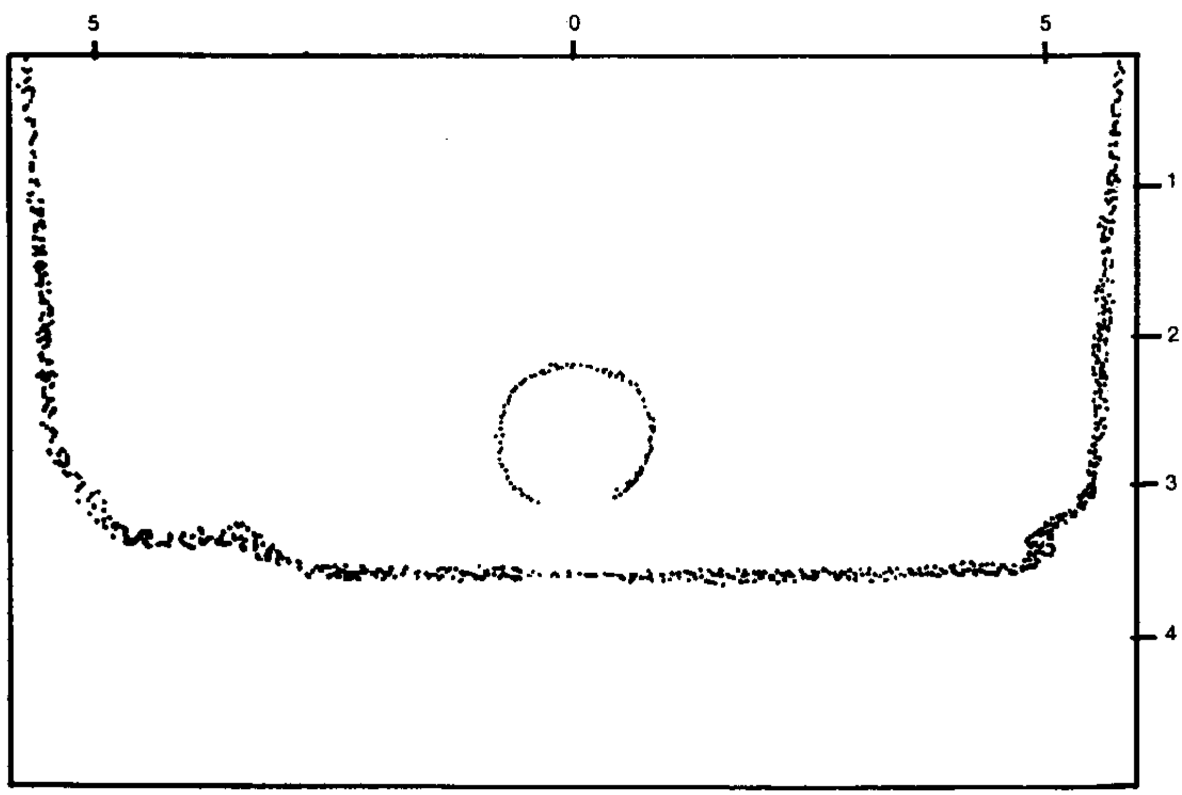


Figure 5.2

Figure 5.1 illustrates the various survey kit attached to an ROV during a typical pipeline survey.

5.2.2 Stills Camera

The stills camera will usually be fitted to the pan and tilt mechanism, and may be either a mono, stereo or photogrammetic type. These cameras are explained in the Chapter 16 Underwater Photography. With the stills camera attached to the pan and tilt mechanism photographs can be taken from various angles as the ROV is manoeuvred along and around the pipe and an indication of the field of view will be obtained from the video camera on the same mechanism.

5.2.3 Side Scan Sonar

Side scan sonar is a particular type of sonar that transmits in a sideways direction enabling a plan of the sea bed topography to be plotted as the ROV travels along the pipe. This enables the position of topographical features and debris such as boulders or trawler gear to be recorded relative to the pipe.

5.2.4 Pipetracker

Pipetrackers usually operate on the principles of magnetism, hence, they are usually known as 'magnetic pipetrackers'. An example of this is the TSS 340 which is in common use offshore These are fitted to ROVs to locate and track ferromagnetic pipe and cables. They use a passive sensing technique to give the operator a relative position of the pipe or cable. Some models have a 'SEARCH' and 'SIGNATURE ANALYSIS' mode which allows any field anomaly to be pinpointed, and a full signature analysis made if required. Pipetrackers have a particularly useful role in tracking pipe that is buried and therefore cannot be followed visually and versions are in use to follow and locate faults in buried telecommunications cable.

5.2.5 Sub Bottom Profiler and Trenching Profiler (DHSS Profiler)

The Dual Headed Scanning Sonar (DHSS) Profiler is an acoustic device that enables a profile of the sea bed to be obtained. It accomplishes this by stepping two transducers (one positioned on each side of the vehicle) from the outward horizontal to the vertical downwards position. The distances from each head to the sea bed or other feature is recorded as a sonar return. The DHSS Profiler is essential for determining the 'Depth of Burial' of a pipeline, the depth of a trench or the length of a 'Free-span'. A 'free-span' is an unsupported length of pipeline which may be critical if there is any possibility of movement of the pipe. Figure 5.2 illustrates a cross sectional view of pipe and sea bed recorded from a profiler system. Modern profiling sonar can be used for both sub bottom and trenching applications and are available in both single headed and dual headed models.

5.2.6 Current Density Meter/Contact CP Probe

A Current Density Meter and Contact CP (Cathodic Potential) Probe are usually attached to the manipulator for use on exposed areas of pipeline or anodes. The principles of operation of these is that they monitor the potential to corrode of any exposed metal on the pipeline and the effectiveness of anodes. The Current Density Meter measures the Current Density which indicates the CP cover and the Contact CP Probe measures the potential of the exposed metal with reference to the silver/silver chloride half cell in mV and is expected to be within the following ranges:

Unprotected iron and steel	-500 to -650 mV
Cathodically protected iron and steel	-800 to -900 mV

Zinc (Anodes) -1000 to -1050 mV

The contact CP probe is used because it is inconvenient to maintain an earth connection with the pipe on a moving vessel as is required with the Proximity probe which is normally used for platform inspections.

The above information is to enable the Pilot to have a basic understanding but full information including calibration methods is included in the CSWIP 3.3u ROV inspectors course and handbook.

5.2.7 Temp and Salinity Sensors

These measure the temperature and salinity of the water during operations. Often these are combined with an accurate depth transducer to form a Bathymetric system.

5.2.8 Acoustic Responder/Transponder/Pinger

An acoustic device will be attached to the top of the vehicle. There are three generic types:-

Pinger - This repeatedly emits short pulses of acoustic energy at a set frequency. This can be continuous throughout the dive or can be initiated in the event of a power failure to the vehicle to enable the crew to locate it and effect an emergency recovery.

Transponder - This emits short pulses in response to interrogation from the vessel or other transponders. Each transponder will have its own code and many transponders can operate together each responding to its own code received acoustically and being displayed by individual symbols on the surface display of the Hydro-acoustic Positioning Reference (HPR) System.

Responder - This is similar to the Transponder except that it responds to an electronic signal sent through the umbilical. This is more accurate than the transponder because there is only a one way propagation of acoustic energy through the water. Calculation of through water range and bearings is subject to errors due to variations in sound velocities due to variations in the waters density, temperature and other bathymetric conditions.

These devices will allow the surface vessel to track the vehicle and record the position of the ROV relative to the vessel as the survey progresses.

5.2.9 Odometer

The Odometer is a device much like the wheeled devices that Surveyors push around to measure distances. For ROV applications these are typically used to measure the distance of an area of damage from the nearest Field joint and to measure the depth and extent of the damage itself. Potentiometers produce signals transmitted through the umbilical to the surface to indicate the number of turns of the wheel and its displacement.

5.3.0 Additional Instrumentation Required for Pipeline Survey.

In addition to the equipment fitted to the vehicle it is necessary for navigation and control purposes to have additional systems other than those already outlined above.

5.3.1 Surface Navigation System

The surface vessel will constantly track its position with the aid of radio beacons or satellite navigation systems. Examples of radio systems are; Decca, Sylledis, and Pulse 8. These require land or platform based transmitters to accurately (Usually well within 1 meter) position the ship usually in terms of 'Northings' and 'Eastings'. It is becoming more common recently to position the surface vessel with GPS (Global Positioning System) Satellites. These are updating quicker and becoming more accurate. Depending on the Global area the surface vessel is in, the particular system in use and the number of satellites in use the accuracy can be between +/- 50m at worse +/- 10m as the norm and +/- 2m at best.

5.3.2 Telemetry System

This system enables control, instrumentation, sensor, and possible video signals to be communicated between the surface vessel and the vehicle. Either electrical conductors or optical fibres are used to carry the signals in digital form. Fibre Optic telemetry has the following advantages over conventional 'Hard Wired' telemetry:-

a) A higher update (Baud) rate

b) No electrical interference

c) Negligible signal loss through the length of the umbilical

Fibre optics have the disadvantage that the fibres may part and may consequently be more difficult to join or re-terminate in the field. The part of the telemetry system that switches the information onto the line in sequence is known as the multiplexer. It is preferable to use a fibre optic telemetry system for pipeline survey work due particularly to the very large volume of data that is required to be transmitted to the surface and the enhanced video quality that is possible.

5.4.0 Drill Support

This section outlines the various stages of the drilling programme and indicates the areas where the vehicle can provide valuable assistance. Before the programme commences the operations controller should advise the drilling supervisor of the capabilities of the vehicle and where it can assist the drilling operation. There is a tendency to under estimate the assistance that an ROV can provide to a drilling operation. For this reason an overview of the tasks has been given, these will be explained later in the chapter.

5.4.1 Overview Tasks

General tasks to assist with the overall operation will include:

a) Survey site and sea bed prior to spudding-in.

b) Acoustic beacon placement and recovery.

c) Guidance of packages and tools.

d) Observation and guidance during critical drilling sequences.

e) A-X ring replacement.

f) Emergency BOP or package release.

g) Debris removal.

h) Recovery of dropped objects.

i) Setting Wellhead charges.

j) Guide wire cutting and replacement.

k) Setting guidepost cutting shaped change.

5.4.2 Drilling Programme

The following section outlines a typical drilling programme. At each stage of the drilling operation a brief description of the vehicles assistance is given.

Drilling Programme	**Vehicle Programme**
1) Rig on site	Survey site and sea bed prior to 'spudding-in'.
2) Drilling to set 30" casing	Place marker buoys to assist in well relocation.
3) 30" casing stab-in	Observe relative position of casing to hole. Advise required direction to move. Use sonar to provide distance of casing to marker buoy and advise when ready to stab-in.
4) 30" casing cementing	Monitor cement operation and check bulls eye on guide base.
5) Drilling to set 18 5/8" casing	Observe entry to guide base and assist by pushing if required.
6) 18 5/8" casing entry	Observe entry to guide base and assist by pushing if required. Observe BOP latching operation. Check bulls eye and ball joint inclinometer on stack. Carry out full inspection of stack, lower marine riser package and riser/conductor.
7) Drilling to set 13 3/8" 9 5/8" 7" conductors	At this point in the programme the vehicle changes from an active to passive role. It is recommended that regular checks on the stack are carried out and the distance and direction of the beacon to the stack cross-checked by sonar. Other task requirements will depend largely on the problems encountered during the drilling programme and could vary from locating and recovering dropped objects to

emergency release of the stack in the event of total system failure.

The programme outline may vary depending on the type of well, or rig and the depth being drilled. A copy of the actual well programme will be available in the drill supervisors office.

5.4.3. Liaison with Drilling Staff

It is preferable that before mobilisation the drilling supervisor(s) and sub-sea engineer(s) are contacted. Not only to outline the assistance the vehicle can provide but also to verify the equipment installation, the type of stack in use etc. A great deal of time can be saved at this stage and possible problem areas ironed out. Also, it is worthwhile presenting optional equipment such as the emergency stack release panel and A-X ring replacement system so that fitting requirements, configuration and positioning can all be verified in advance. A very useful preparation is to paint tools and equipment that are to be used underwater with white markings to enable them to be more easily seen by the vehicles video cameras.

5.5.0 Blow Out Preventer (BOP)

This is a safety device installed at the top of the well that can typically be 10 metres in height and weigh around 150 Tonnes.

5.5.1 Functions of BOP

Should a drill string reach an area of pressure that is higher than the hydraulic head of pressure exerted by the drill mud then a blow out or 'kick' will occur. This results in an uncontrolled blow out of mud followed by oil or gas. The BOP allows the well to be shut off whilst heavier mud is pumped down thereby bringing the well under control.

5.5.2 Operation of the BOP

The BOP contains one or more pairs of rams made of steel or tough rubber. Should a blow out occur then the rams are hydraulically closed. There are two kinds of rams Pipe (choke) and shear (kill). The kill rams cut through the drill pipe and seal off the well. Choke rams close and seal around the drill pipe. Both rams are held in place, once activated, by hydraulic pressure. Once this task has been completed heavier mud is pumped down the flow and choke lines to the drill string below the rams whilst the drilling operations and BOP are shut down until the pressure due to the head of mud is greater than the pressure from the gas or oil in the formation thereby stabilising the situation

5.5.3 Tasks on a Blow Out Preventer

a) Check kill line connector

b) Inspect slip joint, flex joint and hoses

c) Guide line replacements

d) Align riser into BOP

e) Check connection of production control systems

f) Manually over-riding hydraulic connector for lifting BOP

g) Changing gasket between BOP and connector housing

h) Guiding BOP into place in wellhead

i) Deployment and replacement of transponders

5.6.0 Detailed Tasks During Drilling Operations

The following are a possible set of detailed procedures for the various tasks the vehicle may be required to carry out during the drilling operations outlined above. Drilling support Task Procedures are described in detail here because they do not appear in any of our other Handbooks, whereas, only an overview of inspection Tasks is included as they are included in detail in the CSWIP 3.3u ROV Inspectors Handbook

5.6.1 Sea bed Survey

a) Locate the centre of the area to be surveyed. This is normally done using a mini beacon and the rig/ship Hydro-acoustic Positioning Reference System (HPR).

b) Carry out a 360^{o} sonar search and enter the relative position of any targets on the log sheet (see Fig. 5.3).

c) Locate and identify any significant targets. Note the dimensions and composition.

d) Pass the information to the drilling supervisor. (see chart Fig. 5.3)

5.6.2 Place Marker Buoys

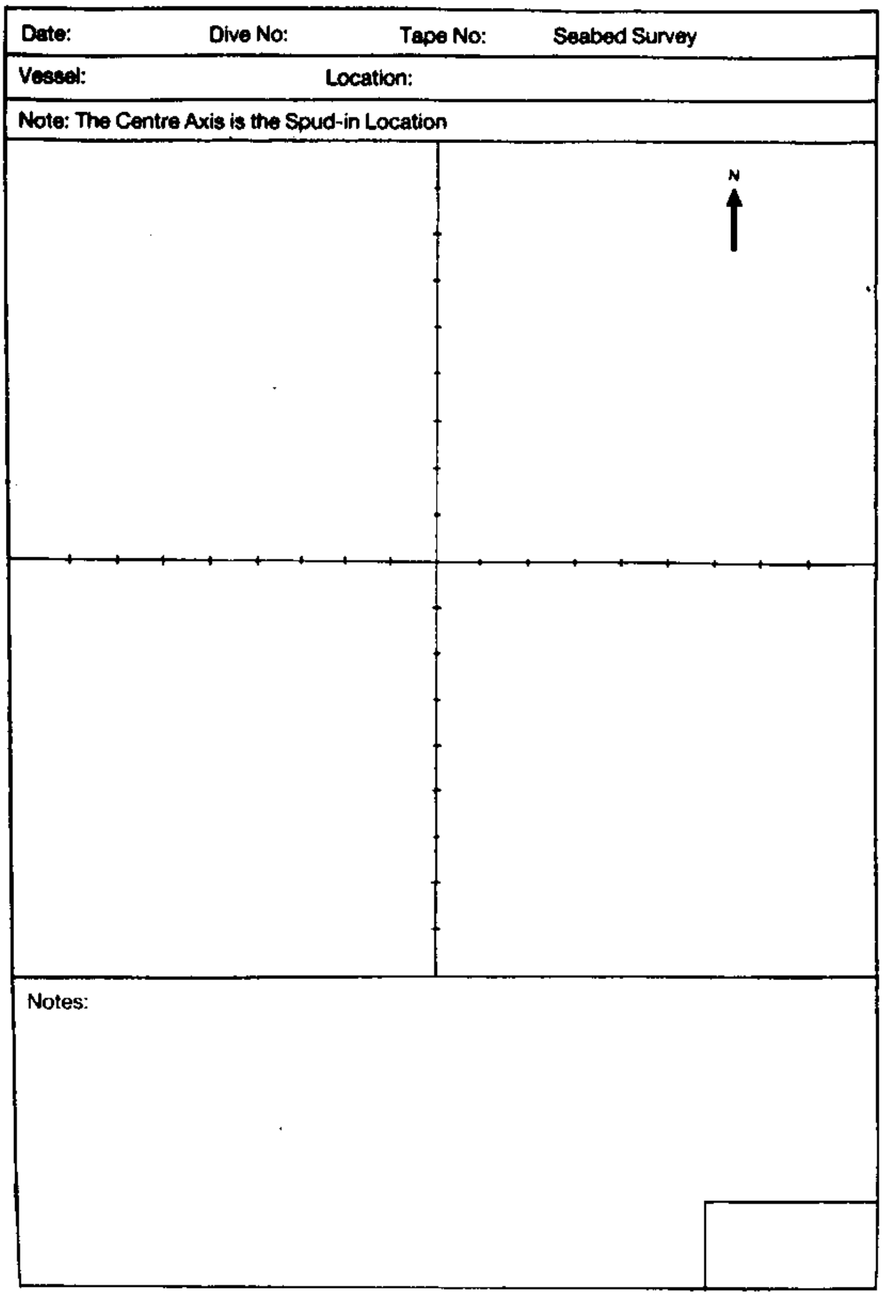
The reason for placing these buoys is to allow easy re-location of the hole after the 36" bit is withdrawn and consequently reduce time required for the 30" casing stab-in.

a) Make up two markers. These should be single and double white painted Grimsby floats attached to suitable weights by approximately 5 ft of line. (one 200 mm dia... metal Grimsby float gives about 4 kg uplift).

b) Prior to the field string being recovered launch the vehicle and place the marker buoys using sonar at the positions indicated. See Figure 5.4

NOTE: The double buoy should be placed due North of the string and the single buoy due South for ease of orientation.

c) Ensure a video hook up with the bridge and the drill floor is functioning. Recover the vehicle.


Date: Dive No: Tape No: Seabed Survey

Vessel: Location:

Note: The Centre Axis is the Spud-in Location

Notes:

Figure 5.3

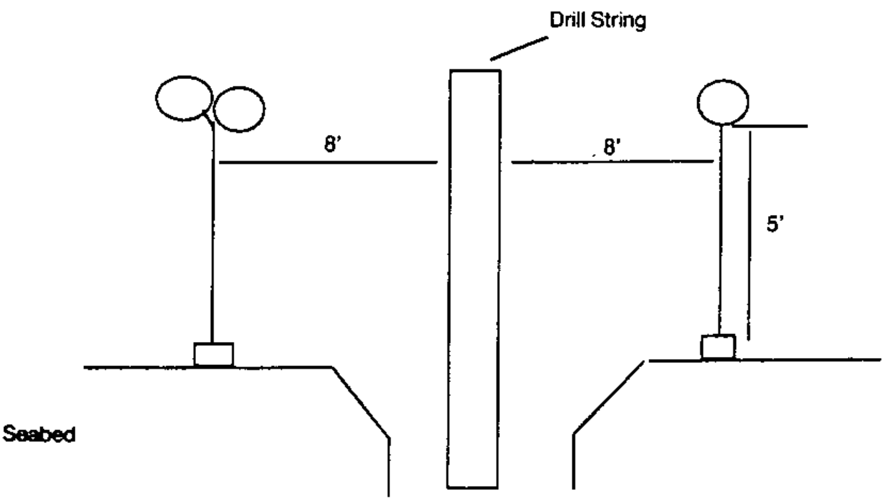


Figure 5.4

5.6.3 30" Casing Stab-in

1) When the 30" casing is 2 to 3 joints from the sea bed launch the vehicle.

2) Descend on the casing and when at the base carry out a sonar scan for the Grimsby floats.

3) Pass the relevant directions to the bridge.

NOTE: It is better to agree beforehand on the procedure here and it is suggested that "go to" directions are given. i.e. move the casing 30 feet on a heading of 270^{o}.

4) Once visual contact is established with both the buoys and the base of the casing in view the vehicle should remain on a constant heading either to the North or South of the casing. This will enable the bridge to work from a known orientation and make the final adjustments necessary to bring the casing between the 2 buoys.

5) When the casing is between the buoys the vehicle should close up on one set of buoys and indicate the North or South movement required to centralise the casing. It should be noted that while not usually obvious the hole diameter at the sea bed is approximately 6 ft and providing the order to stab-in is given when the casing is above the hole it will gravitate into the hole (a hundred feet of penetration is possible without there being a hole). It is possible for the vehicle to push the casing over the hole and this is often easier than moving the whole rig by adjusting anchor tensions. In order to accomplish this the vehicle should have a locating frame attached and the casing should be marked with white rings to allow the carefully positioned cameras to observe the penetration.

6) While the casing is being fed in the vehicle can standby on the sea bed until the guide base is in position (normally 5 ft above the sea bed). The base should be checked to ensure it is level and, if required, the bull's eye can be recovered.

NOTES: To allow removal of the unit on one occasion .an old A-X ring was welded to a guide base and the bull's eye fitted to this

7) After checking the guide base monitor the string to casing unlatching operation and recover the vehicle.

5.6.4 30" Casing Cementing

1) Liaise with the drill supervisor to determine the launch time.

2) The vehicle should descend on the riser and take up a position up current of the guide base to prevent the obscuring of the visibility.

3) Check the cement is over spilling around the guide base. Usually the excess volume allowed is 100 - 150%.

NOTE: It is quite difficult, especially where only monochrome video is used, to differentiate between mud, in fill and cement however with practise it is possible.

4) When the supervisor is satisfied with the cementing operation recover the vehicle.

5.6.5 Drilling to set the 18 5/8" Casing

1) When the 30" casing has been cemented the bit will be lowered to drill for the 18 5/8" casing, 3-4 joints off the guide base launch the vehicle.

2) Monitor the position of the string to guide base and direct as necessary.

3) Assist by pushing the string into the guide base if required.

NOTE: The deeper the sea water depth the easier it is for the vehicle to push the string into position, but the Pilot should be wary during strong currents.

4) When the string is in position recover the vehicle.

5.6.6 18 5/8" Casing Entry

The procedure here is similar to that outlined for the 30" casing stab-in.

1) When the casing is within 3 joints of the guide base launch the vehicle.

2) Assist in guiding the casing to the guide base, by pushing if required. The casing is fed in until it is approximately 4 feet above the bottom of the permanent guide base. Monitor the string being detached from the casing (a left hand thread connects the two).

3) It is normal to fit the stack at this stage. Check with the supervisor on the time span and based on this it may be worthwhile keeping the vehicle on standby on the sea bed.

4) Monitor the stack latching operation. Depending on how modern the rig is this will be an 18 3/4" 10,000 psi unit or 20 3/4" 2000 psi stack. In the latter case a 30 5/8" 10,000 psi unit is fitted at a later stage.

5) Verify the degree of tilt on the bulls eyes.

6) Check the angleometer(s) on the ball joint (where the lower marine riser package joins the BOP).

7) Carry out a full inspection of the stack. Ensure sonar reflector and beacon arms are in the correct position and that no oil leaks or damage is apparent.

8) Ascend on the riser/conductor and inspect this and hose lines for damage and security of attachment.

5.7.0 Possible Tasks Requirements

The following tasks occur haphazardly during the course of drilling operations and may be carried out only infrequently.

5.7.1 A-X/V-X Ring Replacement (Hydraulically operated units only)

The metal gasket which seals between the guide base and the BOP is usually called the V-X ring and the gasket that seals between the BOP and the Lower Marine Riser Package is usually known as the A-X ring. If these fail two choices are open to the supervisor: round trip the stack and effect the change out on surface or lift the stack clear, eject the A-X ring and have the vehicle place a new ring in the guide base. The method chosen will largely depend on the depth of sea water and consequently the round trip time for the stack. However the recommended procedure for a vehicle change out is listed below.

1) Fit the A-X ring carrying frame in accordance with the instruction supplied.

2) Check out the system, fit the A-X ring in position and launch the vehicle.

3) Descend on the riser and move into the position over the guide base/BOP.

4) Exact positioning of the ring in the guide base is critical so ensure that the self centring frame is level prior to ejecting the ring. When satisfied that the positioning of the vehicle is correct operate the vertical thruster pot to give 60% of down thrust and actuate the A-X ring tool.

5) Ascend clear of the guide base and video the unit in position.

6) Monitor the stack replacement and standby while it is latched.

7) Liaise with the drilling supervisor and recover the vehicle when appropriate.

5.7.2 Emergency BOP or Package Release

This task will only be required if the stack or marine riser package cannot be conventionally released i.e. if the primary and secondary hydraulic systems fail. However, it only needs one such failure with worsening weather conditions to validate the need to have a separate back-up system, which can be independently operated. The emergency stack release and lower package release panels must be pre-mounted on the stack and plumbed into the existing system. The following procedure could be used when this task is undertaken.

1) Fit the emergency stack release panel tool to the manipulator.

2) Fit the rig supplied "hot line" to the quick connect and fit this to the tool. Allow a reasonable amount of slack to allow for the manipulator rotation before taping the hose to the vehicle. (NB ensure the tape can be broken after hose is connected to panel).

3) Launch the vehicle and descend on the riser. Once at the stack go to the appropriate panel and turn off the valve

4) Insert the quick connect into the guide cone and ensure a positive lock before releasing the hose.

5) Once the hose is connected advise the drilling supervisor, break free of the tape holding the hose to the vehicle frame and standby to monitor the unlatching.

6) When he stack is unlatched recover the vehicle.

5.7.3 Debris Removal

Small items of debris or transponders may be removed by the vehicle without assistance simply by taking hold of it with the manipulator however, where large, heavy objects such as dropped lengths of drill string require moving assistance from the drill floor will be required.

5.7.4 Recovery of Large Dropped Objects

This task may crop up from time to time and the item can vary from a drill string to a complete stack. As the vehicle's lift capability using the manipulator is in the order of 90 kg it will often be necessary to attack hooks or slings. This is a common-sense task and the following guidelines are presented as a guide only.

1) Liaise with the necessary personnel to determine the exact shape of the object(s), its approximate weight and suitable lift attachment points.

2) Based on the information supplied decide on the method of recovery, i.e. slings, single hook, net, multiple hooks or string deployed retrieval tool.

3) While the slings, wire ropes, hooks or string deployed retrieval tools are being fashioned and lowered launch the vehicle and locate the object. Mark the position relative to the well head and standby for tools to be lowered.

4) Attach the recovery tool and ensure the object is lifted clear of the sea bed before recovering the vehicle.

NOTE: It is good practise to ensure that the vehicle always remains above the object being lifted in case the lifting device should disengage and the object fall onto the vehicle, the speed of lift should be varied if difficulty in achieving this is experienced. Clear this point with the rigger/charge hand prior to the lift commencing.

5.7.4 Setting Wellhead Charges

This will normally be carried out from a ship after the well has been plugged and abandoned and the rig has moved location. The primary task of the team would be to locate and mark the Wellhead then follow the explosive experts direction for placing the charge. It is recommended that the ROV Supervisor is aware of all the necessary precautions for handling explosives and that the explosives expert gives a safety talk to the team prior to mobilisation. This talk should cover the method and procedures for placing and detonating the charge.

5.7.5 Guide Wire Cutting/Replacement

Where a guide wire system is used the vehicle may be required to cut and replace a wire. It should be noted that the standard rig equipment can normally carry out this task without assistance by using the remaining 3 wires. However, where equipment failure or other circumstances necessitates the use of the vehicle possible guidelines for this task are listed below.

1) Launch the vehicle and descend to the guide base.

2) Cut any remaining wire protruding from the post. This should be cut as close as possible to the post and the stub fed inside the post.

3) Place latch release tool over existing latch and lift unit clear.

4) Locate the new wire and grip immediately above the latch, the closer the better.

5) Manoeuvre the vehicle into position above the post and place the cone of the latch over the post.

6) Release the wire, maintain position, raise the manipulator and bring it down quickly and sharply onto the latch. This is necessary to force back the spring loaded clip which holds the latch to the guide post.

7) When satisfied the latch is in position and connected to the guide post check this by tugging on the guide wire.

8) Monitor the latch while tension is applied from the surface and when this has been completed, recover the vehicle.

5.7.6 Setting Guide Post Cutting Charge

This may be necessary if a post has been badly bent and does not allow re-installation of the stack. As no shaped charges are carried the first action will be to contact the base and arrange for the charge(s) and an explosives expert to be sent. Check with the drilling supervisor that the lead times quoted by base are acceptable. On receipt of the charge(s) the action to be taken is as follows:

1) Discuss with the explosives expert the procedure to be followed for placing the charge. Use video previously taken to highlight any significant areas of damage to enable him to decide the best position for the charge.

2) When the procedure is settled satisfactorily ensure each man is aware of his role and launch the vehicle.

3) Locate the bent post and place the charge. Video the placement and have the explosives expert verify it is correctly positioned.

4) Recover the vehicle and detonate the charge.

5.7.7 Drilling Support (General)

The above section is by no means exhaustive and will not be relevant to every situation. It is true, however, that ROVs are the normal method of providing underwater support for drilling operations. It is good practice for at least one member of the ROV crew (usually the Supervisor) to remain on the drilling rig for a number of wells to allow him to become familiar with particular methods, as practised, in what is, undoubtedly, a specialised area of ROV operations.

5.8 Platform Inspection

Legislation requires all offshore structures have a valid certification of fitness renewed once every 5 years. Oil companies may have their structures inspected on an annual basis, each yearly inspection is collated in order to apply for the 5 year 'Certificate of Fitness'. It is not the intention of this section to discuss platform inspection in detail as it is a specialised area that is described in detail in the CSWIP 3.3u ROV Inspectors Handbook/Course and is normally required to be carried out by qualified personnel. The intention is to highlight the areas where ROVs play a key role.

5.8.1 General Visual Inspection

General Visual Inspection (GVI) is normally undertaken on platforms annually by ROVs. The ROVs used for platform inspection will be observation class complete with tether management systems operating from either a dive support vessel or from the platform itself. Typical types of ROV used for this purpose include; the Seaeye 600, the Offshore Hyball and the Sprint.

The items that will be inspected include the risers and conductors which are of particular concern as they carry the Hydrocarbons from the wells and away from the platforms. Other key items to be inspected will include the anodes, the members, welds, the mudmats and other items such as clamps and pile guides.

The inspection will be planned from the 'Workscope' provided by the client and will normally include the following tasks:-

1) Assessing amount of marine growth deposits
2) Locating debris
3) Locating areas of general damage to structural components
4) Coating condition
5) Cathodic potential measurements using the proximity silver/silver chloride probe (CPP) at anodes and other areas of interest.
6) The condition and integrity of clamps
7) Relative movement between clamps and risers
8) Flooded member detection
9) Mudmat surveys
10) Inspection of the spool piece and sea line flange
11) Anode condition

Results are logged either by computer systems or on data sheets and these together with video tapes form the inspection report required by the client. Once the general visual inspection has been completed then a close visual inspection may be required. This is normally carried out by divers but ROVs are being developed that are capable of carrying out these tasks.

5.8.2 Close Visual Inspection

Close visual inspection is carried out when defects have been highlighted by the general visual inspection or as required by the workscope. Work class vehicles may become involved in this part of the inspection in the following ways:

1) Cleaning of welds and removal of marine growth using rotating wire brushes or water jets. Water jets can be either high pressure (HP) or Low Pressure (LP) and may be sand entrained. It is extremely important to adhere to any pertinent safety regulations where high pressure water jetting is being utilised. In general low pressure water jetting will be sufficient to remove loose or soft marine growth prior to ultrasonic flooded member detection or wall thickness measurement. High pressure water jets will be used where a bare metal finish is required prior to weld inspection or crack detection.

2) Photography of anomalies. If the anomalies are large they may be photographed using 'stand-off' photography during the GVI but close-up photography using special NDT or Photogrammetic cameras will be required for weld or crack photography.

The practice of Non Destructive Testing (NDT) involves the testing of welds and members by ultrasonic, electro-magnetic and radioactive methods. These tasks are normally carried out by divers but more recently specially adapted tooling packages have allowed work class ROVs to carry out these tasks.

1) Flooded member testing - The [redacted] or [redacted] testing of a member to determine if water ingress has taken place.

2) Wall thickness measurement - The ultrasonic testing of a member to determine the wall thickness.

3) [redacted]nspection (MPI) - The inspection of a welds for defects utilising magnetising coils or prods and fluorescent ink. This method is usually undertaken by divers but has been accomplished by ROV.

4) ACFM and ACPD are two methods of finding weld defects more suited to ROVs as the electronic probes are smaller than the equipment required for MPI. The probes use electronically sophisticated methods to detect defects that are beyond the scope of this book.

The involvement of ROVs in platform inspection is constantly increasing and it is quite feasible that the whole inspection programme will be carried out by ROVs in the near future. This is particularly so as weld inspections are becoming less frequent as weld defect predictability becomes better understood and ROVs and there operators are becoming more capable. This is due to technical advances and improved operator standards with the emergence of the CSWIP 3.3u ROV Inspectors training courses and qualification.

5.9.0 Intervention tools

The main impetus for **ROV Intervention** has come from the fact that a fully equipped ROV support vessel (ROVSV) will cost between 1/3rd and 1/10th of the cost of a dive support vessel (DSV), ROV intervention is therefore considerably cheaper. In Norway, Norsk Hydro's TOGI and Oseberg Development Projects represent important milestones for remote intervention. These were the first projects in which there were **primary** operations on the subsea installations which were carried out **solely** by ROV. Until this point, ROV underwater intervention on permanent installations had been restricted to back-up and override tasks in case the prime actuation systems failed. With the increased reliability and availability of ROV systems, such operations could be much more cost effective. Typically such operations include opening and closing valves where the operation can be planned some time in advance and are not part of the installation control system operated automatically or via the sea bed umbilical.

5.9.1 Norway

Norway has taken a lead in remote intervention because exploration and production operations are occurring in ever increasing water depths and are already at and beyond the reasonably practical and economic depths for manned diving (around 350 to 400 metres or 1150 to 1310 feet). In addition it is considered socially unacceptable in Norway for people to be taking the risks associated with deep diving operations.

5.9.2 Other Areas Of The World

Other parts of the world are also making progress with the development of diverless intervention techniques. These include areas of the world where exploration and production are moving into water depths beyond the capacity of saturation diving. Operators in the Gulf of Mexico have set many records for such activities. In particular, Shell have drilled in 2,292 metres (7517 ft) of water from the drill ship 'Discoverer Seven Seas' with underwater intervention support provided by an Oceaneering HYDRA 2500 ROV. Shell are also bringing their Auger leg platform (TLP) on stream in 872 metres (2,860 ft) of water. In Brazil, Petrobras are operating subsea completion's tied back to production systems in over 1,000 metres depth.

5.9.3 Methods of Interventions

There are three main methods of carrying out remote intervention; the Remotely Operated Tool (**ROT**), the Remotely Operated Vehicle (**ROV**) and the Remotely Operated Maintenance Vehicle (**ROMV**).

5.9.3.1 The Remotely Operated Tool System (ROT)

This is a development of existing drilling intervention techniques where tools are deployed, via guide wires, lowered from the surface. Once landed at the work site, the tool can carry out its specific tasks. Usually such tools are controlled by separate umbilical cables from their topside control station. ROTs can deploy and operate larger and heavier tool systems than would be considered using ROV methods. Also the tool is securely locked into the installation, providing a firm base for precise operations. The tools can be used to recover and replace large components, such as control pods and valve inserts. ROTs have high reliability and are very task specific, they are also designed to require very little operator 'skill'.

ROTs are limited by water depth for guide wire operation, the need for a more sophisticated support vessel with the increased associated costs. Also there is always a risk of the tool 'dropping', and damaging the subsea intervention.

5.9.3.2 Remotely Operated Vehicle (ROV)

ROV operations are normally low-force, or more correctly, low mass. This is not to say that high forces cannot be generated, only that the ROV tools are individually smaller. Typically a range of intervention tools could include; a subsea ROV winch, an interface system to a valve, a series of tool to remove covers, access valve inserts, an 'elevator' to recover the removed components, tools to inspect and clean inside valve insert bodies, seal surface inspection, cleaning and refacing tools etc. The tools can be fitted to the ROV or can be lowered to sea bed in a separate basket, they are fitted with buoyancy material to reduce their in-water weight and then handled in turn by the ROV. The tools are usually job specific, but often can be used to address several similar tasks in different locations giving cost savings.

The ROV tool spread is often cheaper to build and operate, the surface support vessel can be just an ordinary ROV DP support vessel, often making the operations cheaper than with ROTs. Careful design with guides and latches to establish the tools in the right alignment and involving automatic operations thereafter can be used to minimise the operator skill requirement and ensure repeatability.

5.9.3.3 Remotely Operated Maintenance Vehicle (ROMV)

The third method is where effectively an ROT is deployed into a subsea installation, where the tool can move within the structure and carry out several tasks and is known as a **remotely operated maintenance vehicle (ROMV)**. An example of this is the Saga Petroleum Snorre Subsea Production system. Figure 5.5 shows the Snorre subsea production system. Figure 5.6 shows the manifold control module and ROMV end effecter which is used to recover and replace all types of subsea control system modules.

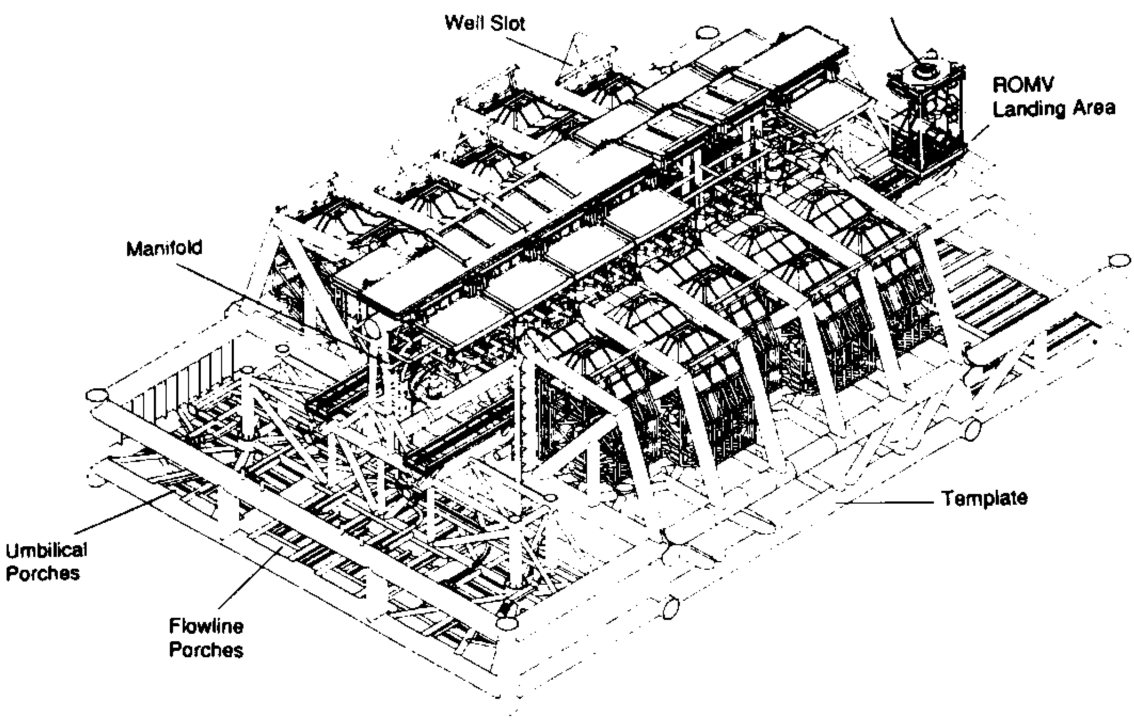


Figure 5.5
Snorre subsea production system

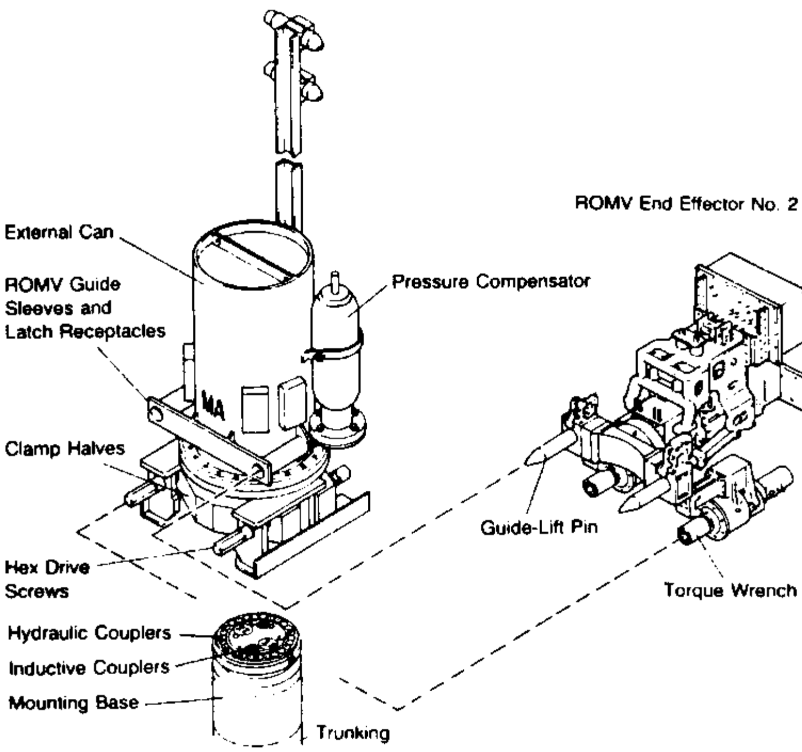


Figure 5.6
Manifold control module and ROMV end effector

5.9.5 Typical intervention tasks by ROV

a) Pull-in and connection using an ROV as the sole means of operating the Pull-in Connection (PIC) tool and other pull-in methods. See Figure 5.7

b) Inspection and cleaning by ROV tools. See Figure 5.8

c) ROV support for Remote Operated Tool Packages. see Figure 5.9 which shows an MRV with purpose built intervention package added at the rear for Mobil.

d) Electrical and hydraulic connector cleaning by custom ROV tools.

e) Electrical cable installation tooling.

f) Control system for a series of ROTs

g) ROV intervention panels for hydraulic "hot stab" operations. See Figure 5.10 which shows a Tronic mini C-E connector and receptacle and Figure 5.11 which shows a subsea tree with stab-in panel.

h) Remote crack detection and sizing by ROV.

i) ROV based welding. See Figure 5.12

j) ROV based dredging. See Figure 5.13

The above serve to illustrate the range of ROV intervention tasks, and is not intended to be exhaustive as this is a specialised area of work with teams of tool design specialists employed by all the major ROV Contractors.

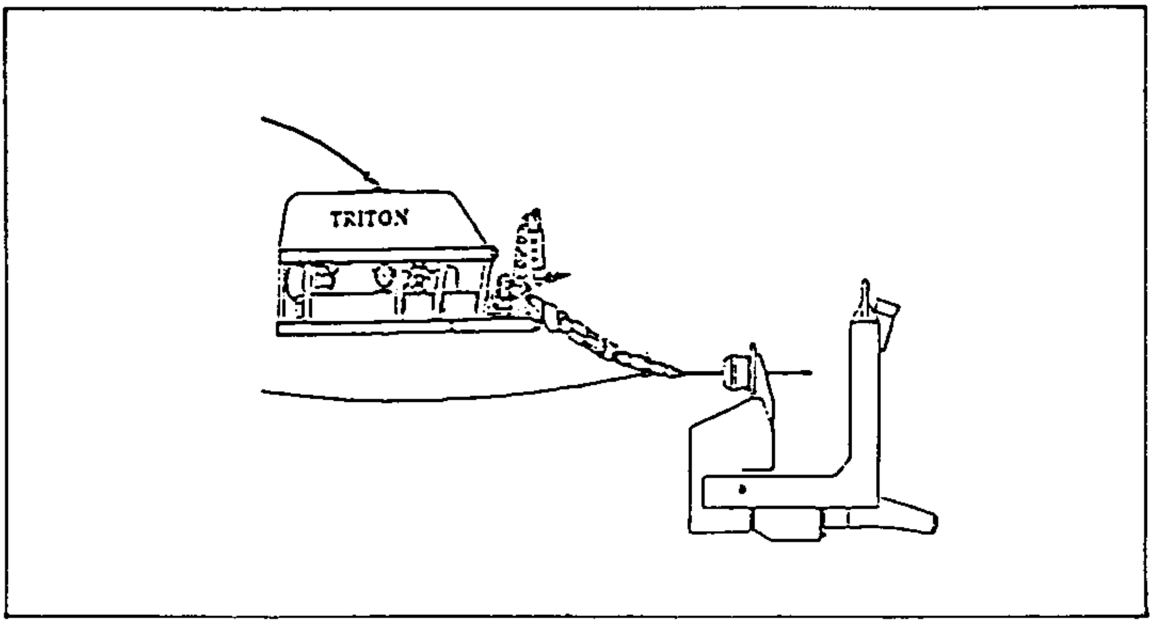


Figure 5.7
ROV Flow line Pull-in

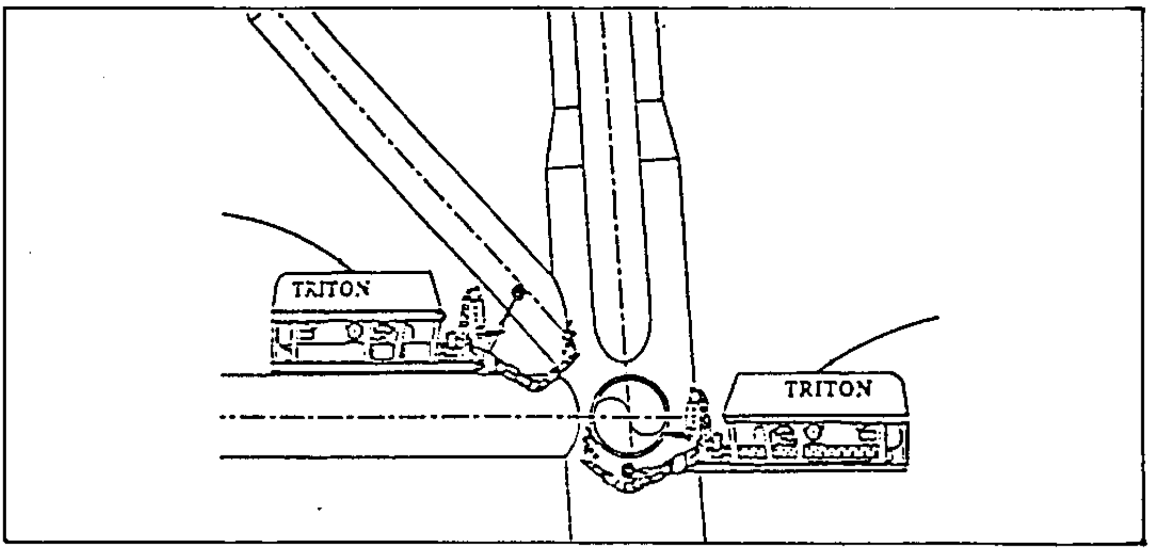


Figure 5.8
ROV Structural Cleaning

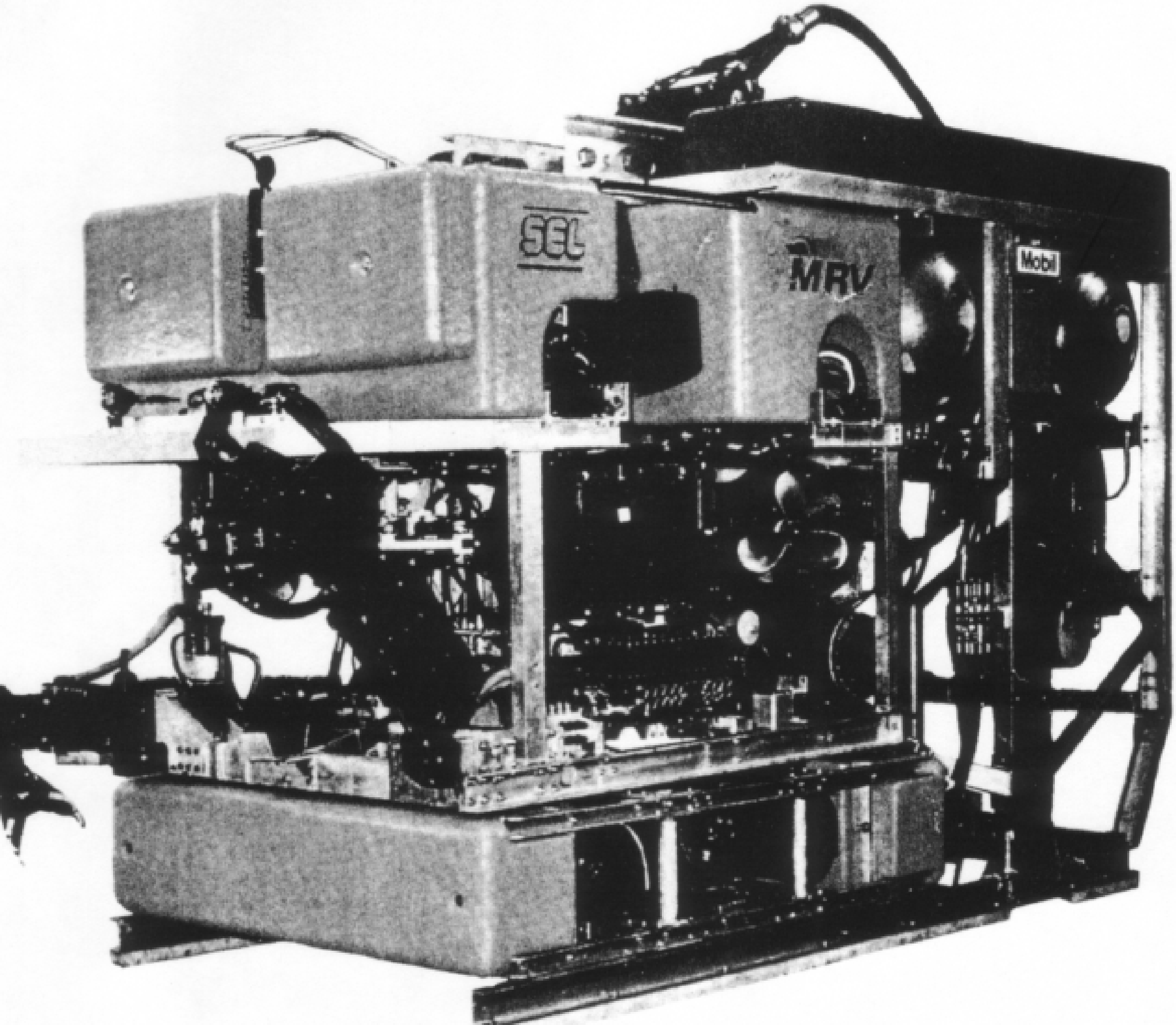


Figure 5.9
MRV With Tooling Package

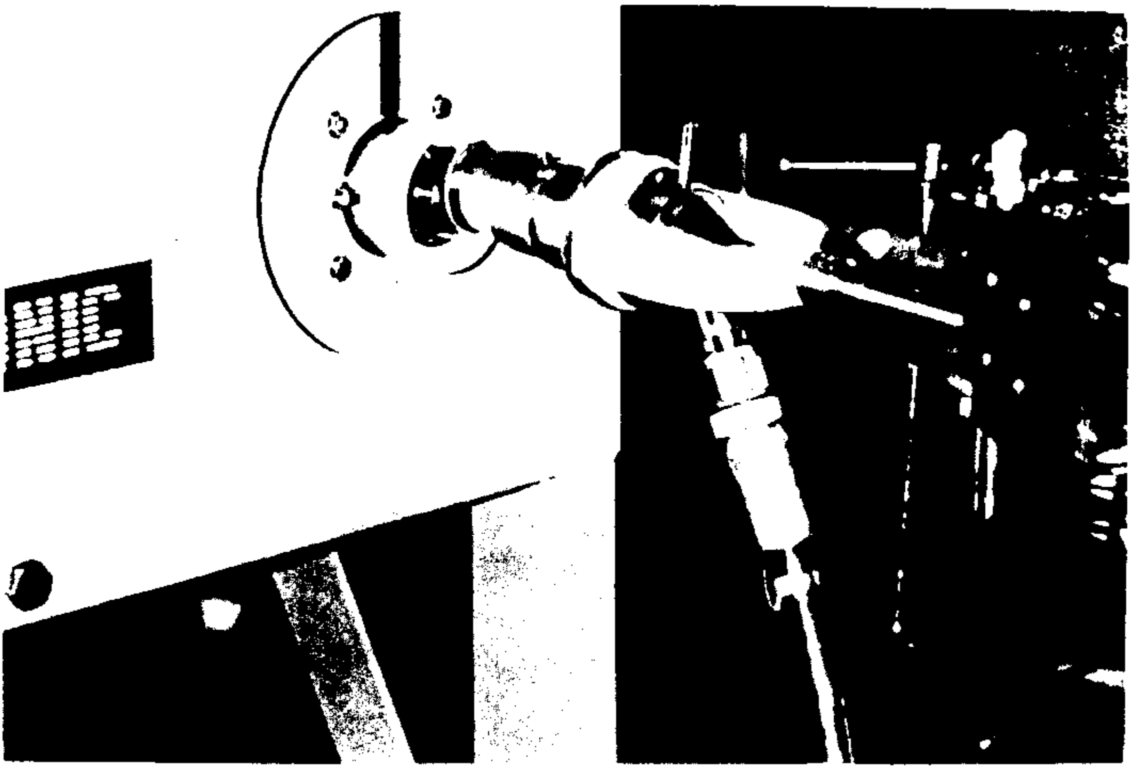


Figure 5.10a
Tronic C-E Mini Connect

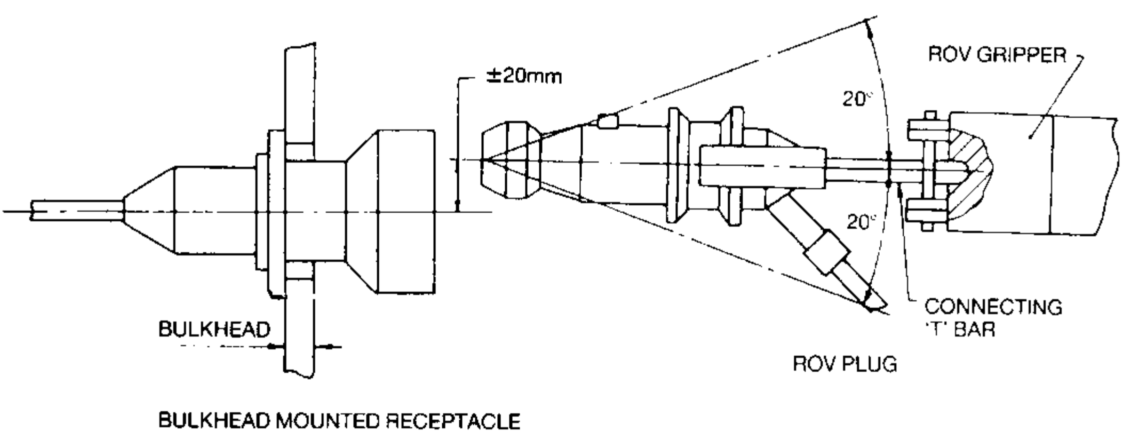


Figure 510b
Tronic C-E Mini Connector Tolerance To Misalignment

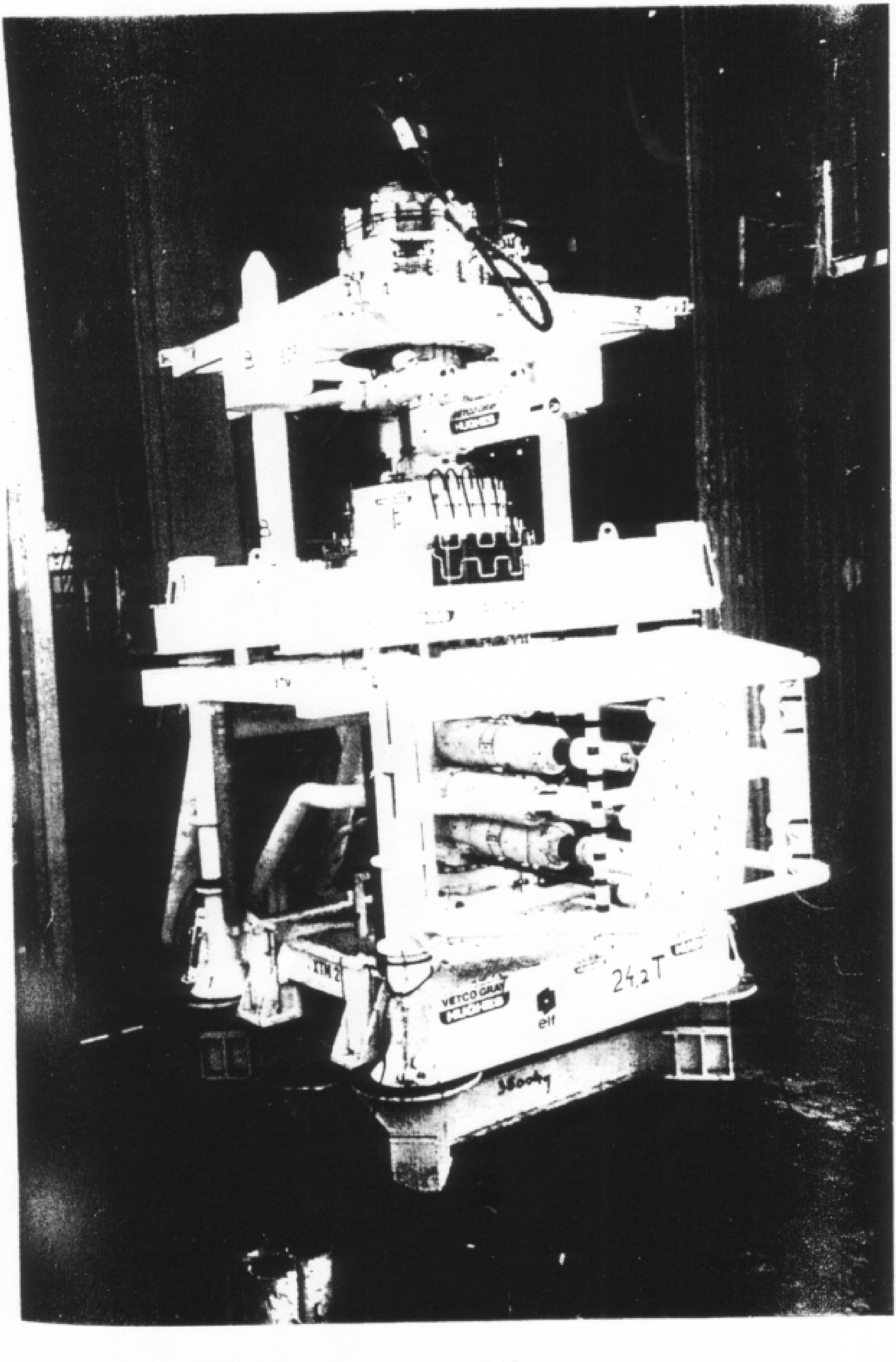


Figure 5.11
Subsea Tree With Stab-In Panel

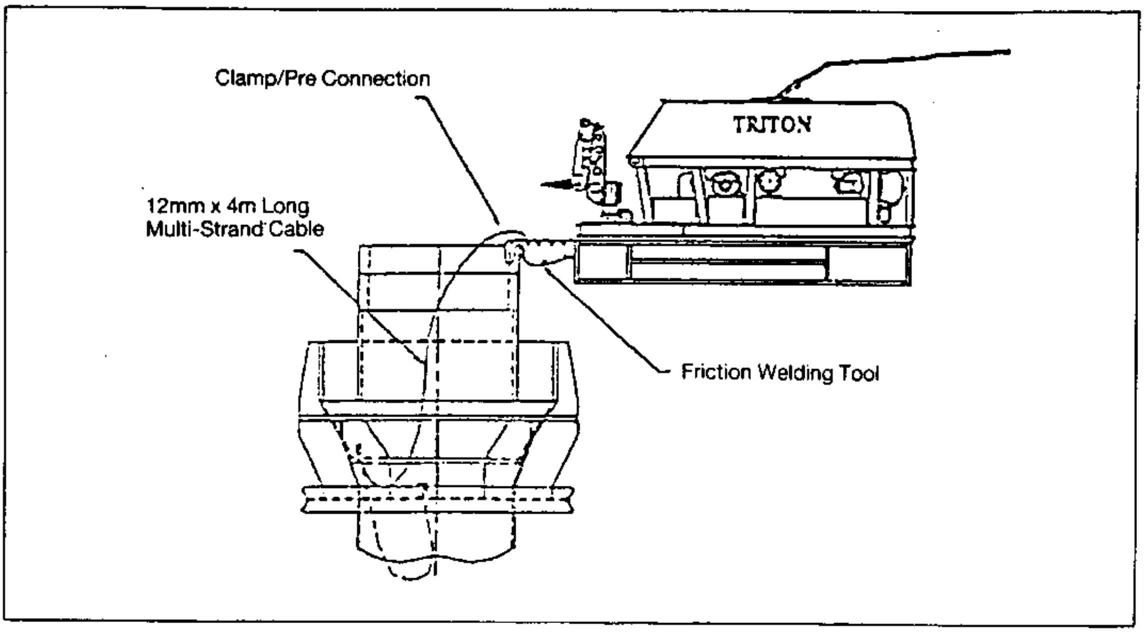


Figure 5.12
ROV Based Welding

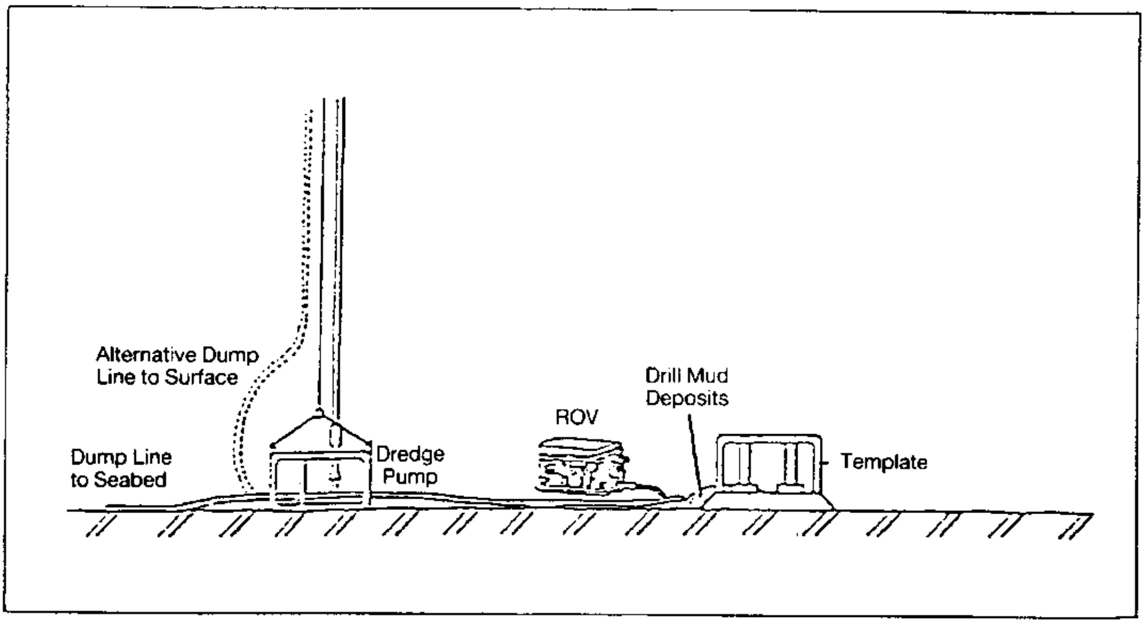


Figure 5.13
ROV Based Dredging

5.10.0 Telecommunications Cable Laying

Telecommunications Cable laying is a world wide operation carried out by companies such as Cable and Wireless (Marine) Ltd with increasing frequency as the telecommunications revolution gathers pace. Similar methods are used in the offshore oil industry for laying control umbilicals, flow lines and pipelines.

5.10.1 Laying Operations

In laying operations a work class ROV may be required to carry out the following:-

1 Pre-lay survey - The survey carried out before the cable is laid to assess the relief of the seabed.

2 Touch-down monitoring - The ROV is required to observe the point at which the cable makes contact with the seabed. This enables engineers to determine if the tension of the cable is correct during the lay down procedure.

3 Post-lay survey - The surveying of the cable once laid, this task resembles that of a pipeline survey, except the ROV is free flying, and is to ensure that the cable is laid correctly on the seabed.

5.10.2 Burial

Often the cable or control umbilical is required to be buried. This is likely to be required in shallow areas where there is a likelihood of trawling or similar activities damaging the cable. This is achieved in one of two ways; a plough is towed behind a ship which ploughs a trench and positions the cable in it, or a trencher which is a tracked ROV creates a trench with water jets. After the cable is placed in the trench by the trencher normal sea bed action is left to fill the trench, whereas the seabed will in-fill behind the plough share to cover the cable.

5.10.3 Eureka Trenching System

An example of the Eureka trenching system and a SMD plough are shown in chapter 3 'Types of ROV'.

5.10.4 Modular Plough System

Figure 5.14 shows a description of the Modular Plough System.

5.10.5 Submersible Trenching System

Figure 5.15 shows a description of the Submersible trenching system.

5.10.6 Summary

The information presented here is intended as a brief overview of cable laying equipment. Although Cable laying and burial is a specialised area, the technology is fundamentally similar to all ROVs. Ploughs and trenchers tend to be large, (typically 10-20Tonnes), and therefore often require dedicated support vessels and crew familiar with the launch and recovery procedures. These are normally carried out with 'A' frames at the stern of the vessel. Operations involving ploughs and trenchers require very close co-ordination between the ship and the ROV crew due to the requirement for accurate positioning and monitoring of cable and tow forces. Ploughs can be steered in a limited sense by moving the steering arms in the opposite direction to the required direction typically by as much as 15 degrees. In both cases profiling and bathymetric sonar (see chapter 19) are used to ensure that the cable is being laid in the trench and is entering the machine at the correct angle due to the very poor visibility experienced during these operations. Detection coils are positioned on each side to aid location of buried cable and responder beacons are attached to enable the surface vessel to 'track' the plough or trencher with its' HPR system.

5.11.0 Construction

Specially adapted trenchers similar to the one described in 5.10 previous have been adapted to undertake sea bed construction work. A good example of this was the building of a round concrete barrier wall around the central concrete storage platform in the Ekofisk field operated by Phillips Petroleum (Norway). A full description of this project is described in the Society Of Underwater Technology (SUT) journal 'Underwater Technology' Volume 17 No.2 1991. It is sufficient to state here that such projects are possible by adapting trenchers with such things as; sea bed levelling tools, debris collection rakes and scraper collection tool.

5.11.1 General Construction Work

General construction work usually involves the installation of steel jackets. These are floated off a barge and lifted into position on the sea bed by a Derrick Barge. Typical ROV tasks on such installations include the following:-

i) Pre installation sea bed survey

ii) Placing transponders and positioning the jacket

iii) Checking the mud mats

iv) Monitoring the pile driving and depth of penetration

v) Monitoring the cement returns at sea bed for pile cementing

vi) Diver Observation

vii) Post installation survey

Particular care must be taken with regard to safety when undertaking these kinds of construction operations. Care must not only be taken not to harm divers that may be in the water but deck work must be done with care as many dangerous operations such as heavy lifting, welding and cutting will be taking place.

5.12.0 Remotely Operated Television (ROTV)

A good example of an ROTV system is the FOCUS (Fibre Optic Controlled Underwater System) 400 Inspector. This is a versatile, stable, controllable, towed sensor platform. The modular design approach permits designs to depths of 6000m with cable lengths of up to 10000m. The innovative hydrodynamic 'box kite' design lends itself to carrying a multitude of sensors. These are commonly fitted with video cameras, obstacle avoidance sonar's, side scan sonar, sound velocity probe, still cameras, lights, pan and tilt units and transponders. Everything in fact that a pipeline survey ROV might carry except the thrusters. ROTVs can offer a cost effective answer to pipeline survey work. ROTV Pilots, however, need fast reactions as ROTV surveys are often faster (around 2 knots) than normal ROV survey (around 1/4 - 1/2 knot). Control is accomplished through control foils at the stern of the vehicle. Figure 5.16 shows the FOCUS 400 performance curves.

5.13.0 Other applications

Other applications include the military use of ROVs for Mine Counter Measures. This is a specialised area where the ROVs in use are required to be; reliable, quiet with a minimal magnetic signature. ROVs are being widely used by customs officials and the police to counter terrorism and drug smuggling where attachments may be found on the underside of vessels. Headline grabbing applications include the survey of the Titanic and the MV Derbyshire. Other more romantic applications include the dredging for gold off South Africa and the harvesting of Pearls off Japan. There are as many applications of ROVs as man can imagine, and it has to be true that there will be many more in the future as the explorations of the oceans is still considered to be in its infancy.

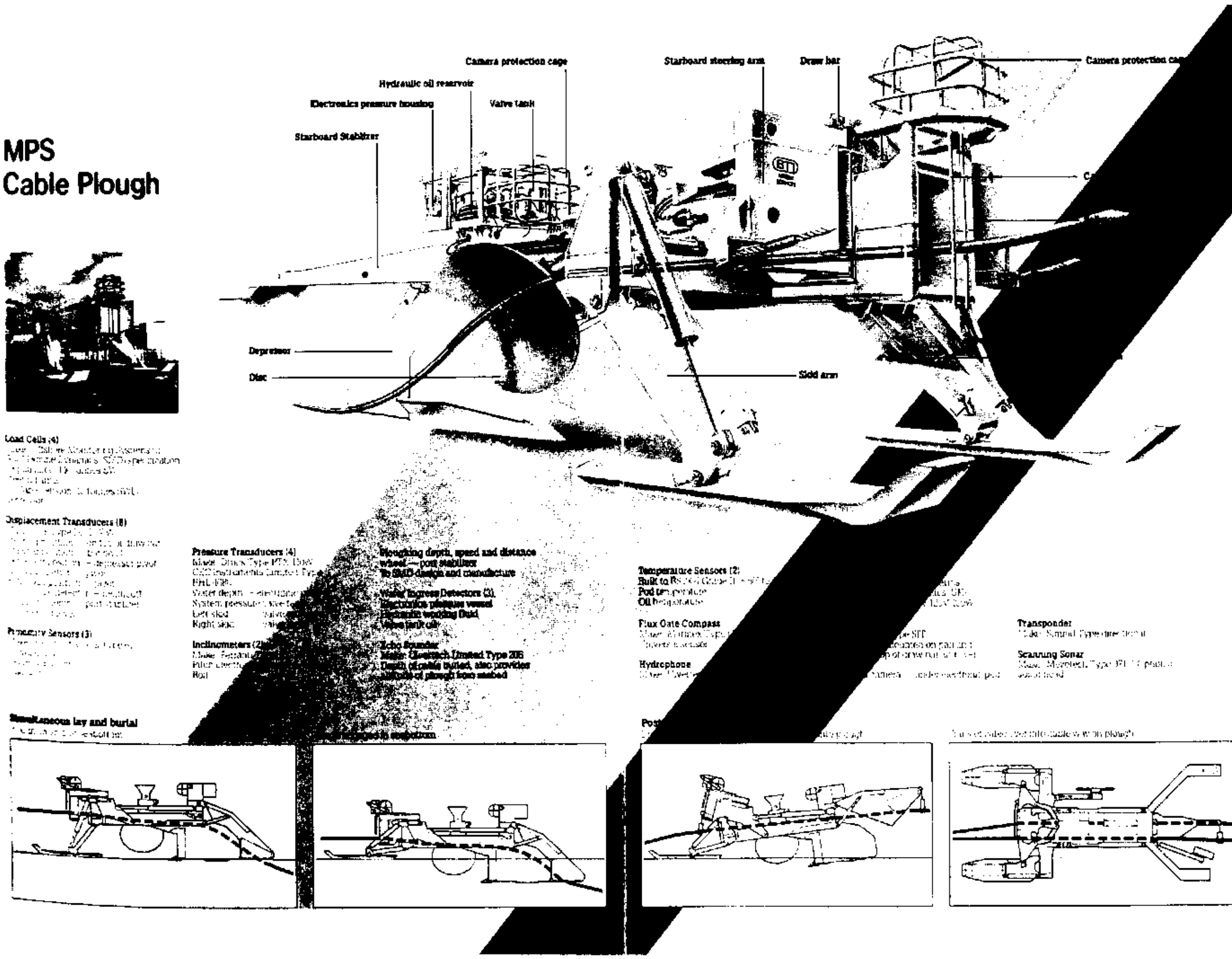
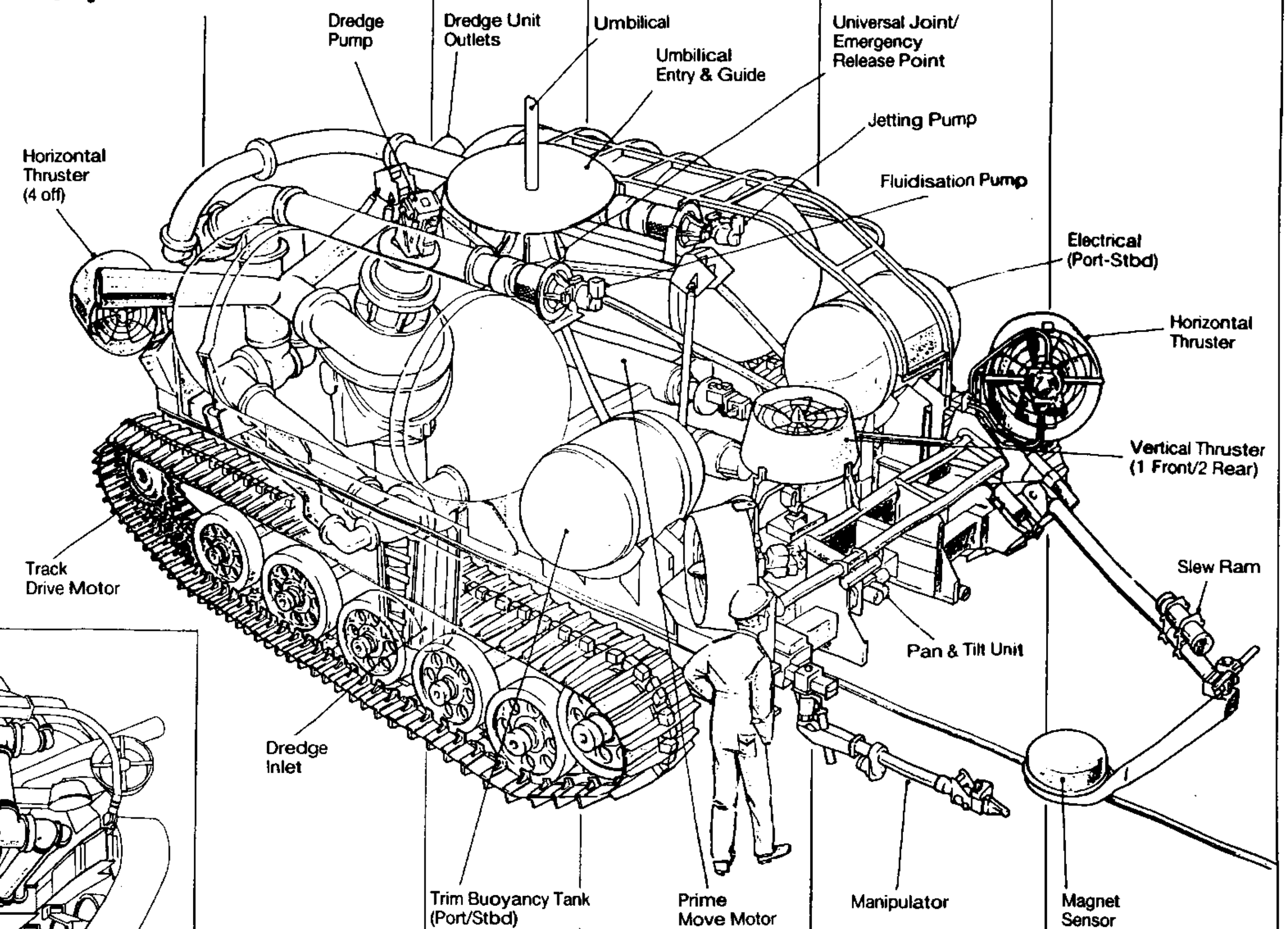


Figure 5.14

The Submersible Trenching System Profile

Designed and developed to trench, inspect and repair cable, umbilical and other subsea plant.
The BT Marine Submersible Trencher is ideal for working in the offshore sector particularly in confined and potentially difficult environments.
The Submersible Trenching system consists of a remote submersible trencher, control umbilical, 'A' Frame launch and recovery unit, and an on board service and control module.
With a capability of being installed on any suitable vessel, the BT Submersible Trenching system offers a versatile and cost effective method of trenching cable and umbilical subsea systems in a single operation.
A variety of other work can also be carried out including:
Pipe trenching up to 14" diameter
Assisting span correction to pipelines
Assisting installation and maintenance of other subsea plant
Seabed profiling
Cable and umbilical cutting and recovery



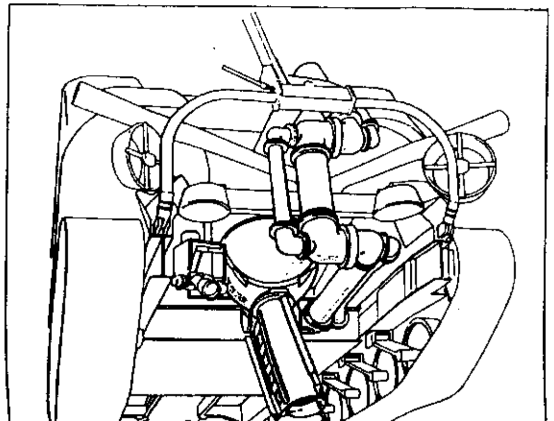


Figure 5.15

PERFORMANCE CURVES

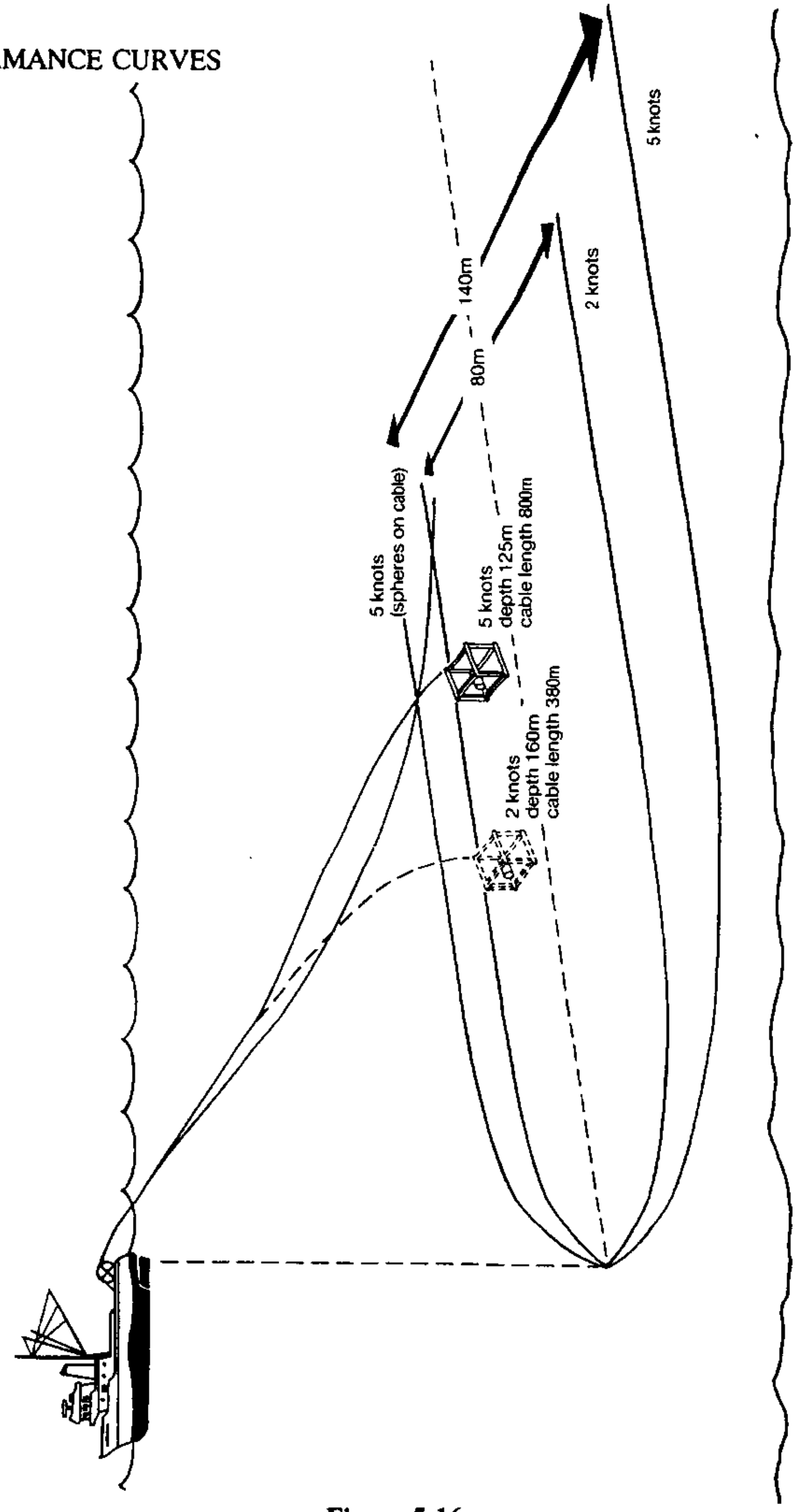


Figure 5.16

Chapter 6 Electrical principles

6.1 Introduction

In order to be able appreciate the ROV Electrical system thoroughly, a basic understanding of the Electrical principles is essential. The first section of this chapter concentrates on revising these principles so they can be applied when carrying out maintenance on any system.

6.1.1 Voltage and Current

In order to understand the nature of electricity and the basic electrical properties of materials, a knowledge of the structure of atoms is required.
All materials are made up of atoms and all atoms contain tiny particles called electrons which orbit a central nucleus.

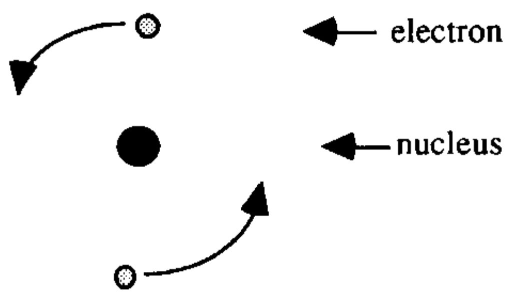


Figure 6.1

Electrons have a negative charge while the nucleus has a positive charge. Like charges repel while unlike charges attract each other, therefore the negative electrons are attracted to the positive nucleus and are held in orbit.

In conductors, electrons are not tightly held to their atoms and may break free and move from one atom to another. These 'free' electrons normally move around randomly.

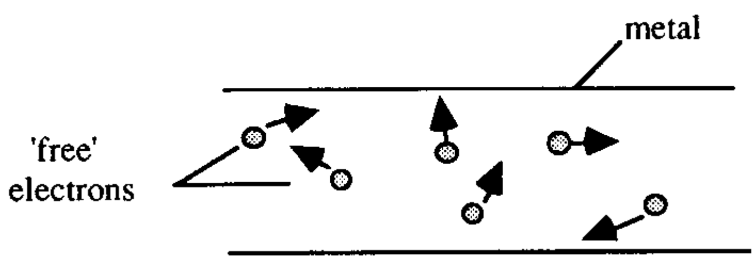


Figure 6.2

If these free electrons are made to flow in the same direction, the result is an electric current.

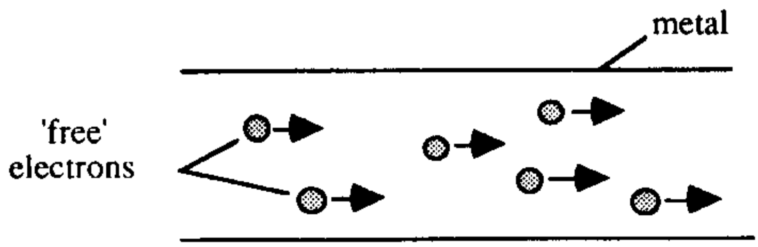


Figure. 6.3

Insulators are materials in which electrons are strongly bound to their atoms and there may be few free electrons. It is therefore difficult for current to flow. (For example, glass and rubber.)

Free electrons can be made to flow in one direction in a conductor by applying a positive charge to one end and a negative charge to the other. The positive charge at one end will attract free electrons while the negatively charged end will repel electrons.

Current is the number of electrons passing any one point in a conductor in one second. In other words applying a potential difference (or voltage) across a circuit will cause a current to flow. The Potential Difference creates a force, known as ELECTRO-MOTIVE FORCE which gives rise to current flow.
The size of the current will depend on the size of the voltage and also the amount of resistance in the circuit.

The symbol for current is I, it is measured in amps.
The symbol for voltage is V, it is measured in volts.
The symbol for resistance is R, it is measured in ohms.

6.1.2. Resistance and power

Resistance is an opposition to current flow that gives rise to power being dissipated and work being done. The power may be dissipated in the form of light, heat or motion. Figure 6.4 illustrates a simple electrical circuit involving the basic electrical principles.

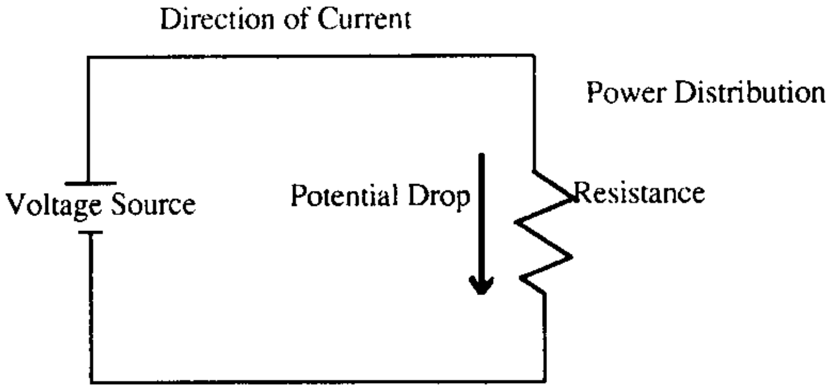


Figure 6.4

In this situation the current source develops a potential of charge, the units of which are called VOLTS. It follows therefore that there will be a drop in potential across the resistance due to some of the electrical energy being converted to heat, light or motion.

6.1.3 Relationship Between Voltage, Current, Resistance,and Power

There is a mathematical relationship between voltage, current and resistance.
OHM'S LAW states that the current in a circuit is directly proportional to the voltage and inversely proportional to the resistance. These quantities are linked by the following equation.

VOLTAGE = CURRENT x RESISTANCE

$$(V = I R)$$

Power is the amount of work that can be done in a standard unit of time (1 second). Electrical power is expressed in units known as WATTS. One watt represents the power used when one ampere of current flows due to an Electromotive Force (E.M.F.) of 1 volt.
Power is related to Voltage, Current and Resistance by the following equation.

POWER = (CURRENT $)^2$ x RESISTANCE

$$P = I^2 R$$

POWER = VOLTAGE^2 / RESISTANCE

$$P = V^2 / R$$

6.1.3. Electromagnetism

Figure 6.4. shows that an electric current flowing through a conductor produces a magnetic field around the conductor, the direction of which depends on the direction of current flow.

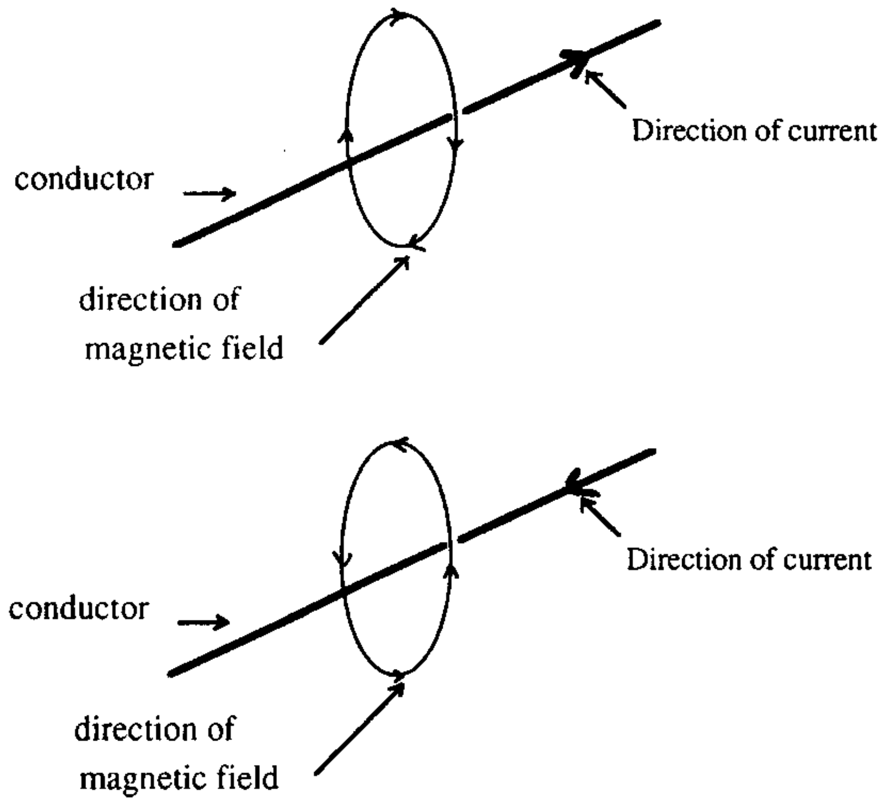


Figure. 6.5

If the conductor is formed into a coil and a current is passed through it, a magnetic field is produced which is similar to that of a bar magnet.
This is known as an electromagnet.

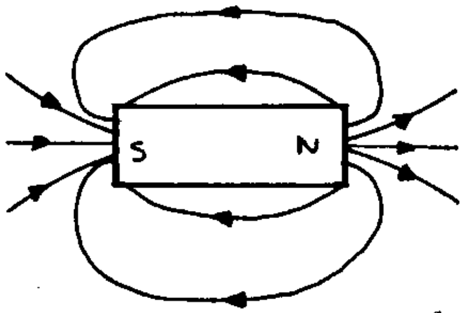


Figure 6.6
Magnetic Field Produced by Bar Magnet

The magnetic field is increased by:-

1 increasing the number of loops in the coil
2 increasing the current through the coil
3 using a ferrous core

6.1.4 Electric motors

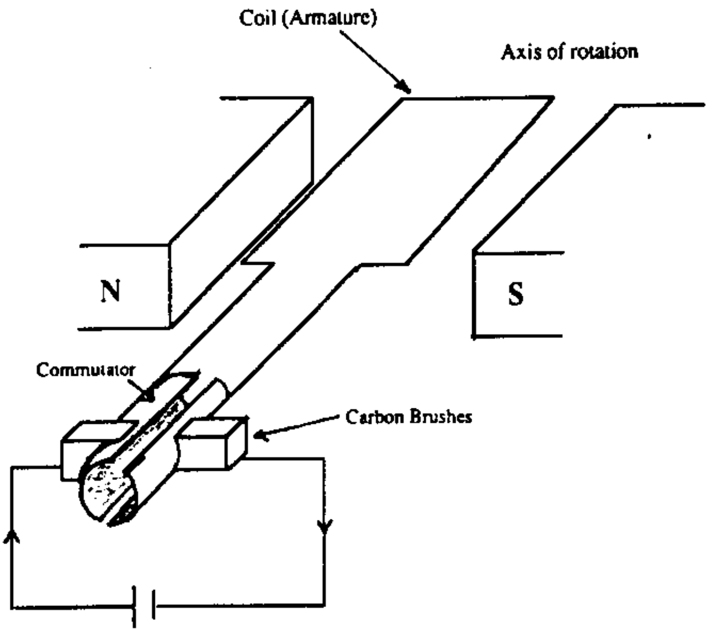


Figure. 6.7

Figure 6.7 shows the basic action of an electric motor. If a current carrying conductor is placed in a magnetic field the conductor will move in a rotational direction that is dependent upon the direction of current flow. In practice a motor is made up of thousands of coils wound on a former. The interaction between magnetic field and electrical current is stronger allowing the motor to develop a greater torque.

6.1.5 Direct Current

Figure 6.8 illustrates the relationship between voltage and time. In this situation the current has constant magnitude and direction .

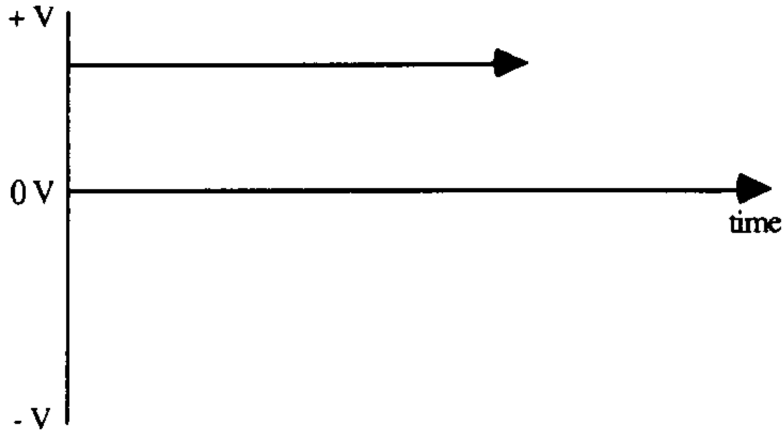


Figure. 6.8

6.1.6 Alternating Current Figure 6.9 illustrates the relationship between voltage and time. In this situation the current varies in magnitude and direction. The current varies between a positive level and a negative level over a period of time. The time taken for one complete cycle is known as the PERIODIC TIME, and the number of cycles that occur in one second is termed the FREQUENCY.

It follows therefore that:

$$\text{FREQUENCY} = \frac{1}{t}$$

where t = periodic time

The advantage of alternating current over direct current is that it is possible to transform alternating current by means of either a 'step up' or 'step down'transformer

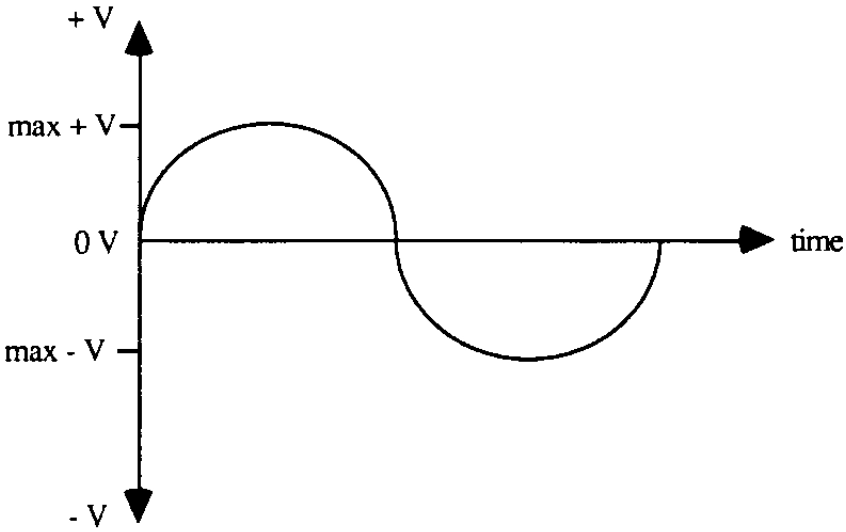


Figure 6.9

Figure 6.10 illustrates how the simplest form of AC. current is generated. The generated current is fed from the coil in such away that each side of the coil is connected to the same output. The output at terminal Z varies in phase and magnitude according to the position of coil W in the magnetic field.

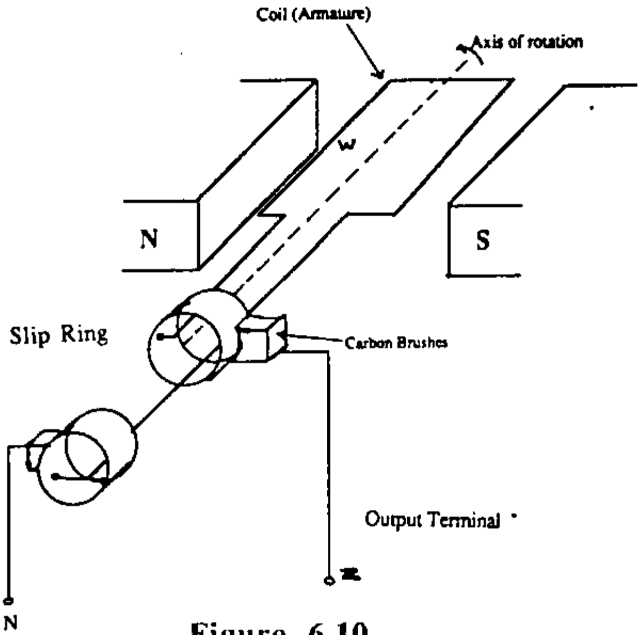
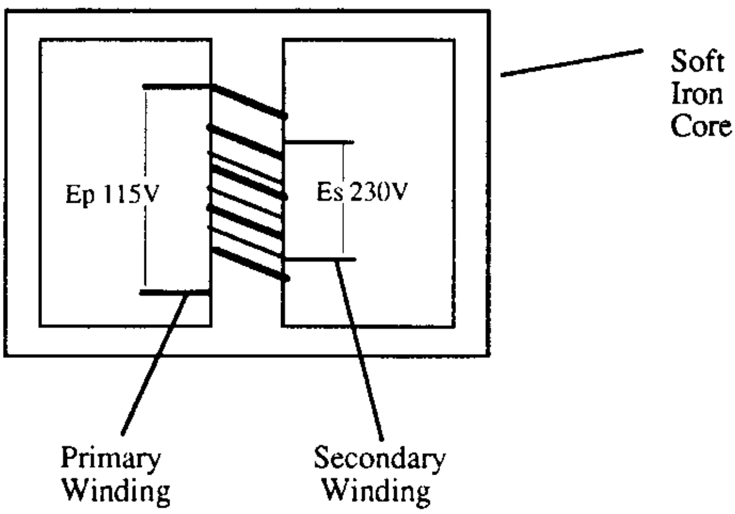


Figure 6.10

6.1.7 Transformer action

A transformer is a device that transfers AC energy from one circuit to another without there being any electrical contact between the two circuits.
Transformers operate according to the principles discussed in section 6.1.3. If an AC current is applied to a conductor then the resulting magnetic field will build up and collapse in sympathy with the varying magnitude of the current. If this conductor is placed in close proximity with another conductor then the magnetic field will induce a secondary current into this conductor. In practice the conductors are made up of coils of wire known as **primary** and **secondary coils.**



(1000 turns) (2000 turns)

Figure 6.11
Step up Transformer

The relationship between the primary voltage and the secondary voltage is dependent on the number of turns on the coils. Figure 6.11 illustrates the step up and step down transformer. The output voltage is directly proportional to the number of turns in the coil. The example shows an input voltage of 115VAC to a coil with 1000 turns. The secondary coil has 2000 turns and an output of 230VAC.

Example:

RATIO OF PRIMARY COIL TURNS TO SECONDARY = 1 : 2
INPUT VOLTAGE = 200 VOLTS.

Therefore

$$\text{Secondary Voltage} = \frac{2 \times 200}{1} = 400 \text{ V AC}$$

6.1.8 Relays

Relays are electrical switches that operate on the principle of electromagnetism. Figure 6.12 illustrates a simple relay circuit.
The diagram shows the contacts when the relay is in its de-energised state. In this state they are referred to being normally open or normally closed. When current is applied via the controlling circuit the relay becomes energised and the contacts change to the opposite state. This in turn connects the high voltage source to the motor.

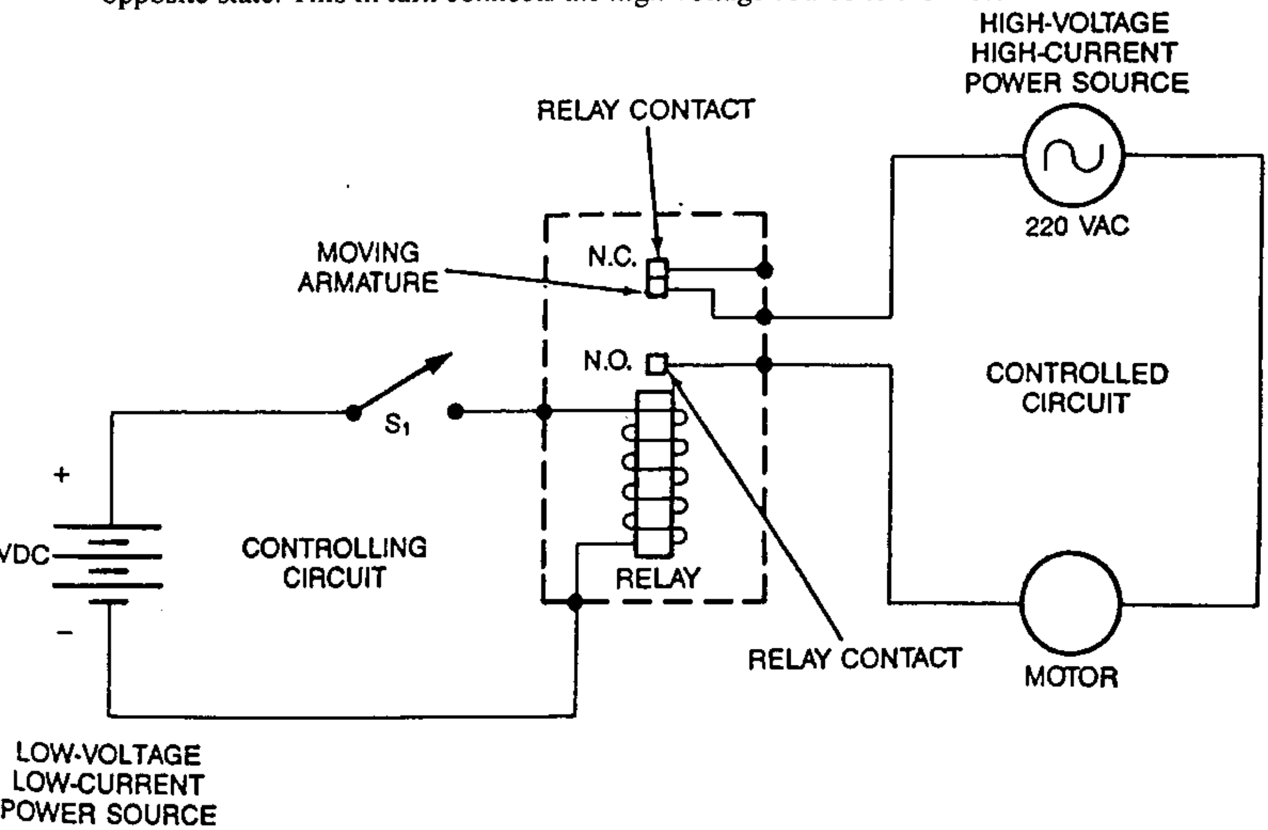


Figure 6.12

6.1.9. 3-Phase electricity

Fig 6.9 illustrated the relationship between single phase current and time. The disadvantage of single phase current is that it is not suitable in situations where a high power factor is required.
Figure 6.13 illustrates the principles of generating 3-phase electricity. Three coils are set 120 degrees apart resulting in three separate phases of current being induced into each coil. It can be seen therefore that the phases are also offset from each other by 120

degrees. In practice each coil is made up of many thousands of turns, this being one of the main factors that influences the magnitude of the generated current.

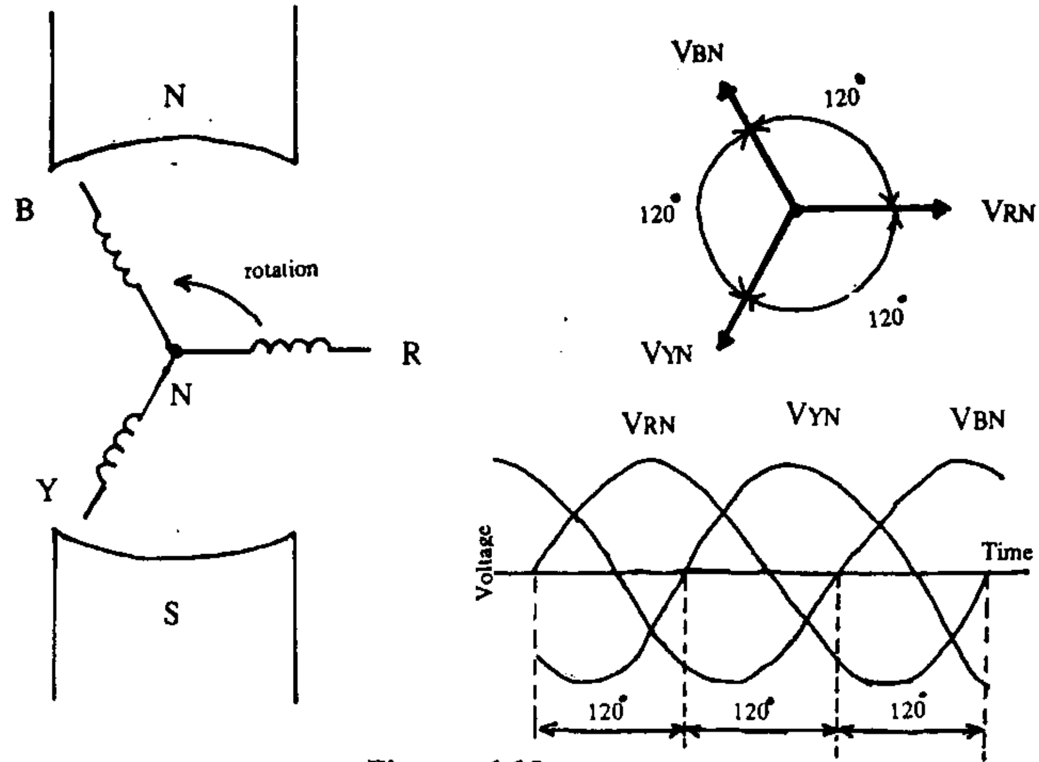


Figure 6.13

6.1.10. Transformer configurations

3 Phase transformers are normally connected in either STAR or DELTA configuration depending on their specific requirements. Figure 6.14 illustrates the two modes of connection.

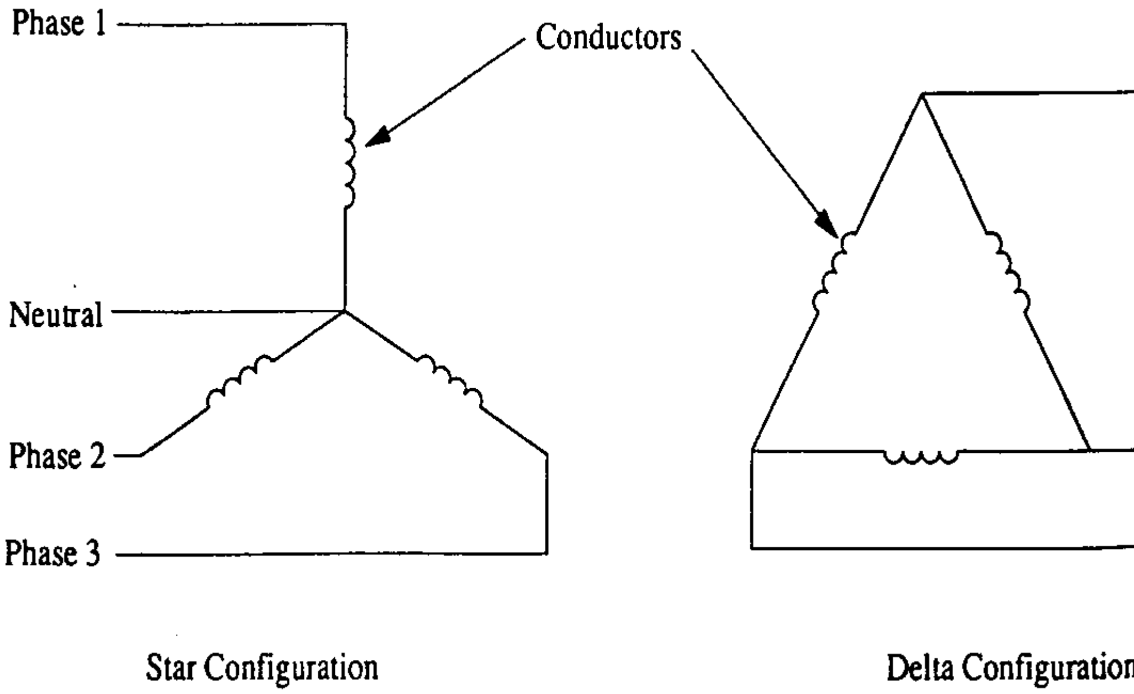


Figure 6.14

It can be seen that in the star configuration that the three windings have a common return line as oppose to the delta connection where no return is present. With star transformers the line insulation is only required to withstand the phase voltage and not the full output voltage. Also two choices of load voltage are available between the windings if the neutral line is used.

The main disadvantage of the star configuration is the transformers behaviour when harmonics of the fundamental frequency exist in the secondary windings.
The delta configuration does not suffer the same disadvantages as the star configuration. In this situation the closed form of the delta provides a path for the harmonics to circulate and prevents them flowing into the power system.
The most common configuration on ROV systems is a star/delta Switching Mechanism. In the delta mode the output is ungrounded, the grounding of one phase will not seriously effect the operation of the power system as the fault current has no direct return path to supply. If the output was in star then a fault current would have a direct sea return path to the supply. Another advantage of this configuration is that any unwanted harmonics are prevented from propagating through the power system. It is usual practice to employ a star / delta configuration in the power supply. Initially star configuration provides a low start up current for the electric motor, once running at operating speed the system switches to delta configuration which runs more efficiently.

6.1.11 Power supplies

The main parts of a power supply unit (PSU) are a transformer, rectifier, smoothing circuit and a stabilising circuit (see figure 6.15).

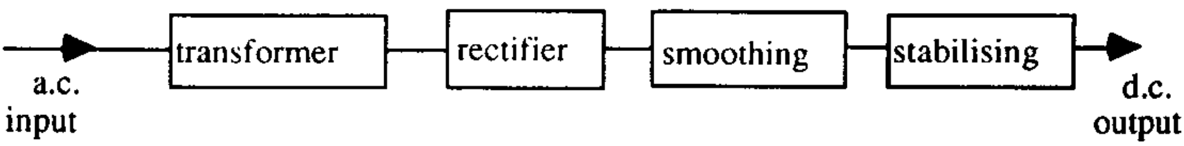


Figure 6.15

a) The transformer

The transformer takes an ac input voltage (e.g. mains) and 'steps' (converts) it to the required voltage. A transformer may therefore be step-up' or 'step-down' depending on the turns ratio between the secondary and the primary windings.

b) The rectifier

The transformer output is an ac. voltage. This is then converted to a dc voltage by the rectifier, however this is not a steady dc voltage and as such is not suitable for many applications.

c) The smoothing circuit

Most equipment and electronic circuitry require a constant and steady supply voltage in order to operate. This circuit smoothes the rectifier output to give a steady dc voltage.

d) The stabilizing circuit

Because of internal resistance, the dc output of a PSU or battery decreases from a maximum as the current drawn increases. The greater this decrease, the worse is said to be the **regulation** of the supply.

Figure 6.16 illustrates the effect of current loading on a power supply.

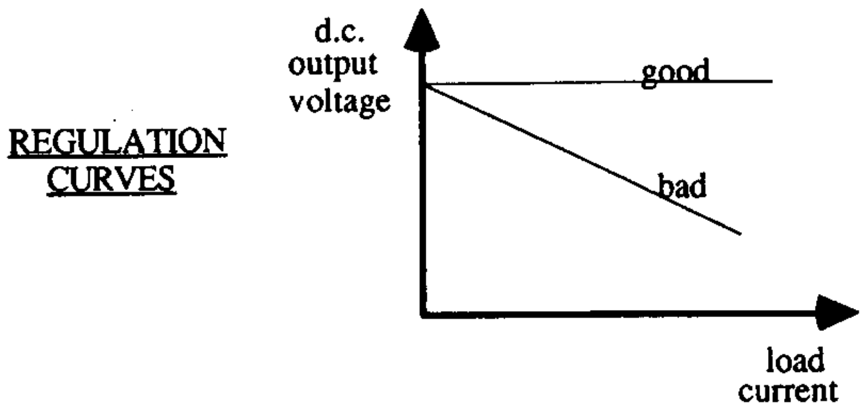
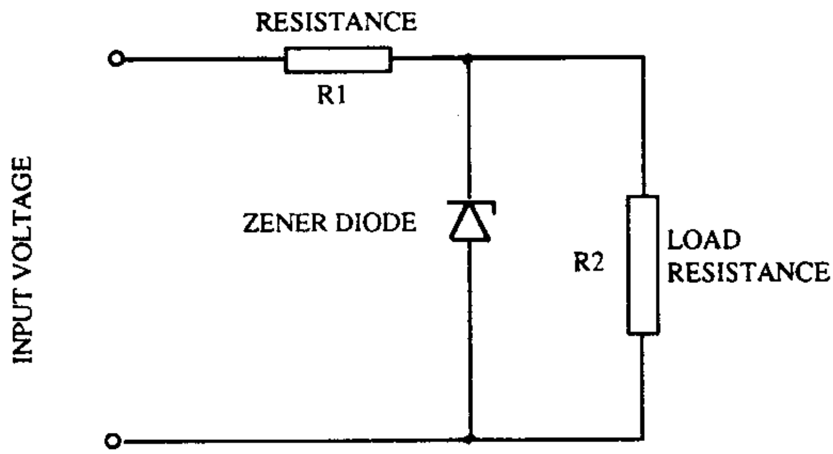


Figure 6.16

The stabilising circuit overcomes this problem ensuring the output voltage remains constant.



Circuit Action.
As the current drawn by the load increases the current through the diode decreases and a constant voltage across R1 is maintained.

Figure 6.17

Figure 6.17 illustrates how a device known as a Zener Diode is incorporated into the output stage of the circuit. The diode 'clamps ' the output voltage at the desired level regardless of the external loading. It is not the intention of this section to dwell on the circuit theory of these electrical devices as there are many text books available that cover the subject quite adequately, but to provide sufficient information to cross-train a mechanical Pilot/Technician to be able to assist an Engineer with electrical tasks.

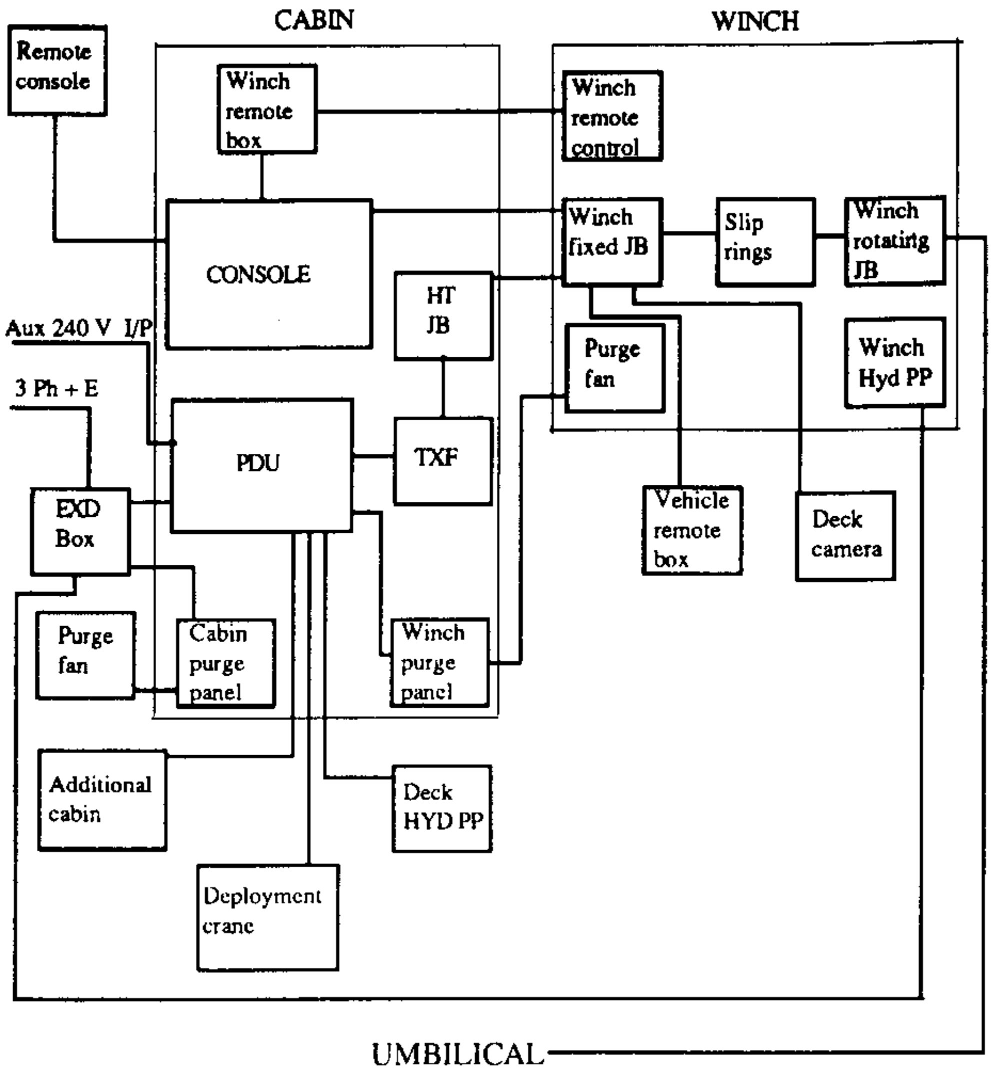

CABIN
WINCH
Remote console
Winch remote box
Winch remote control
CONSOLE
Winch fixed JB
Slip rings
Winch rotating JB
HT JB
Aux 240 V I/P
Purge fan
Winch Hyd PP
3 Ph + E
PDU
TXF
EXD Box
Vehicle remote box
Deck camera
Purge fan
Cabin purge panel
Winch purge panel
Additional cabin
Deck HYD PP
Deployment crane
UMBILICAL

Figure 6.18.

6.2 Introduction To The System

In chapter 3 figure 3.1 illustrates the basic layout of a typical ROV system. It can be seen that the system is comprised of a surface unit, winch, umbilical , Tether Management System and vehicle. It is the intention of this section to discuss the basic principles of operation of these individual units.

6.2.1 Surface Unit

Figure 6.18 illustrates the surface unit of a typical work class ROV (SEL Multi Roll Vehicle). There is one main power input which may be supplied from the vessel or installation or from a customised generator.An auxiliary input of 240V is also provided as a domestic supply.

The main input, typically 440VAC, is fed via a junction box to the main Power Distribution Unit. Power is then distributed to the following main units.

a) Purge System.

b) Deployment Crane.

c) Winch Power Pack.

d) Step up Transformer.

e) Control Console.

6.2.1.1 Purge System

The purge system provides a pressurised safe area thus enabling the us of non-zone related equipment in the control cabin and winch junction box.
When the system starts up a fan pressurises the cabin to 0.75 milli Bar, this is monitored by the Purge Panel for a period of twenty minutes. After this period, should no problems occur then the vehicle system will be switched on. During operations, should cabin pressure fall below 0.25 milli Bar then the Purge system will automatically shut down the system. It follows therefore that if the vessel or installation is in a situation where inflammable gas is present the positive pressure inside the cabin will prevent the gas intruding, if the pressure falls then the power will be cut off preventing any electrical arcing occurring and causing an explosion.

6.2.1.2 Deployment Crane

The crane hydraulic power pack consists of a 3-Phase electric motor, the power for which is taken from the PDU.

6.2.1.3 Winch Power Pack

The winch power pack operates on the same principle as the crane. A 3-Phase Electric motor is directly coupled to a hydraulic pump. The motor receives its' power from the PDU

6.2.1.4 Step Up Transformer

The step up transformer is supplied with 440VAC which is converted to a suitable level as to overcome line losses in the umbilical.
Typical surface voltages for ROVs are as follows:

a) RECON IV 160VAC

b) SCORPIO 1100VAC

c) HYDRA 1800VAC

d) RCV 150 950VAC

e) MRV 3300VAC

6.2.1.5 Control Console

The control console houses the surface electronics control instrumentation and displays the vehicle sensor information.

a) Surface electronics and control instrumentation
The surface electronics processes the signals received from the vehicles primary controls (e.g. joy-stick, manipulator master control). The primary controls produce a varying dc voltage that may vary proportionally between ±5V depending on the system. These signals are digitilized and multiplexed before being transmitted down the umbilical to the vehicle electronics. Section 6.3 in this chapter looks at multiplexing in more detail.
Figure 6.19 illustrates the basic process of control and instrumentation.

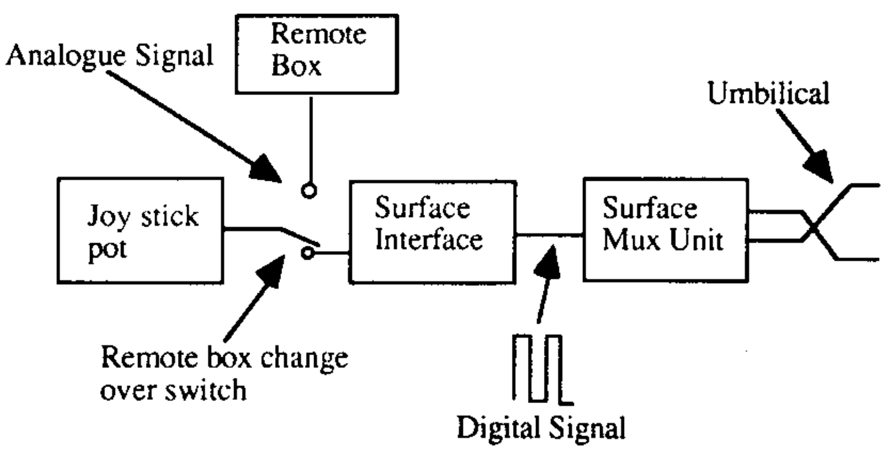


Figure 6.19

The remote box is a replication of the primary flying controls and enables the deck officer to steer the ROV away from the vessel or installation during the launch procedure into a safe diving position. Once in position the control is reverted back to the main controls in the control cabin.

The joy stick potentiometer is simply a variable resistor that produces a proportional analogue voltage. There is one potentiometer for each plane of the joy-stick.
The surface interface unit amplifies the analogue signal to a suitable level to be applied to the multiplexer (mux) unit.

b) Sensor information
Chapter 5, section 5.2.2 discusses the various sensors that may be found on a typical ROV. The vehicle electronics incorporates a 'two way data link' which allows data to be transmitted to the vehicle from the surface, as is the case for

the control information, and **from** the vehicle to the surface, as is the case for the information from the sensors.

The sensors consist of transducers that converts one form of energy (e.g. pressure, temperature or acoustic) to electrical energy. The electrical energy is in the form of an analogue signal that is converted to digital and transmitted in the same manner as the control signal. The sensor information is displayed to the pilot on the control console.

6.2.1.6 Switch On Procedure

It is important when switching the system on to follow the correct procedure.

a) Console Power

b) Vehicle Power

c) Hydraulic Power

If this procedure is not followed complications with the systems telemetry can occur. The telemetry system works on the Master / Slave principle, the surface electronics being the master and the vehicle being the slave. If the vehicle power is switched on before the console power then the situation arises whereby the slave is enabled and receiving no command from the surface master. This is an undesirable effect and can lead to possible damage of the telemetry system. When powering down the system the procedure should be followed in **Reverse Order.**

6.2.1.7 Display Unit

As well as housing the vehicle control system the surface unit is required to display video and sensor information. The system incorporates a number of video monitors which are capable of being switched video cameras and sensors as required.
Some ROV systems have a **Self Diagnostics Programme**. All the circuit boards in the system are continually monitored, should a fault occur then a surface computer allows the operator to step through a programme which will locate the relevant circuit board.

6.2.2 Winch Systems

All ROV systems require a system to deploy the vehicle to the work site. Most winches are electro-hydraulic and are designed to control the length of umbilical as oppose to physically lifting the vehicle. When submerged the vehicle controls its own depth, and when at the surface a latching mechanism attached to the crane lifts the vehicle out of the water. There are some exceptions to this in which case a more powerful winch is fitted with a specially designed lifting umbilical.

Figure 6.18 shows the main units on a typical winch.
The system incorporates two junction boxes connected together by slip rings.

6.2.2.1 Fixed Junction Box

The fixed junction box is a two way junction box that passes power to the umbilical, video signal from the umbilical and data signal in both directions.

6.2.2.2 Rotating Junction Box

The rotating junction box, as the name implies is attached to the main drum of the winch and carries out the same function as the fixed junction box.

On systems where fibre optics are used (see section 6.4) the rotating junction box may house fibre optic transmitters and receivers. This overcomes the problems caused when transmitting light energy from a fixed junction box to a rotating junction box. The signal passing between junction boxes remains electrical which is more compatible with the slip ring assembly.

6.2.2.3 Slip Rings

The slip rings provide the interface between the fixed junction box and the rotating junction box.
Figure 6.20 illustrates the operation of the slip ring.

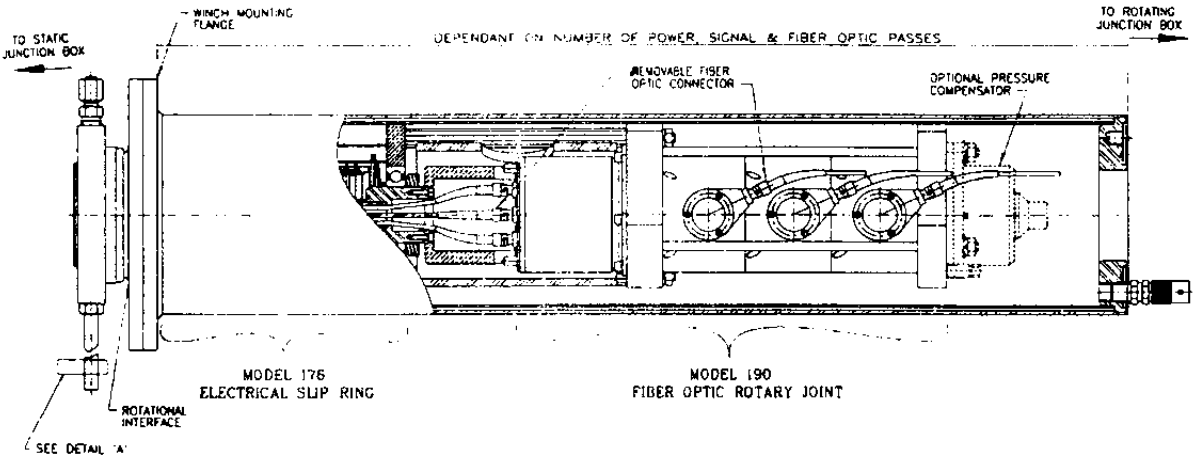


Figure 6.20

The unit consists of a number of contacts known as brushes (one brush per conductor) mounted on a central core which is static and directly connected to the fixed junction box. The core is mounted in a cylinder which is free to rotate and is directly coupled to the winch drum. Inside the cylinder there is another set of contacts that make physical contact with the brushes on the static core. It follows therefore that electrical continuity is maintained at all times during the rotation of the winch drum. The slip ring in Figure 6.20 also incorporates a fibre optic rotary joint which allows light signal from the static junction box to pass through a prism network which in turn directs the light onto a lens. The lens then converges the light onto a receptor in the rotary section of the joint before it is sent down the umbilical. It becomes obvious that the efficient functioning of the whole system is dependent on the integrity of the slip rings and for this reason they are manufactured to a high degree of quality. Correct maintenance is crucial, an outline of which is referred to in chapter 11.

6.2.3 Umbilicals

The umbilical provides the electrical link between the surface and the ROV Umbilicals may be armoured depending on whether they are required to lift the vehicle out of the water during the recovery operation. The lifting strength is provided by a steel wire wrap that surrounds the umbilical. Umbilicals of this nature are heavy and require dedicated winches.
Figure 6.21 illustrates a typical umbilical for a work class vehicle.

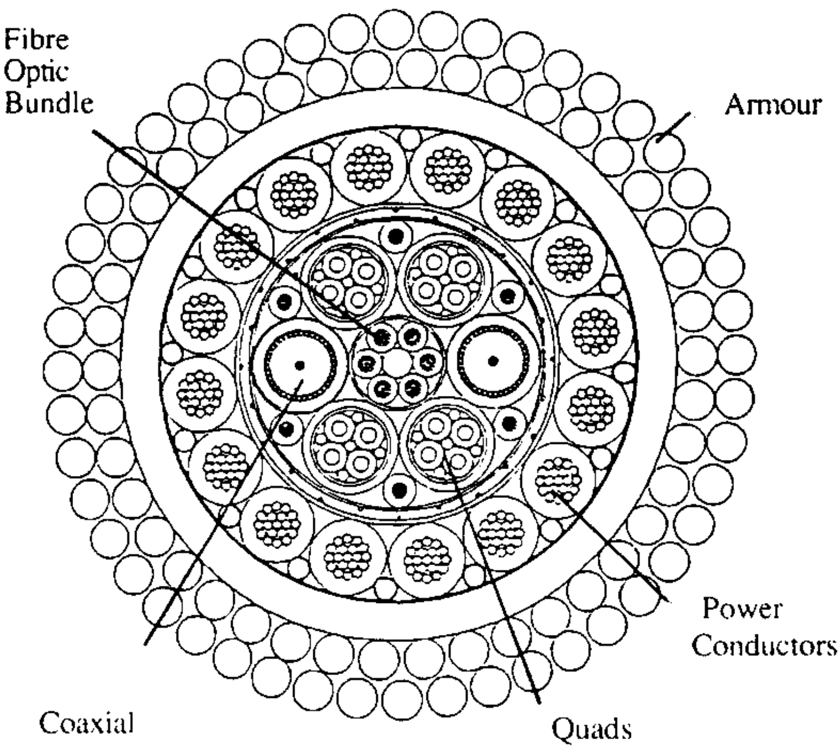


Figure 6.21

6.2.3.1 Types of conductor

This umbilical consists of the following conductors:

a) 16 Power conductors, each phase being spread over 4 conductors. In this case 4 conductors act as neutral line.

b) 4 Quads. A quad consists of two wires called 'twisted pairs'. The twisted pair carry the telemetry signals and data up from the sensors. For this reason the twisted pairs are screened to protect the signal from external interference.

c) 1 Fibre Optic bundle. These fibres may be used to carry video or any form of digital signal as required.

d) 2 Coaxial Cables. Coaxial cable is normally used to carry video signal from the vehicle to the surface unit.

The Quads and coaxials are shielded by a copper braiding. If this was not the case the high voltages in the power conductors would lead to severe interference and corruption of the data signals.

It should be noted that if fibre optic bundles are incorporated in the umbilical, because of their delicate structure, they are usually placed in the centre to minimise breakage due to bending of the umbilical.

The conductors are enclosed in a plastic sheathing which provides insulation and protection. This would be a standard umbilical and would not be suitable to lift the vehicle. By covering in armour the umbilical is then given its lifting capabilities.

6.2.3.2 Safety Factors

During launch and recovery operations the umbilical is often wavering at head height. If extreme care and attention is not exercised at all times then severe injury or even death can occur to careless personnel. It is the responsibility of the ROV team to make everyone aware of these dangers during the launch / recovery period.

6.2.3.3 Umbilical Breakdown

Conductors within the umbilical can break due to excessive tension or severe twisting or bending. Faults of this nature can lead to long periods of down time and the pilot should always be aware of the umbilicals state during diving operations.
The maintenance and repair of umbilicals is covered in chapter 11.

6.2.4 Garages And Cages

Many ROV systems employ a garage or cage which houses the vehicle during the launch / recovery process. In this situation the vehicle will be protected from possible damage whilst passing through the 'splash zone'.

Small ROVs are limited at what depth they can work due to the drag factor of long lengths of umbilical. This problem is overcome by deploying the vehicle in a garage, once at the working depth the vehicle only has a short distance to 'swim' in order to reach the work site. By working from the garage the large drag factor has been eliminated.

The garage employs what is known as a **Tether Management System** (TMS). The TMS controls the paying out and reeling in of the umbilical during the diving operation.

The TMS is controlled by the pilot from the control cabin. The TMS control signals pass down an armoured lifting umbilical in the same format as the ROV control signals. They are then processed in the TMS electronics bottle and used to control the appropriate hydraulic valve. The ROV umbilical is housed on a hydraulically controlled drum. From this the umbilical passes through a system of guides and rollers that maintain the correct tension on the umbilical whilst paying out and reeling in. A pan and tilt camera is also fitted to the system to aid the pilot when latching and unlatching the ROV.

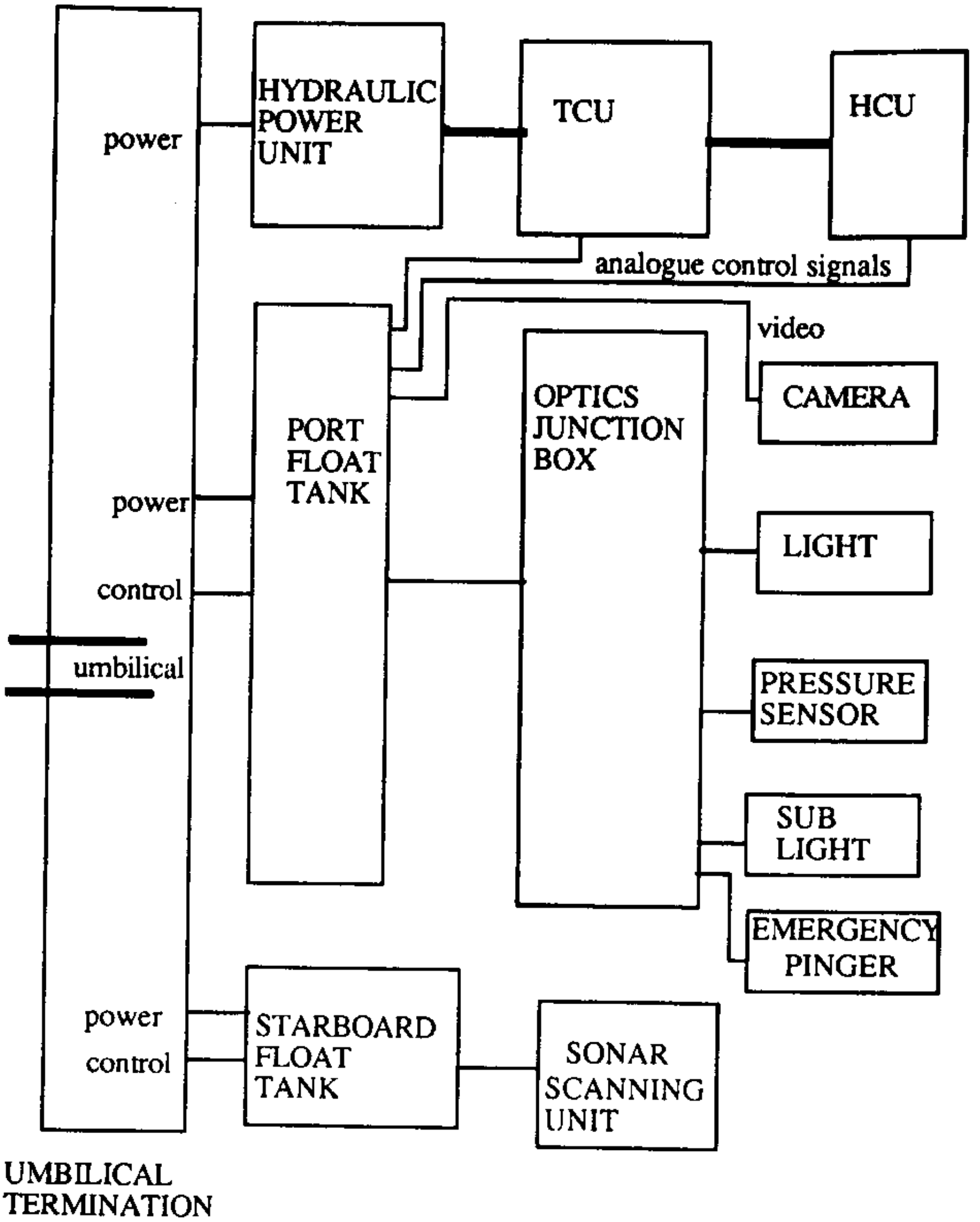

power
HYDRAULIC POWER UNIT
TCU
HCU
analogue control signals
video
PORT FLOAT TANK
OPTICS JUNCTION BOX
CAMERA
power
LIGHT
control
umbilical
PRESSURE SENSOR
SUB LIGHT
EMERGENCY PINGER
power
control
STARBOARD FLOAT TANK
SONAR SCANNING UNIT
UMBILICAL TERMINATION

Figure 6.23

6.2.5 Vehicle Electrical System

Figure 6.23 illustrates the basic electrical units of the ROV

6.2.5.1 Umbilical Termination

The umbilical is terminated in an oil filled junction box which is compensated (see chapter 8). The signals are routed through dedicated subsea connectors to the relevant units.

6.2.5.2 Hydraulic Power Unit (HPU)

Three phase power is supplied to an electric motor which is directly coupled to the hydraulic pump. On some systems the power signal may pass through a step down transformer prior to reaching the motor. When the hydraulic power is switched on at the surface a control signal is sent via the systems data communication link an activates a relay and applies the power to the electric motor.

6.2.5.3 Port float tank

The actual layout of the electronics for ROVs varies from vehicle to vehicle depending on its workscope. For example an ROV that is intended for mainly survey operations will possibly have an extra pressure vessel incorporated into its design to house the necessary electronics.
This particular example of ROV incorporates two float tanks. The telemetry circuits along with the power supplies sensor cards, and gyro will be housed in this tank. The port and starboard float tanks are electrically connected as the main system power supplies also supply the equipment in the starboard float tank.

6.2.5.4 Starboard float tank

The starboard tank may house the electronic circuits that control the survey equipment. This example illustrates the sonar scan assembly power being derived from the starboard float tank. There may also be power supplies housed in here to drive various other pieces of survey equipment such as profilers, pipetracker or sidescan units.

6.2.5.5 Optics junction box

The optics junction box is a unit that is common to most work class /large inspection class vehicles. It is simply an oil filled junction box that may distribute power to the vehicle lights, compass and other sensors. The diagram illustrates the typical situation in which the power for each light comes in on a common cable (typically 120VAC per light), it is then distributed to various lamps situated around the vehicle.

6.2.5.6 Vehicle lights

The number of lights on ROVs varies considerably and depends on the number of cameras fitted and the task to be carried out. The operation is standard and consists of a relay or power control module dedicated to each lamp. The relays are 'switched' by control signals from the surface and once energised connect power to the relevant lamp.

6.2.5.7 Thruster control unit

The hydraulic operation of the thruster control unit (TCU) has been discussed in Chapter 8. The unit receives a varying analogue signal from the **Servo Driver Cards** housed in the main electronics bottle or in the case of figure 6.7. the port float tank. The servo driver card consist of a group of amplifiers that boost the control signal to a suitable level to drive the servo valves in the TCU.

6.2.5.8 Hydraulic control valves (HCU)

The hydraulic operation of this unit has also been discussed in chapter 8. This unit receives analogue signal of a positive or negative polarity depending on the direction that the manipulator limb or pan and tilt unit is required to move.

6.2.6 Auto control functions

The task of flying the ROV is made easier by the inclusion of Auto Control functions into the vehicle electronics. These functions normally include Auto Heading and Auto Depth.

6.2.6.1 Gyrocompass

The auto heading function operates on a similar principle to a ships auto pilot in the sense that it will remain on a pre-determined heading so long as the function remains selected.

The ROV is fitted with a Gyroscope which is basically a 'mass' spinning on an axis. If a right angle force is applied to a gyroscope then the unit will try to exert an equal and opposite force in order that it may return to its central axis. In practice the gyro is powered by an electric motor and it is imperative that its speed is sufficient in order that it does not topple.It is also important that the gyro is aligned with the earth's magnetic field, this is achieved by incorporating what is known as **Flux Gate**.

A flux gate is a transformer with one primary winding and two secondaries. The secondary windings are connected in opposition, the induced fields will therefore cancel each other out. Each secondary coil interacts with the earth's magnetic field in such a way that it is in addition with one field and in opposition with the other. This gives rise to a voltage being induced into the secondary windings. As the flux gate is rotated the magnitude and phase of these induced voltages changes in sympathy with the changing earth's magnetic field.

It follows therefore that the difference between the phase of the primary and secondary voltage is proportional to the magnetic heading of the flux gate. The signal that is produced by this phase difference is mechanically coupled to the gyro thus permanently aligning it to magnetic north. In general the gyro is 'slaved' to the flux gate and its output is controlled by the earth's magnetic field. This situation is undesirable when the ROV is in close proximity of steel structures whereby the magnetic field may become distorted. To overcome this the gyro may be decoupled from the flux gate and allowed to run in 'free drift' mode.

The output from the three synchro phases is converted into a voltage which is proportional to the vehicle heading. This voltage is then input to the vehicle multiplexer system and produces either a digital or analogue compass heading at the control console.

6.2.6.2 Auto heading

On selecting the auto heading function the output of the gyro is constantly monitored and compared to a reference voltage. The resultant 'error' signal is processed and fed to the thruster control circuits. The thrusters act in such away as to reduce the error signal and thus maintain the vehicle on a fixed heading.

6.2.6.3 Auto depth

The auto depth function works on a similar principle to the auto heading in that a voltage that is derived from a pressure sensor is compared to a reference signal. The resulting 'error' signal is applied to the vertical thruster which acts in such a way as to counteract the change in depth.

Auto functions in their simplest form require the pilot to switch the device on at the surface. The vehicle is totally controlled by the auto function in this state and the pilot has to physically switch the device off to regain control. More complex systems allow the pilot to make fine adjustment using trim controls.

6.2.6.4 Trim controls

Trim controls allows the pilot to apply a control signal to the ROV from a source other than the joystick. The sources are usually in the form of a single turn potentiometer which maintain a fixed control signal to the vehicle as oppose to the pilot determined signal from the joystick. The commonest trim controls are:

a) Forward / Reverse trim. (cruise control)

b) Vertical Up / Down trim

c) Lateral Port / Starboard trim

The principle of operation is the same for each trim in that the potentiometers 'add' a signal to the main input control signal. They are useful when flying the vehicle into a current or if the vehicle is being subject to a cross current. The pilot can use these controls to make the flying operation less strenuous
Some systems have heading trims which can be used in conjunction with the auto heading and enables the pilot to make fine adjustment to the direction of the vehicle.

6.2.7 Sensor functions

It is essential that the vehicles overall condition of operation is constantly monitored in order to minimise unnecessary breakdown time. The following items are monitored.

a) Oil Temperature.

b) Oil Pressure.

c) Oil level.

d) Water ingress.

e) Water ingress to connectors.

The sensors operate on a similar principle in that a transducer monitors the pressure or temperature and converts this to a DC voltage. These signals are multiplexed and travel on the vehicles 'up' data link.

The water ingress sensors are located in the pressure vessels and usually consist of two contacts located at the lowest point of the vessel. Any water ingress will short these contacts together and form an electrical circuit.

The resistance between all the conductors that are attached to the relevant subsea connectors is also monitored. If water ingression takes place at the connector then the resistance will fall and provide a readout at the surface unit. The resistances may be displayed on a bar chart on the surface display and are commonly termed IRs. They may be AC or DC depending on the circuit being monitored.

6.3 Telemetry

6.3.1 Introduction

Section 6.2 of this chapter discussed the basic electrical units and various sensors that are found on ROV systems. It also discussed the method by which the vehicle is controlled from the surface unit.

It is now necessary to look at how control and sensor information is transmitted between the surface unit and the vehicle. The system that carries out this task is commonly known as the **Telementry System.**

6.3.2 Analogue Signals

Analogue signals vary continuously with time and assume any amplitude level within the limitations of the electronic circuitry. It is these types of signals that are produced by the potentiometers in the joystick control. Figure 6.24 shows a typical output signal, in analogue form from a control joystick. It follows that the output from the joystick potentiometer must be transmitted via the umbilical to the thruster control circuitry on the ROV. During this process this signal would be subject to line losses and distortion due to the physical properties of the conductors in the umbilical.

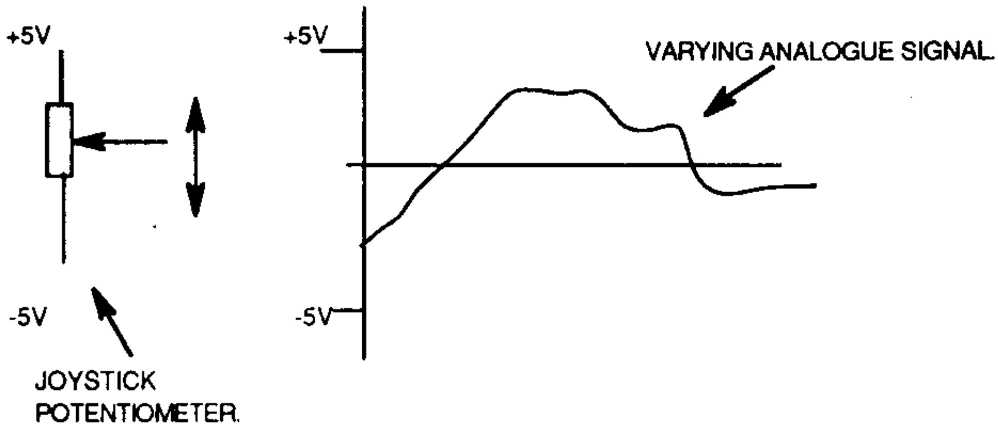


Figure 6.24

6.3.3 Digital Signals

Digital signals are not continuous as are analogue they have two discreet levels, one level is a constant positive voltage and the other is zero volts. Figure 6.10 shows an example of a digital signal. It follows therefore, that a simple on/off signal will still be susceptible to line losses and distortion but will however, be easier to 're-shape' once it has travelled through the umbilical. For this reason the analogue signal is converted into a 'train' of digital pulses known as a 'word', a particular output voltage level at the joystick will have a dedicated digital code:

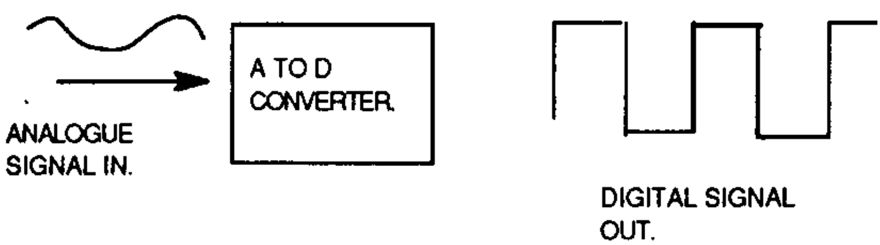


Figure 6.25

6.3.4 Line losses

Line losses is a condition that effects electrical signals when they are transmitted through conductors. Physical properties of metal conductors are such that they will absorb some of the signal being passed through them, thus resulting in line loss.

6.3.5 Data Transmission

All the commands for the ROV are sent via a two wire screened data link known as a twisted pair. The function of the data link is as follows:

a. Reduces the number of conductors in the umbilical by using a two wire link.

b. Connects surface master controls to the ROV

c. Time Division Multiplexing increases data handling capacity.

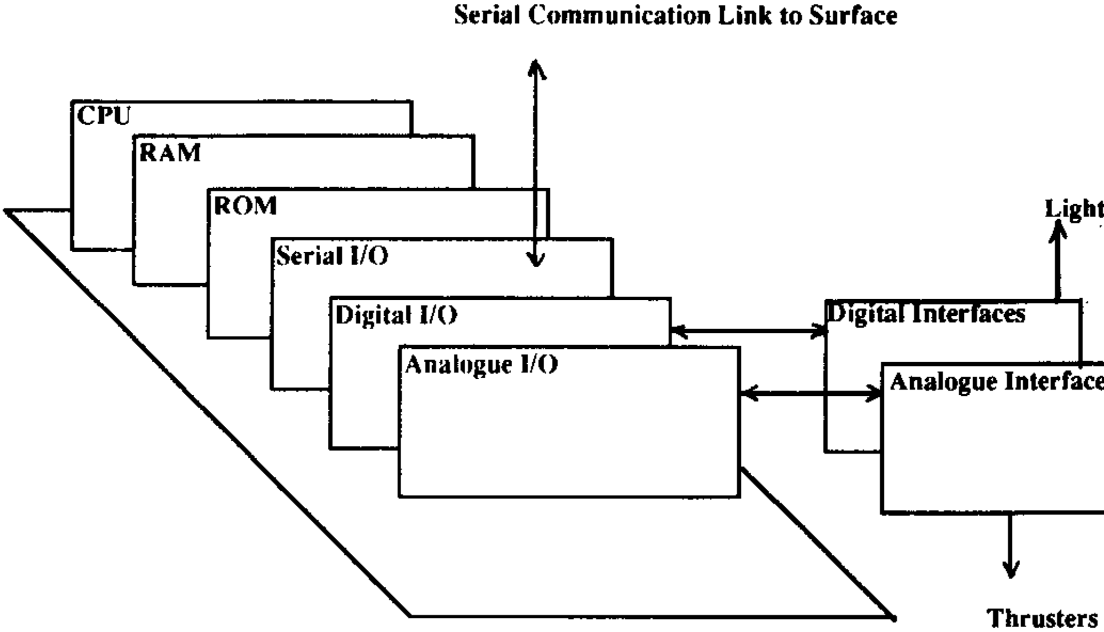


Figure 6.26

6.3.6 Time Division Multiplexing

Figure 6.26 illustrates a standard multiplexing system. Command signals are digitilized and continually sampled. Each sample is known as a 'word' normally consisting of digital bits which are multiplexed to form a 'frame'of serial data. The frame normally consists of 16,32 or 64 words. When using 64 words the system is said to have a 64 channel multiplexer.
The system illustrated above is controlled by a standard microprocessor that processes the serial data and interfaces it to the analogue and digital control circuits.
Information from the vehicle sensors is also processed by the multiplexer and sent to the surface via the data link, the system therefore operating in simplex mode.

6.3.7 Word format

Each word is comprised of a standard number of bits. Many systems use a format known as Manchester Biphase in which each word comprises of 24 bits. Bits 1,2 and 3 are the synchronising pulse which initiates the decoding circuitry. Bits 4 to 11 contain address information which activates the appropriate multiplexer channel. Bits 12 to 23 contain data information from the actual command. Bit 24 is a parity check bit.

6.3.8 SELMEC System

The standard multiplexer discussed so far is controlled by one standard processor along with one set of interface cards. This system has its disadvantages in the fact that one card will lead to total system failure and there is a possibility of system overload.
The Slingsby Engineering Limited SELMEC utilises individual processor and interface cards throughout the system. For example the thrusters, manipulators, sensors and lights have separate processor and interface cards that are totally isolated from each other. The advantage of this system is that faults can be easily isolated and expansion is easy.

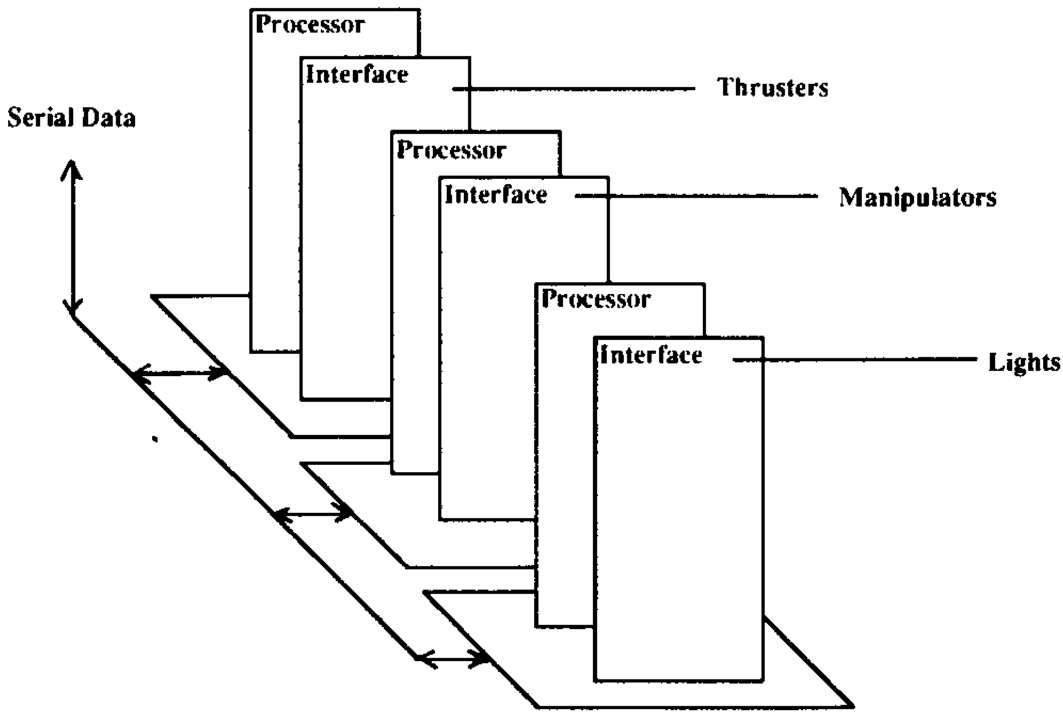


Figure 6.27

6.4 Fibre Optics

6.4.1 Introduction

Line transmission has, over the years steadily improved. The last twenty years has seen revolutionary innovations such as digitalisation and optoelectronics dramatically alter technology and cost effective of data transmission. It is only recently that the ROV industry has made use of Optical Fibre data transmission in the transmission of telemetry and video signals.

6.4.2 Theory

The principles of optical fibre transmission makes use of theories that have been known to man for centuries. Fig 6.28 illustrates how a light beam behaves when it passes from one medium to another of different densities. It can be seen that when a beam of light is directed at a transparent medium (glass), although some of the light is reflected back into the originating medium (air), a high proportion of the light will pass into that medium.

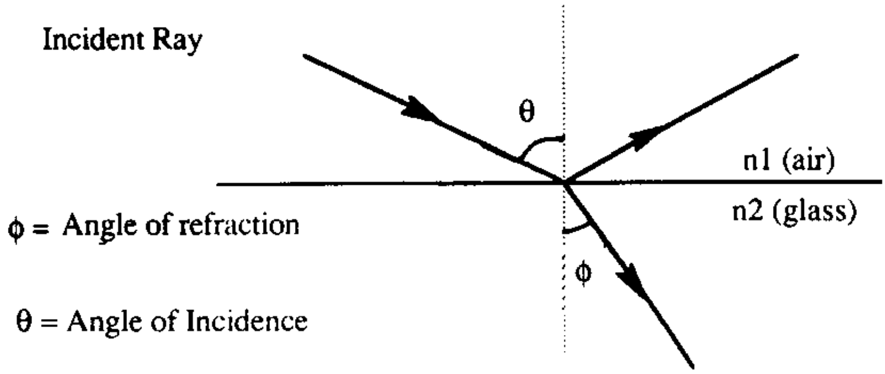


Figure 6.28

6.4.3 Refractive Index

Refractive index refers to the optical density of a material. It is a direct proportion between the velocity of light in a vacuum to the velocity of light in the material.

$$\text{Refractive index} = \frac{\text{Velocity of light in vacuum}}{\text{Velocity of light in medium}} = n$$

The refractive index is given the symbol n.

6.4.4 SNELLS LAW

Willebrord Snell put forward a theory that claimed that the sine of the angle of refraction (ϕ) depended upon the sine of the angle of incidence (θ). He claimed that the ratio of the sine of angle of incidence to the sine of the angle of refraction is a constant.

$$\frac{\sin\theta}{\sin\phi} = \frac{n1}{n2}$$

Where n1 and n2 are the refractive indices of the material through which the light is passing.
Fig 6.29 shows how a beam of light behaves when passing through a glass block.

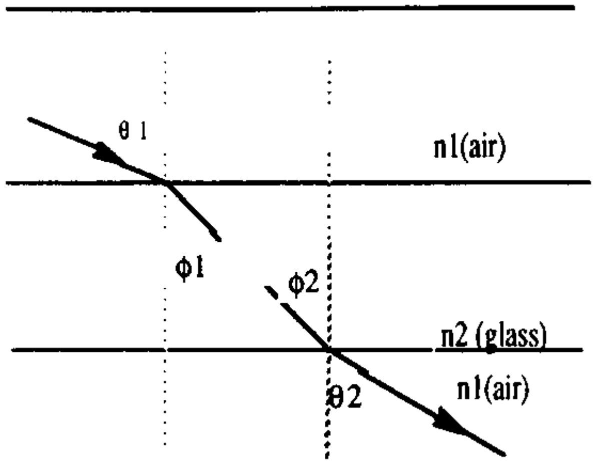


Figure 6.29

Because the glass/air boundaries are parallel then (θ1) must be equal to (θ2).

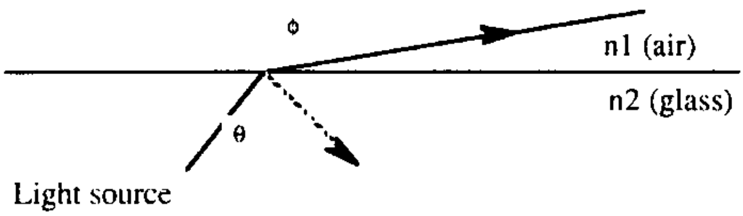


Figure 6.30

Figure 6.30 shows the situation in which light is passing from a dense to a less dense medium i.e. glass to air.In this situation n2 is greater than n1 and therefore the angle of refraction (ϕ) is greater than the angle of incidence(θ).
If the angle of incidence is increased still further then we can see in figure 6.31 that the angle of refraction will eventually exceed 90 degrees. At this point the light will become TOTALLY INTERNALLY REFLECTED.

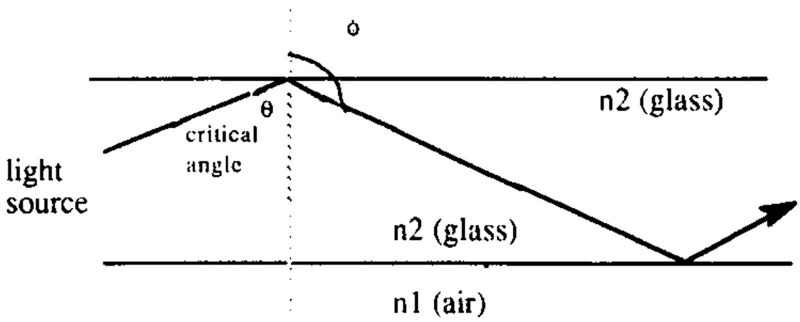


Figure 6.31

It is the principles of Total Internal Reflection that is made use of in the transmission of light through an optical fibre. The glass tube acts as a guide for the light beam, as the light is trapped inside the glass, then any bends that occur in the glass are insignificant. It is necessary however to surround the glass in a cladding, the refractive index of which is slightly less than the glass, in order to minimise dispersion and therefore any significant losses.

NOTE: The angle of incidence that causes the angle of refraction to be greater than 90 degrees is known as the CRITICAL ANGLE and is roughly 42 degrees for glass, with a refractive index of 1.5.

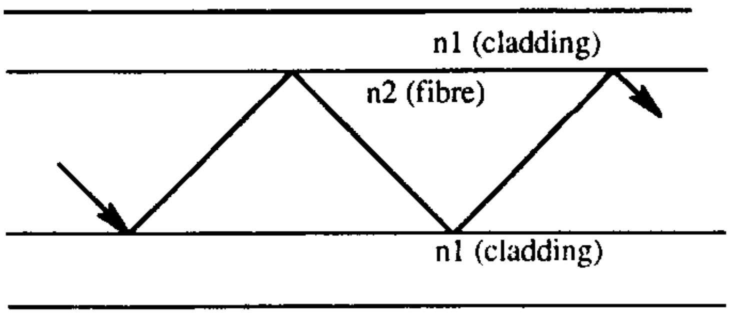


Figure 6.32

Fig 6.32 shows a situation in which the light beam is totally internally reflected through cladded fibre.

6.4.5 Light Transmitters

In order to convert electrical energy to light energy an Optoelectronic semi conductor such as a Light Emitting Diode (LED) or laser diode is used.

NOTE: Light that is emitted from an LED is quite safe to the naked eye, however light emitted from a laser diode is potentially lethal and great care must be exercised when using such devices.

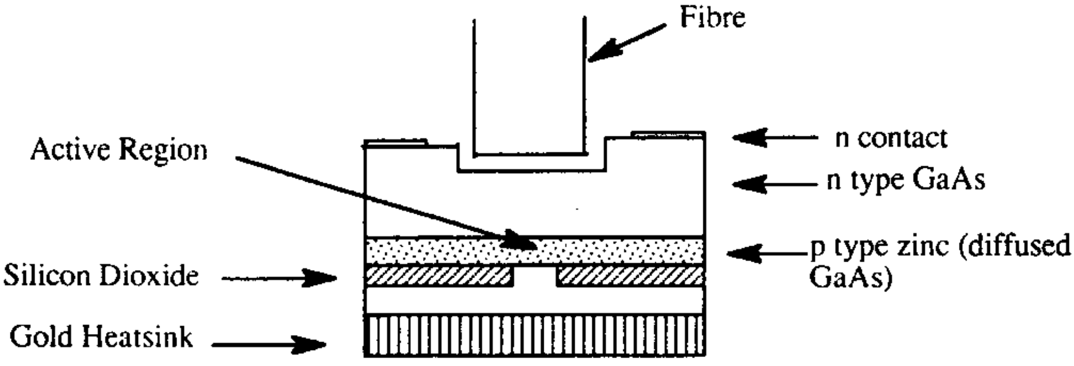


Figure 6.33

Fig 6.33 shows the typical construction of an LED

The applied electrical signal gives rise to the Gallium Arsenide producing "excited" electrons that travel from the p type to the n type material. During this process they produce light energy, a process known as SPONTANEOUS EMISSION.

6.4.6 Receivers and Photodiodes

A photo diode converts light energy back to electrical energy. They are similar to LED's in the fact that the photons (light energy) give rise to the flow of current between the P-N junction.

6.4.7 Types of Fibre

There are two types of fibre commonly available, Stepped index and Graded index fibre.

6.4.7.1 Stepped Index Fibre

As previously stated, propagation along paths is possible once the incident ray has reached the critical angle, (approximately 42 degrees). However this situation gives rise to an increase in attenuation and dispersion losses.
By making the fibre core extremely narrow (approximately 50 micro metres), and enclosing it in a cladding of refractive index which is only slightly less than that of glass, we can not only reduce the critical angle but also reduce losses.
A fibre constructed in this manner is known as step index fibre and is suitable for short distance transmissions as found in ROV umbilicals.

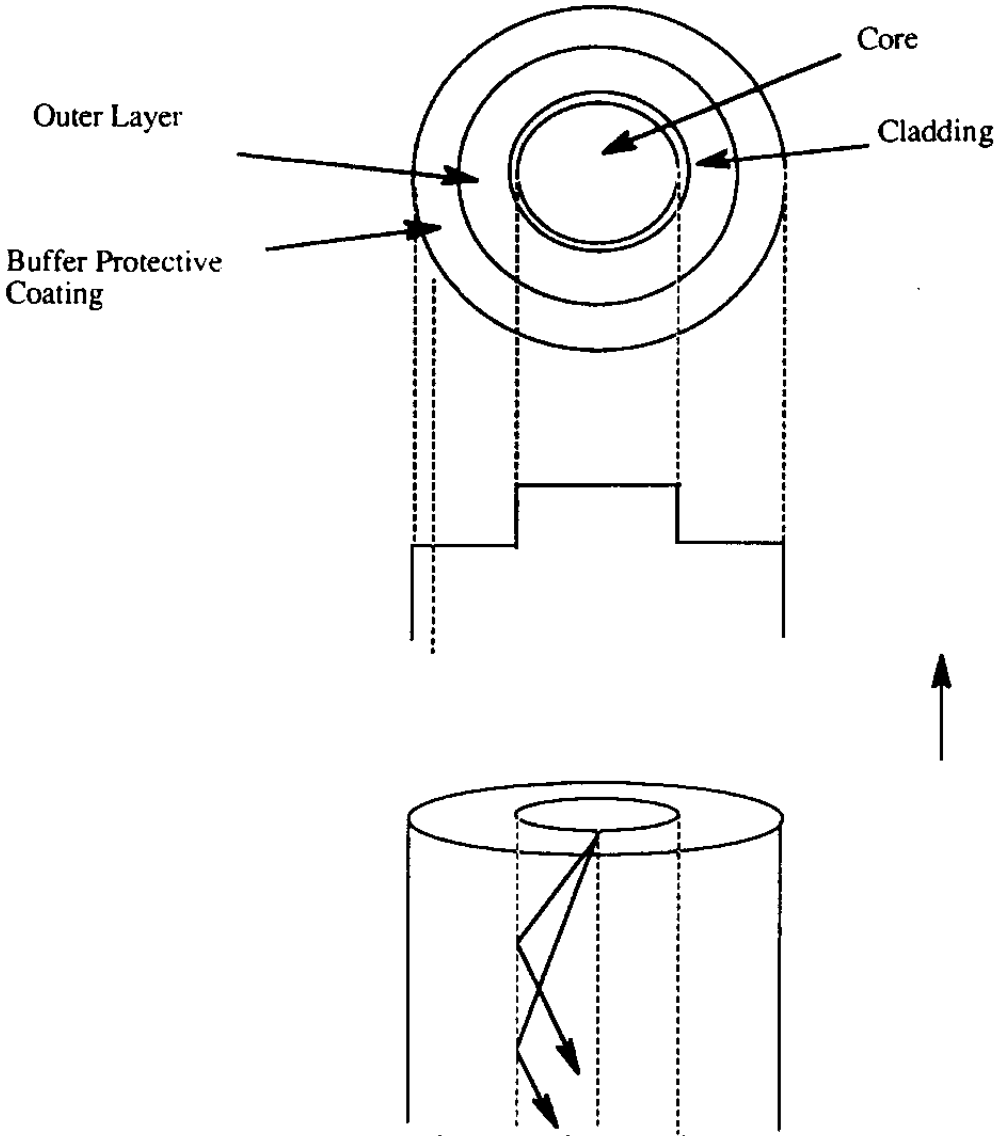


Figure 6.34 Stepped index Fibre

6.4.7.2 Graded Index Fibre

The disadvantage of step index fibre is that the bandwidth of transmission is limited due to the different optical wave lengths caused by the various speeds at which light is propagate.
This can be overcome using graded index fibre. Graded index fibre differs from step index fibre in the fact that the cores refractive index decreases parabolically with radial distance.
The main advantage of using graded index fibre is the low refractive index at the centre of the fibre. This is useful when coupling the sharply focused beam of an LED with the fibre.

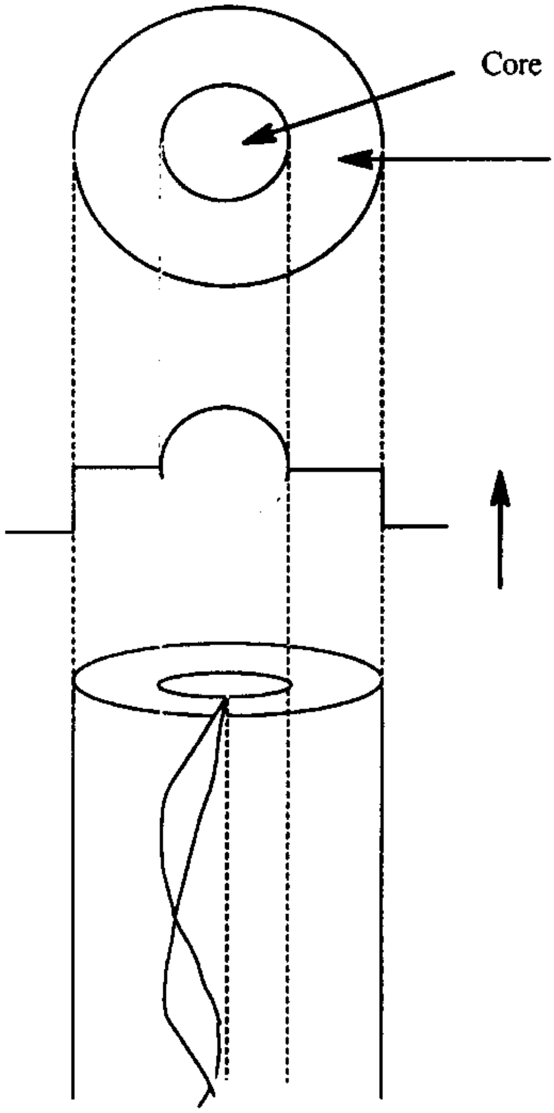


Figure 6.35 Graded index Fibre

6.4.8 Fibre Optic Connectors

It is not the intention of this chapter to list all the fibre optic connectors available. That is adequately covered in the appendix section.
However it is essential that the correct procedure for re-terminating an optical fibre connection is followed in order to minimise unnecessary breakdown time.
The following section lays down the procedure for assembling a STRATOS SS430-01 to a fibre optic bundle. This type of connector is incorporated in many of Slingsby Engineering Ltd ROV fibre optic systems.

6.4.9 Umbilical Optical Termination - Vehicle

The following procedure relates to the assembly of the [redacted] to a tight jacket fibre optic bundle containing 900mm secondary coated fibres, within an umbilical cable. The following equipment will be required:

a Heat curing jig (temperature controlled):

b Stratos tool kit;

c Micropolisher;

d Optical Cable Fault Locator (OTDR);

e Connectors, leads and splices as required;

f Hot air gun;

g Disposable syringes, 5ml and 1ml;

h Stratos syringe needle;

g 19g syringe needle;

h Scalpel;

It will also be necessary to have the following materials:

a ConnectorStratos SS430-01-1.0

b Heatshrink sleevingRaychem Atum 3/1, 6/2, 12/4 and 1/16" RNF 100 or similar;

c Solvents2-propanol (isopropyl alcohol)
Dichloromethane (or paint stripper)
White spirit or trichloroethylene

d Epoxy ResinEpo-tek 360

e Spiral Cable Wrap3mm

f Abrasive Paper360 grit wet and dry

g Abrasive Film30mm, 12mm and 3mm

6.4.9.1 Process Instructions

a Switch on the heat curing jig and set to 95 deg. C.

b Prepare Epo-tec 360 resin as follows:

i. Draw up the required volume of resin (part A), into the 5 ml syringe (allow 0.5 ml per plug) noting that the calibration does not include the volume contained in the nozzle. Withdraw the plunger further to leave an equal volume of airspace above the resin.

ii. Draw up the corresponding volume of hardener (part B), (mix ratio 10:1 by volume) into the 1 ml syringe with the 19 g needle, ensuring that there are no air bubbles and that the needle is full when making the measurement.

iii. Inject the hardener into the resin by entering the needle into the syringe through the nozzle. Mix the resin and hardener by blocking the nozzle and shaking the syringe until an even colour is achieved. Pay particular attention to the material which may become trapped in the nozzle.

iv. Degas the material by holding the syringe nozzle upwards and expel all the air above the resin. Cover the nozzle and draw a vacuum by withdrawing the plunger. Repeat this operation until only a few large

bubbles form. Wipe the syringe nozzle and fit the Stratos needle. Leave the resin to stand for ten minutes before use.
The pot life of the mixture is approximately eight hours at room temperature.

v. Strip 500 mm of sheath from the fibre optic bundle and remove the tape wrap and filler compound.

vi. Cut the centre strength member approximately 50 mm from the cut end of the sheath.

vii. Place 100 mm length of 12/4 heatshrink on the bundle and temporarily position out of the way, by sliding along the cable.

viii. Place onto each fibre in the following order:
   (a) 50 mm length of Atum 6/2;
   (b) 100 mm length of Atum 3/1;
   (d) 150 mm length of RNF 100-1/16"
   (e) Stratos nut (female thread towards end of fibre);
   (f) Crimp sleeve (shouldered end first if applicable);

viii. Strip 50 mm of coating from the fibre using 'No-Nik' tool (or similar) avoiding damage to the fibre.

ix. Immerse the exposed fibres in dichloromethane to remove the remaining buffer. If necessary wipe the fibre with a clean dry tissue. (If using paint stripper, remove residue by wiping with tissue soaked with 2-propanol).
The bare fibre is very susceptible to damage and contamination, do not touch or leave exposed for any longer than necessary.

x. Check that the plug is clear by sighting through, if not, remove white plastic cap and then replace the cap and re-check, Support the crimp sleeve at the end of the coating and assemble the plug, guiding it carefully over the fibre and onto the crimp sleeve, up to the shoulder.

xi. Crimp plug in position: Place the plug in the small jaws. Operate the lever to hold the plug (do not crimp yet). Push the crimp sleeve fully into the plug. Crimp the plug without moving the plug, sleeve or fibre. Once the crimping operation has started, it cannot be aborted.

xii. Using the cleaving tool, touch the fibre flush with the face of the mounting cap and remove the excess fibre by bending it away from the scratch.
Excessive force when scratching the fibre will displace or damage the fibre inside the plug.

xii. Using the back of a scalpel blade and the thumb as a lever, carefully remove the white plastic cap. Remove the cap without twisting.
Examine the end of the plug to check that the fibre is centralized between the balls, then fit the moulded silicone reservoir cap.
Do not attempt to refit the mounting cap after removal. If the fibre is trapped between a pair of balls, or outside them, carefully depress one of the balls with the tip of a scalpel to allow the fibre to return to the centre. Do not touch the fibre.

xiii. Expel the air and a few drops of resin from the syringe to ensure the nozzle is clear. Hold the plug assembly vertical with the reservoir upwards and drop 2-3 drops into the reservoir, taking care not to touch the fibre.

xiv. Clean the needle and insert it into the injection hole in the plug body. Withdraw the plunger to suck the resin into the nose of the plug, if any air enters the syringe remove the needle from the plug and expel the air before continuing. Inject resin slowly into the plug until it reaches the top of the reservoir, tip out resin and repeat until three cycles with no bubbles have been observed. Remove the needle from the injection port and seal the hole with the plastic plug. Wipe away any traces of resin from the plug body.

xv. Check the temperature of the curing jig is 95 deg. C. +/- 5 deg. C. Clamp the plug(s) in the heating block. Take care to avoid trapping the plastic plug. Do not move the reservoir, which, if moved, will allow resin to contaminate the nose of the plug. Allow the resin to cure until 1.5 to 2 mm of cured resin is visible above the plug (cured resin is a red/brown colour). Remove the plug and allow to cool to room temperature.

xvi. Carefully twist and pull off the reservoir. Wipe away the remaining liquid resin. The cured resin should not be allowed to extend further than 3 mm nor should it be left for more than eight hours before removing the reservoir, otherwise, difficulty will be experienced in removing the reservoir without causing damage to the potting in the plug nose.

xvii. If the reservoir appears to be stuck, cut through with side cutting pliers 2-3 mm above the plug nose, and peel off the remaining silicone moulding. Do not exert any sideways force on the resin, which could result in damage to the fibre within the plug.

xviii. Remove the plastic plug.

6.4.9.2 Polishing

a Using 360 grit paper, sand off the protruding resin until the 3 balls are just visible.

b Polish the plugs using Stratos tools with 3M abrasive films in the following order:

i. Tool number 491 with 30mm film (green)
ii. Tool number 492 with 12mm film (yellow)
iii. Tool number 493 with 3mm film (pink)

c Thoroughly wash the plug to remove debris from previous operations and rinse through the polishing tool. Blow off excess water and assemble the plug into the tool and secure with the collar nut. Wet the glass plate and abrasive film and place the film on the plate. Flood the surface with water and polish the plug using a figure of eight or circular motion progressing across the film such that the abrasive is used for one pass only. Keep the film wet during polishing.

d Light pressure only is required on the tool; when cutting is complete a decrease in resistance to motion will be apparent and no track will be left on the abrasive. Rinse the tool under running water and remove the plug.

e Remove abrasive film and rinse off debris, store for further use, (an A4 sheet of abrasive has sufficient area for the polishing of 6 plugs).

f Repeat the operation using the tools and abrasives in the order listed in 6.4.9.1. To avoid damage to other plugs, ensure that the final polish with the pink film is complete.

g Dismantle and rinse the tool and plug in water then re-assemble and polish again with the final tool until no further material is removed. Dry the plug using a clean paper towel paying particular attention to water remaining in the nut and fit the white protective cap.

6.4.9.3 Final Assembly and Testing

a Test each plug using the OTDR with at least 50 m launch length. Typical loss between the two types of fibre will be 2 dB to 4 dB although the system will operate with higher losses.

b When using light-source/power-meter test instruments records should be kept of measured values for reference when fault finding and re-terminating, allowance for shortening of the cable should be made at 3 dB/km (850 nm) or 1 dB/km (1300 nm).

c Slide the 1/16" heatshrink up to the back of the plug and shrink down taking care not to overheat the fibre. Slide the 3/1 heatshrink over the crimped end of the plug allowing 1 to 2 mm for Stratos nut movement and shrink down. Slide the 6/2 heatshrink onto the plug over the previous layer to the same position and shrink down.

d Identify fibres with number sleeves over the plug body, ensuring that the numbers co-incide at both top and bottom of the umbilical by reference to the wiring diagram or discarded umbilical end.

e Wrap the fibres, from the sheath onto the large heatshrink, with the 3 mm Spirawrap as far as the plug body.

f Lay the fibres back into the helix of the bundle and position the heatshrink over the end of the sheath projecting 50 mm beyond the end and shrink down.
Before making connections, ensure plugs and couplers are clean. If dirty, clean with a paper towel soaked in 2-propanol.
JB1 couplers are fitted with an internal 'O' ring on the outboard side only. This is to allow the connector faces to free flood with oil thus avoiding collapse under pressure. Couplers mounted inside junction boxes should have both internal 'O' rings removed.

6.4.10 Umbilical Optical Termination - Surface

The following procedure relates to the assembly of Stratos ST optical fibre connector to

a tight jacket fibre optic bundle containing 900mm secondary coated fibres, within an umbilical cable. The same equipment will be required as laid out in 6.4.9 with the following differences: a rubber mat is required with the micropolisher; no 1 ml syringe, 19g syringe needle, nor scalpel, is required. It will also be necessary to have the following materials:

a ConnectorStratos ST-MC-128 (or ST-LC-128) including white nylon crimp sleeve;

b Heatshrink sleevingRaychem Atum 6/2 and 12/4, 1/16" RNF 100or similar

c Solvents2-propanol (isopropyl alcohol)
Dichloromethane (or paint stripper)
White spirit or trichloroethylene

d Epoxy ResinEpo-tek 353 ND

e Spiral Cable Wrap3 mm

f Abrasive Film12 mm, 3 mm, and 1 mm

6.4.10.1 Process Instructions

a Switch on the heat curing jig and set to 90 deg. C.

b Prepare Epo-tek 353 ND resin as follows:

i. Open the sealed sachet and remove the 'Squish Pack'. Inspect for damage.

ii. Remove the dividing seal between resin and hardener by pulling the pack on either side, do not attempt to slide it as this may puncture the pack. mix the two components by kneading the pack gently with the fingers until the colour is uniform and no streaks remain.

iii. Remove the plunger from the syringe, cut the corner off the squish pack and transfer the resin into the syringe, avoiding trapping air.

iv. Degas the material by holding the syringe nozzle upwards and expel all the air above the resin. Cover the nozzle and draw a vacuum by withdrawing the plunger. Repeat this operation until only a few large bubbles form. Wipe the syringe nozzle and fit the Stratos needle. Leave the resin to stand for ten minutes before use.
The pot life of the mixture is approximately four hours at room temperature.

v. Strip 500 mm of sheath from the fibre optic bundle and remove the tape wrap and filler compound.

vi. Cut the centre strength member approximately 50 mm from the cut end of the sheath.

vii. Place 100 mm length of 12/4 heatshrink on the bundle and temporarily position out of the way, by sliding along the cable.

viii. Place onto each fibre to be terminated (in the order shown):
(a) 50 mm length of Atum 6/2

b) 100 mm length of Atum 3/1

(c) 150 mm length of RNF 100-1/16"
(in oil filled junction boxes only - in dry boxes use boot supplied with plug trimmed to suit coating diameter)

(d) Crimp sleeve (for ST-LC-128 - white end first)

ix. Strip 50 mm of coating from the fibre using 'No-Nik' tool (or similar) avoiding damage to the fibre.

x. Immerse the exposed fibre in dichloromethane to remove the remaining buffer. If necessary wipe the fibre with a clean dry tissue. (If using paint stripper, remove residue by wiping tissue soaked with 2-propanol).
The bare fibre is very susceptible to damage and contamination, do not touch or leave exposed for any longer than necessary.

xi. Check that the plug is clear by sighting through, then fully insert the syringe needle into the back of the plug and inject until a bead of resin appears through the other end of the plug. Remove the syringe whilst still injecting to leave resin in the back of the plug - approximately half fill the receptacle.

x. Support the crimp sleeve at the end of the coating and assemble the plug, guiding it carefully over the fibre and onto the crimp sleeve, as far as it will go without forcing it. Maintain light pressure until any excess resin flows out; carefully wipe resin off without moving the plug.

xi. Crimp plug in position: place the plug in the small jaws. Operate the lever to hold the plug (do not crimp yet). Push the crimp sleeve fully into the plug. Crimp the plug without moving the plug or sleeve.
Once the crimping operation has started, it cannot be aborted.

xii. Check the temperature of the curing jig is 90 deg. C. +/- 5 deg. C. Clamp the plug(s) in the heating block. Allow the resin to cure until the bead of resin on the end of the plug is a red/brown colour. (Approximately 20 - 30 minutes depending upon ambient temperature). Remove the plug and allow to cool to room temperature.

xiii. Using the cleaving tool, touch the fibre flush with the bead of resin and remove the excess fibre by bending it away from the scratch. Excessive force when scratching the fibre will damage the fibre inside the plug.

6.4.10.2 Polishing

a Examine the end of the plug for exposed fibre and, if necessary, lightly polish with dry 12 mm film to remove the glass only.

b Fit the plug into the polishing tool.

c Place the rubber mat on the glass plate. Wet the mat and 12 mm film and place on the mat. Flood the surface with water and lightly polish the plug using a figure of eight or circular motion progressing across the film such that the abrasive is used for one pass only. Keep the film wet during polishing. Regularly examine the plug face until only a thin film of resin in the centre of the face remains.

d Remove the mat from the glass. Wet the glass and 3 mm film and continue polishing. Light pressure only is required on the tool. Regularly examine the plug face until no resin is visible on the ceramic face of the plug.

e Repeat the operation for the remaining plugs.
To avoid damage to the other plugs, ensure that the final polish is complete.

6.4.10.3 Final Assembly and Testing

a Test each plug using the OTDR with at least 50 m launch length. Typical loss between the two types of fibre will be 1 dB to 2 dB although the system will operate with higher losses.

b When using light-source/power-meter test instruments records should be kept of measured values for reference when fault finding and re-terminating, allowance for shortening of the cable should be made at 3 db/km (850 nm) or 1 db/km (1300 nm).

c Slide the 1/16" heatshrink up to the back of the plug and shrink down taking care not to overheat the fibre. Slide the 3/1 heatshrink up to the back of the plug and shrink down. Slide the 6/2 heatshrink onto the plug over the previous layer and shrink down. Ensure the final layer does not foul the sprung sleeve of the plug.

d Identify fibres with number sleeves over the plug body, ensuring that the numbers correspond at both top and bottom of the umbilical by reference to the wiring diagram or discarded umbilical end.

e Wrap the individual tubes from the sheath onto the heatshrink with the 3 mm Spirawrap as far as the plug body.

f Lay the fibres back into the helix of the bundle and position the 12/4 heatshrink over the end of the sheath projecting 50 mm beyond the end and shrink down.
Before making connections, ensure plugs and couplers are clean. If dirty, clean with a paper towel soaked in 2-propanol.

6.4.1.1 Optical Time Domain Reflector (OTDR)

The OTDR is probably the most common piece of test equipment used in the maintenance of ROV optical fibre systems.
This instrument is used for measuring transmission performance, attenuation (i.e. loss verses distance) in situations where fibres have been repaired.
The operation of OTDRs makes use of the principle that the time taken for a pulse of light being transmitted and thus reflected can be measured. It is therefore possible to locate faults over a known length of fibre.

6.5 Fibre Optic Safety Guidlines

This ROV system includes a fibre optic transmission system which contains a **Laser** capable of emitting harmful radiation at a wavelength not visible to the human eye. The following guidelines must be understood to ensure the safety of all personnel.

1) **Never Look Directly Into a Laser Beam** from a bulkhead fitting or a fibre tail when the laser is switched on. Protective covers and/or shielding should be used where necessary to prevent this possibility.

2) **Never Use Optical Viewing Instruments** (ie microscopes) when checking for optical power. The ROV system will have power meters and light sources suitable for checking the continuity of an optical fibre link.

3) **Never Inspect Polished Connectors or Terminations** before ensuring that the laser is switched off and the ROV OCU **Power** is **Isolated** and **Locked Off** at the PDU.

When handling fibre optic cable the following safety information should be understood by all personnel.

1) **Never Casually Discard Glass Fibre Shards** always use the "Sharp Safe" box supplied with each system for proper disposal.

2) **Never Leave Spare Fibre Loose**, always ensure that spare or disused fibres are sealed and protected with heatshrink.

3) **Wear Safety Glasses** when handling the exposed ends of tether and umbilical cables containing optical fibres.

4) **Ensure "Laser Warning" Labels** are displayed on all junction boxes and enclosures containing fibre-optic connections and terminations.

CHAPTER 7 USE OF TEST EQUIPMENT

7.0 Introduction

It cannot be emphasised enough to the ROV Pilot/Technician just how important it is to have a thorough understanding of the basic test equipment available. In general, the vast array of settings on a multimeter can be off putting to the novice technician and confusion tends to arise when the new operator fails to appreciate the basic theory behind the various electrical quantities being measured.

7.1 Electrical Quantities

The quantities and qualities that are of interest to the technician are:

7.1.1 VOLTAGE AC/DC

7.1.2 CURRENT AC/DC

7.1.3 RESISTANCE

7.1.4 CONTINUITY

7.1.5 INSULATION

The theory of those various electrical quantities that are measurable is discussed in chapter 6.

7.2 Measuring Voltage

The unit Volt refers to the potential of electrical charge at a given point in a circuit with respect to 0V or ground as it is commonly known. Depending on the system being tested the voltage may be AC or DC. The diagram below shows a typical situation where voltage is being measured:

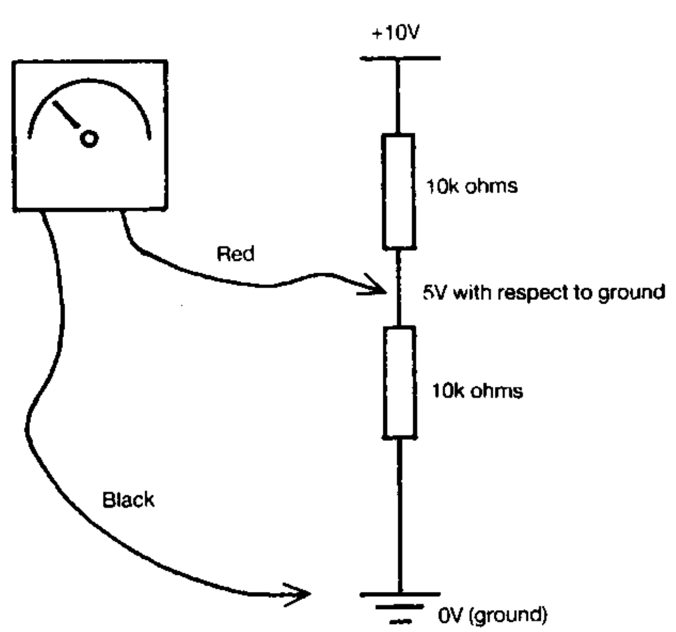


Figure 7.1

7.3 Measuring Current

As with voltage, current may be AC or DC and care must be taken to ensure that the meter is at the correct setting. It may be necessary to re-insert the positive meter lead (red) in another socket for current measurement. Current is a movement of electrical charge through a circuit and therefore the circuit must be 'broken' and the meter inserted in series to obtain the correct measurement. The diagram below shows an example of current measuring:

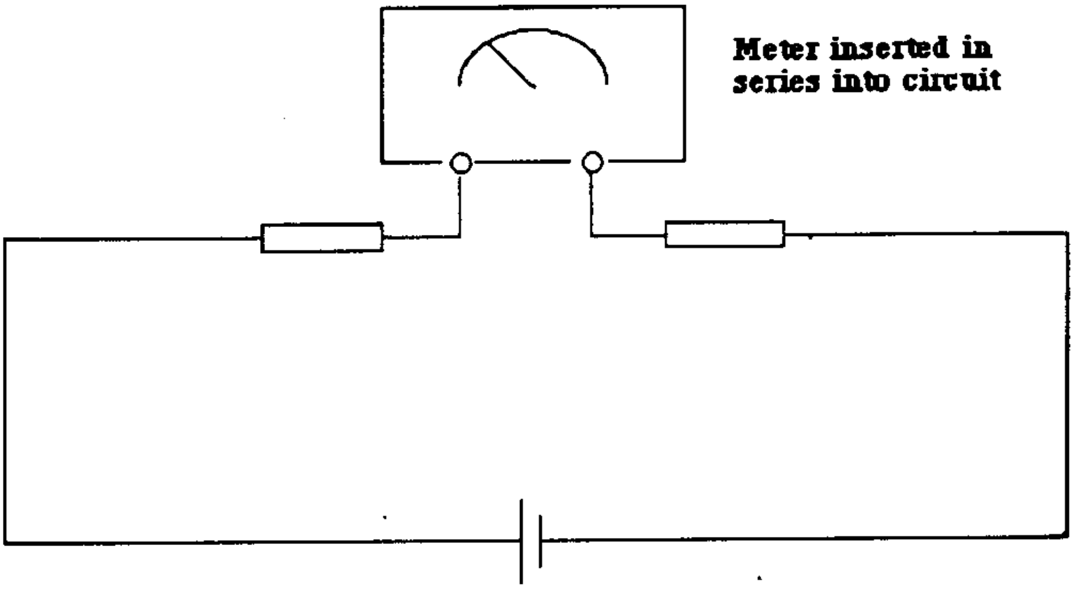


Figure 7.2

7.4 Measuring Resistance

Measuring resistance is quite straight-forward as the meter has only one set of ranges as opposed to voltage. When measuring resistance it is important to switch off the equipment that is being tested. Any components that are being tested should ideally be out of circuit. This is due to the fact that surrounding components may be in parallel with the component being tested and will in effect produce a lower resistance value.

7.5 Continuity Testing

When carrying out fault diagnosis, continuity testing tends to be one of the most common test procedures followed by the technician. The test indicates whether or not there is an electrical connection between two points in a circuit. In the ROV industry continuity testing is predominantly used in order to test subsea cables for conductor breakage. Most multimeters have a dedicated switch setting for continuity testing. This position is indicated by a symbol depicting a diode and an audio tone as indicated in figure 7.3. A tone will be heard provided there is less than a certain value of resistance in the circuit. (This varies from meter to meter, typical examples are 50 ohms or 100 ohms.) This means the tone may not operate on a long length of cable.

Figure 7.3

On placing the test leads on relevant points in a circuit, a bleeping sound will be heard if there is continuity. The test can also be carried out by setting the meter to resistance. Obviously if there is continuity the meter will read close to zero Ohms. The disadvantage of this method is that the operator has to physically look at the meter as opposed to simply listening for an audio tone.

7.6 Insulation Testing

Insulation testing is probably the most common form of test carried out in the ROV industry. Subsea cables and connectors are under constant stress from factors such as high subsea pressure, vibration and corrosion. These factors can lead to a break down in the insulation between the conductors which will eventually lead to a short circuit. For this reason it is important to regularly test the insulation resistance between all conductors in a cable. The test meter used is known as a **Megger Meter**. It is important to appreciate that by just measuring the resistance with an ordinary multimeter we could not determine how the cable would perform in a realistic situation i.e. carrying high voltages. By using a megger meter we in fact apply a high voltage e.g. 500v and measure the resistance at the same time. In practice the meter has two test leads which may be fitted with crocodile clips in order to ensure the safety of the operator. The meter can be set to measure in excess of 200 Megohms. When connected up the operator pushes the test button which applies the voltage. The resistance is indicated by a moving needle. A cable should ideally have infinite resistance between its conductors. The following precautions should be noted when using a megger meter:

7.6.1 Disconnect all cables from any electronic circuitry.

7.6.2 Do not touch probe conductors when carrying out megger test.

7.6.3 Always discharge cables when test is completed. Adjoining conductors will have capacitive properties which may store charge.

7.7 Types of Meter

There are two types of meter commonly available to the engineer.

(a) ANALOGUE METERS

(b) DIGITAL METERS

7.7.1 Analogue Meters

Analogue meters usually incorporate a pointer which can move over a scale and can, within limits, assume any reading i.e. they can indicate continuously any magnitude of voltage or current. There are many types of instruments that fall into this category, but the most common is the moving coil meter.

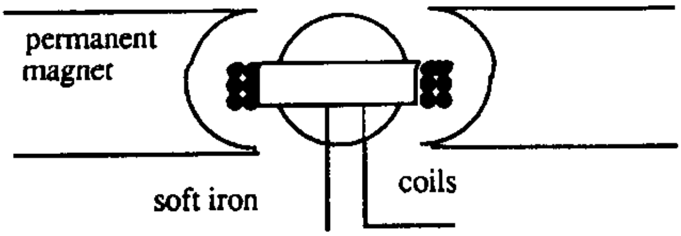


Figure 7.4

The moving coil meter consists of an aluminium former which is pivoted at each end so that it is free to rotate in a magnetic field. Fine copper wire is wound around the former through which current is passed. The magnetic field is produced by shaped permanent magnets, the magnetic circuit is completed by a cylinder of soft iron, so that only a narrow gap remains through which the coil swings. The coil is therefore, positioned in a magnetic field of uniform strength and direction. When current is passed through the coil it takes up a position depending upon the magnitude of the current. The moving coil meter uses the principles of the electric motor which is covered in chapter 6 of this book. Obviously the accuracy of this meter depends on user interpretation of pointer position. To reduce reading error a narrow needle is used and the scale fitted with a mirror. The user simply aligns the needle with its reflection. The magnitude of current that can be measured depends on the resistance of the coil. In order to measure larger currents a resistor is connected in parallel with the coil, this is known as a 'shunt' resistor. The moving coil meter may also be used as a voltmeter by connecting a resistor in series with the coil, the resistor is known as a multiplier. With the aid of an internal battery the moving coil meter is capable of measuring resistance. For electronic servicing work a meter that is capable of measuring all electrical quantities is used, this is known as an **Avometer**.

7.7.1.1 Multipliers.

This section discusses the principles of using a multimeter to measure voltage by incorporating a multiplier resistor. In this example the meter has an internal resistance of 1kΩ and a full scale deflection of 40µA. This simply means that the meter needle will be deflected across the full range when a current of 40µA is passed through it.

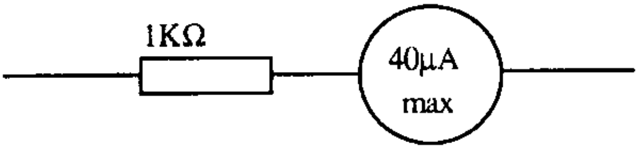


Figure 7.5

$$\text{Max voltage} = 1k\Omega \times 40\mu A$$
$$V = 0.04V$$
$$V = 40mV$$

Therefore this meter in its 'raw' state could only read up to 40mA or 40mV. If we wish to read higher voltages or currents we need to adapt the circuit.

Placing resistors in series will increase the voltage measuring capability, resistors in parallel will increase the current measuring capability.

Example: If the above meter was to measure 1 Volt, what series resistance would be required?

Total resistance must equal; 1 volt/40μA= 25kΩ (R = V/I)

Therefore a 24kΩ resistor is required in series with the 1kΩ resistance as shown in figure 7.6

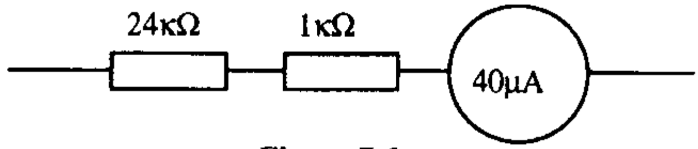


Figure 7.6

This is termed a multiplier and enables use of the meter as a voltmeter.

7.7.1.2 Shunts

In order to read current, a parallel or shunt resistance is required in circuit.

Example: If we wish the same meter to read 10mA f.s.d., what value of shunt resistance is required?

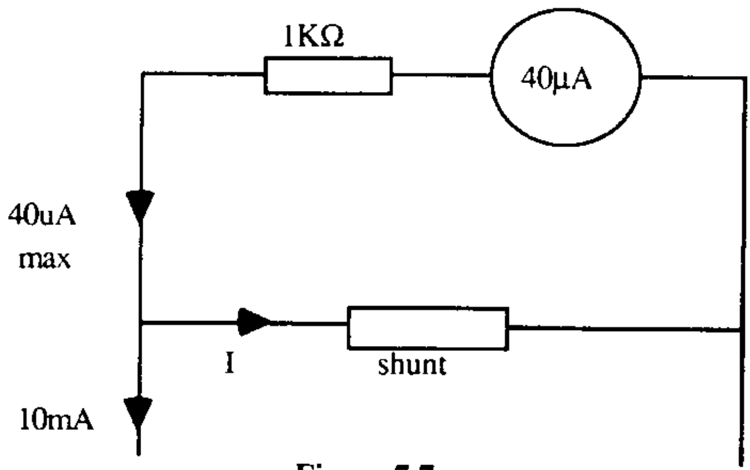


Figure 7.7

$I = (10\ mA) - (40\mu A) = 9.96mA$

$V = 40uA \times 1k\Omega = 40mV$

$R = V/I$

$R = 40mV / 9.96mA$

$R = 4.02\Omega$

Example: What value of shunt is required to make a 40μA, 10kΩ meter read 1A f.s.d.?

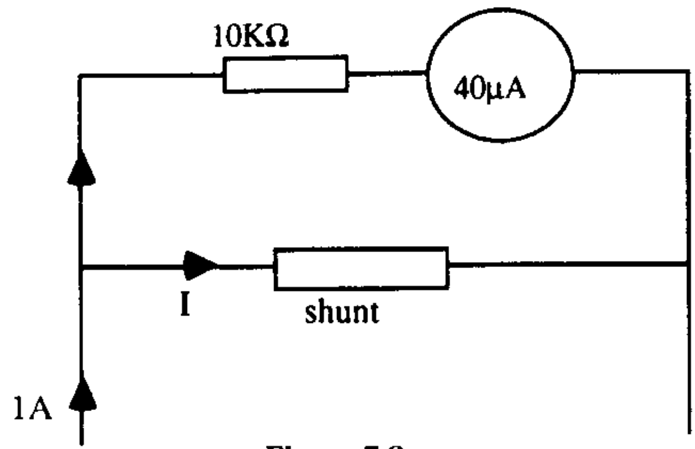


Figure 7.8

$I = 1 - 40\mu A$

$I = 0.99996A$

$V = I \times R$

$V = 40\mu A \times 10k\Omega$

$V = 0.4V$

Shunt resistance = 0.4V / 0.99996A

Shunt resistance = 0.4 Ω

7.7.2 Meter loading effect

The process of using shunts and multipliers means that our meters have a specific resistance value for each voltage range on the meter. This resistance is conditional on the range in use and is normally quoted in kΩ /V e.g. an AVO Model 8 has 20 kΩ /V on both the ac and dc voltage ranges. This means that on the 1V range the meter system has 20kΩ resistance, while on the 5V range it has 5 x 20kΩ =100kΩ .

This has serious implications when measuring small voltages across high resistance's.

Example: What voltage should be measured in the circuit below and what voltage would be measured assuming that the meter is an AVO 8 (20kΩ /V) on the 5V range?

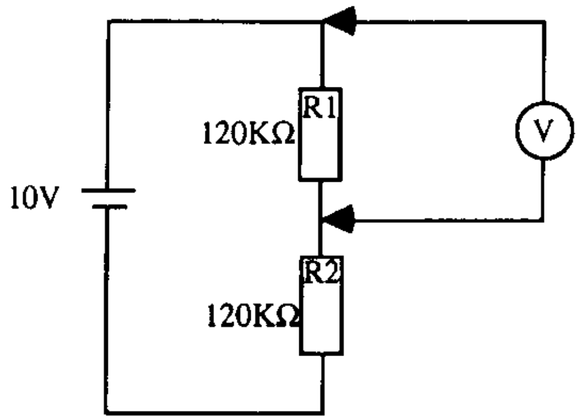


Figure 7.9

Expected voltage: 5 V

Measured voltage:

Meter resistance	= 5 x 20kΩ = 100kΩ
Total circuit. resistance	= 54.5K + 120kΩ
	= 174.5kΩ
Current drawn	= 10 / 174.5kΩ = 57.3μA
Voltage across R2	= 57.3μA x 120K = 6.876V

Therefore voltage across R1 and meter = 10 - 6.876 = 3.124V

7.7.3 Digital Meters

Digital meters give a direct read out that is free from human error. The instruments have no moving parts and are generally less expensive than analogue meters.

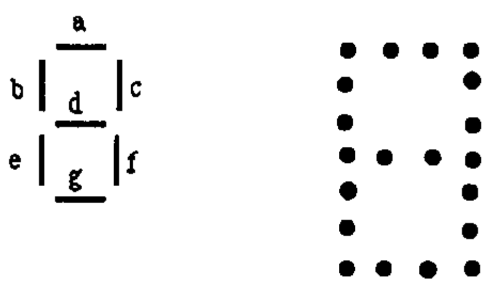


Figure 7.10

The diagram above shows the typical layout for a digit on a meter. Each segment may be represented by four light emitting diodes (LED's). The LED's emit light when a suitable voltage is applied to them.

7.8 Safety Precautions

a) **Check Test Leads** for damage to insulation.

b) Always set meter to highest range before taking reading.

c) Ensure voltage being measured is within range of meter.

d) Remove any jewellery before working on live equipment.

e) If possible always work with somebody else present.

f) If possible carry out measurement using only one hand.

7.9 Oscilloscope

The cathode ray oscilloscope (CRO) is a measuring instrument in which the deflection of an electron beam displays an applied voltage.
An electron beam is directed through a vacuum on to a face plate that is coated with fluorescent powder. When the electron beam strikes the face plate it produces a spot of light on the screen. The oscilloscope incorporates a system of plates that, on application of a voltage, deflects the electron beam either horizontally or vertically. The resulting movement of the spot of light can now be used to measure the applied input voltage.
The deflection system incorporates two sets of plates known as X and Y plates, the X plates provide horizontal deflection and the Y plates vertical deflection. If the input to the deflection system is rapidly varying , persistence of vision will make the moving spot of light on the face plate appear as a continuous line.

7.9.1 Advantages of the oscilloscope

a) Low inertia of electron beam permits the measurement of rapidly changing input wave forms.

b) The deflection along two axis allows a graphical display of voltage against time.

c) Oscilloscopes have a very high input impedance which prevents the circuit under test becoming loaded.

7.9.2 The basic system

All ROV systems will have an oscilloscope included in the tool kit, many different types are in existence, however, the principles of operation are the same for all models. The oscilloscope consists of three basic blocks. These are :

a) A cathode ray tube (CRT).

b) Vertical deflection system (Y Plates).

c) Horizontal deflection system (X Plates).

7.9.3 Cathode Ray Tube (CRT)

The CRT contains an electron gun that consists of a cathode that when heated emits electrons. The electrons are accelerated towards the face plate by electrodes that also regulate the intensity of the beam. It follows therefore that these electrodes determine the brightness of the trace on the display.

The electron beam is focused by an electron lens. The electron lens achieves focusing by either electromagnetic coils or field shaping electrostatic electrodes. Most oscilloscopes use electrostatically focused tubes.

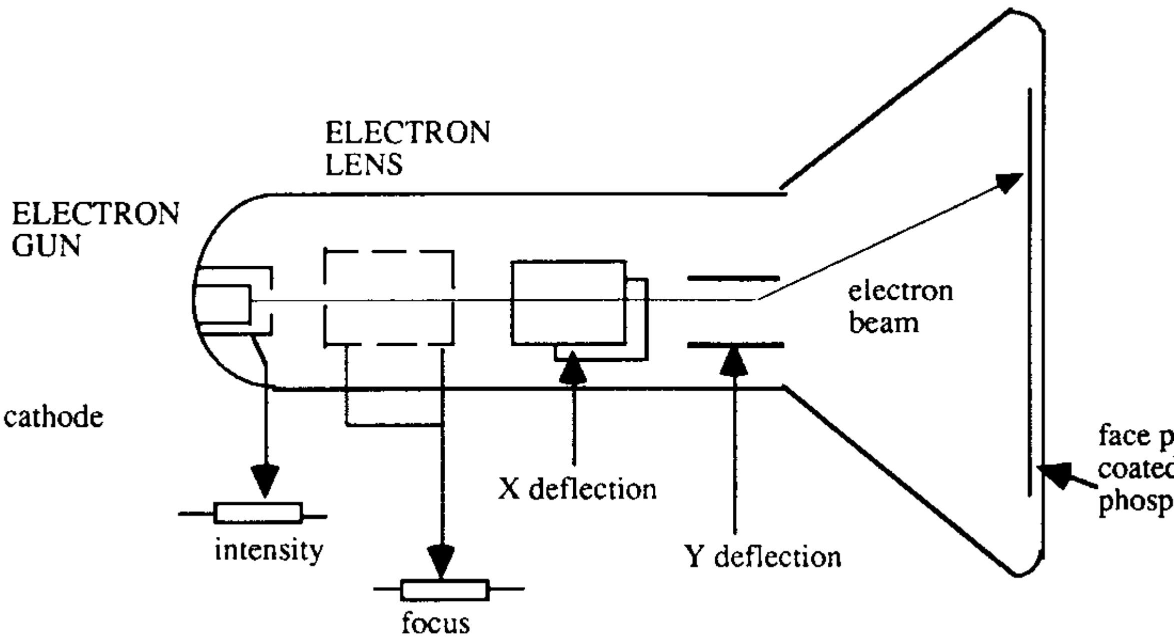


Figure 7.11

7.9.4 Vertical deflection system

The vertical axis is used to measure the magnitude of the input voltage and normally requires a voltage of between 20 and 30 volts to produce a full scale deflection of the electron beam. An amplifier and attenuator network allows a wide range of input signals to be measured, the attenuator having a switched range that is manually controlled.

The oscilloscope screen is therefore graduated with a fixed number of centimetre squares, each square representing a fixed voltage level depending on the setting of the VOLTS / DIV control.
The Y gain control is normally variable and allows the operator to make a wave form occupy a fixed number of squares. This function becomes useful when using a dual trace oscilloscope and comparison of two input signals is required. A dual trace oscilloscope, as the name implies, has two electron beams that are independently deflected allowing two signals to be displayed at once.

7.9.5 Horizontal Deflection System

In order to give a voltage against time display the spot must be made to sweep from left to right across the display. This is achieved by applying a ramp wave form to theX plates. The ramp wave form is commonly known as a sawtooth wave form and is generated by an oscillator circuit within the oscilloscope.

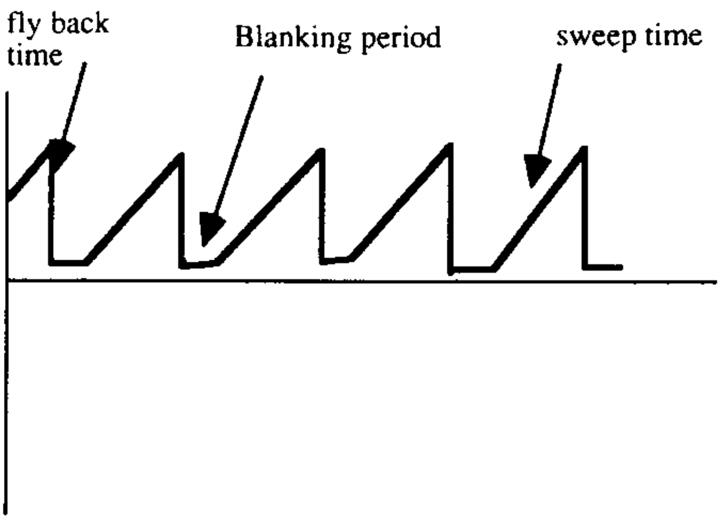
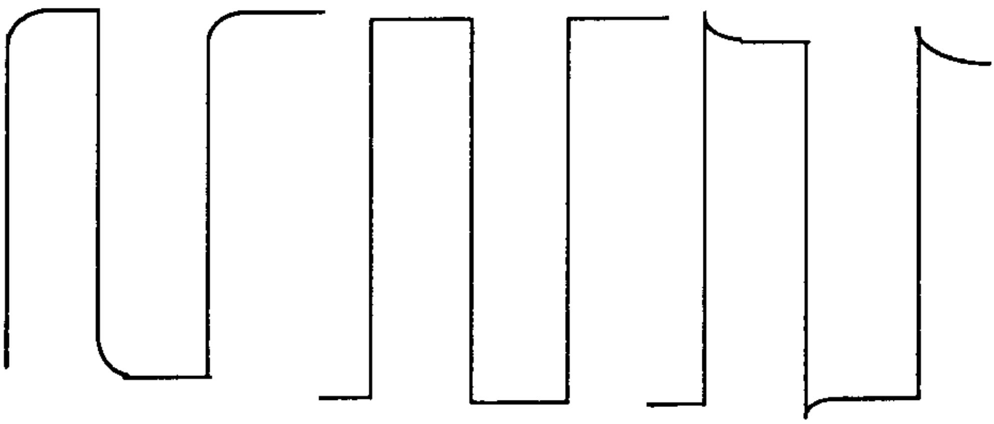


Figure 7.12

The rising edge of the SAWTOOTH gives rise to the spot moving across the display. The sharp falling edge represents the spot returning to the left hand side of the display and is known as the 'fly back' period. During this period the electron gun is turned off and therefore only the left to right trace is displayed.
The sawtooth is generated by an oscillator known as a timebase oscillator. This oscillator can generate different sweep speeds thereby altering the time it takes for the spot to sweep across one square. The timebase control determines the output of this oscillator and is calibrated in TIME / DIVISION.

7.9.6 Oscilloscope probes

Oscilloscope probes are used to detect the actual signal, they have fine metallic tips that allow measurements of signals to be made from various components on a circuit board.
The probe is connected to the oscilloscope via a screened cable. For this reason the probe has an earth clip which must always be attached to a suitable earth point on the circuit.
It is also necessary to calibrate the probe before use in order to compensate for the built in reactance. This is achieved by connecting the probe to the square wave output of the oscilloscope and altering the adjustment screw on the actual probe. This is adjusted until the square wave has a uniform shape as shown in figure 7.13



INCORRECT CORRECT INCORRECT

Figure 7.13

7.9.7 Oscilloscope controls.

Figure 7.4 illustrates the controls on a typical dual trace oscilloscope. It is not the intention of this chapter to discuss every function available as they are not normally required for the basic test procedures carried out on an ROV system. However the main controls that are necessary are outlined below.

2 POWER ON / OFF: Turns oscilloscope on and off. Operating condition is indicated by an LED.

13 X POS: Controls horizontal position of trace.

14 TIME / DIV: Selects timebase speed.

3 INTENSITY: Intensity control for trace brightness.

4 FOCUS: Focus control for trace sharpness.

1 CALIBRATOR: O.2V peak to peak square wave output for calibration of test probe.

8 Y POS: Controls vertical position of trace.

9 VOLTS / DIV: Selects sensitivity in either mV/Cm or V/Cm.

6 DC - AC - GD: Selects input coupling to either DC,AC or Ground.

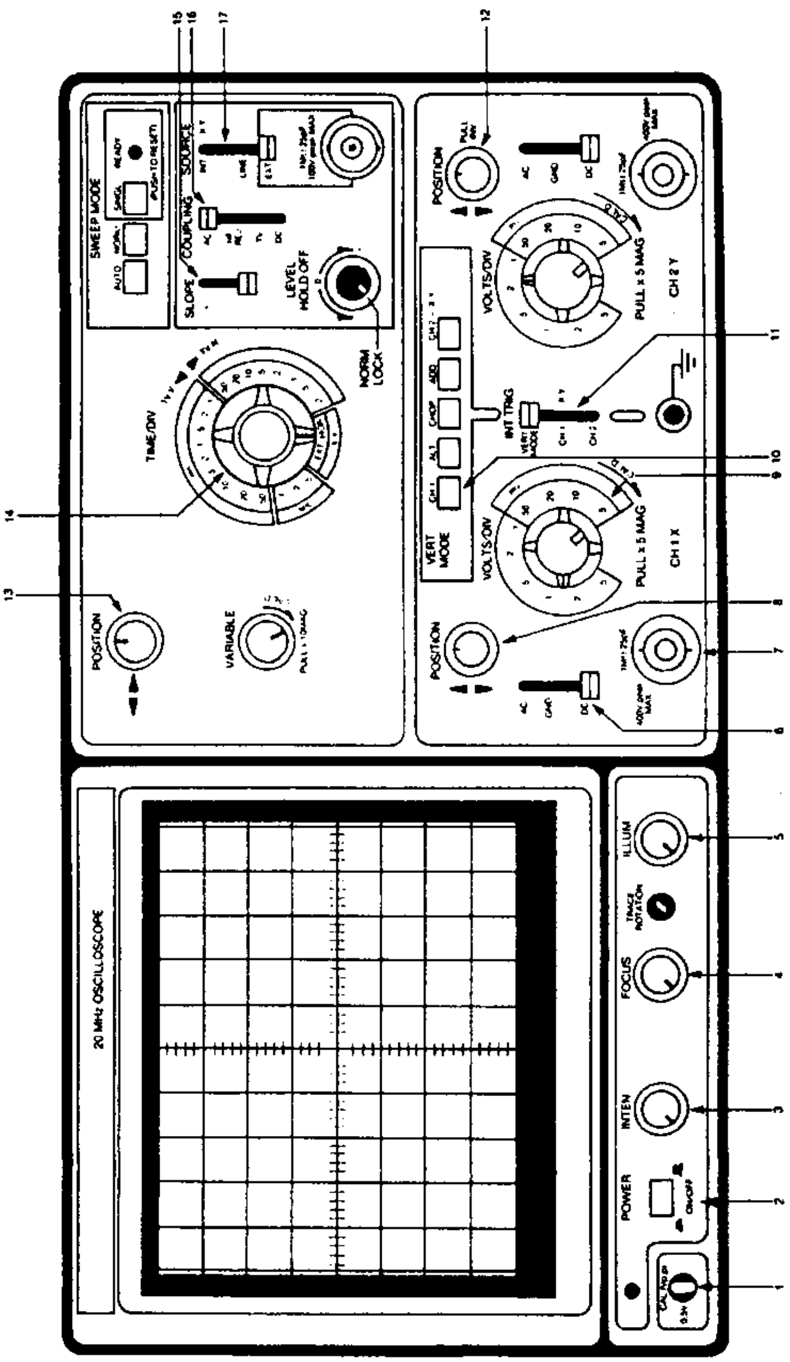


Figure 7.14

7.9.8 Typical uses of oscilloscope

Oscilloscopes do not come into everyday use as do test meters, however in certain situations they become essential to the technician. Typical tests are as follows.

a) Monitoring of video signal during either calibration of camera or fault finding on the video system. (See chapter 15).

b) Monitoring of telemetry signal during fault finding procedure.

Telemetry signals, being digital signals are best suited to being measured with an oscilloscope.
It is not possible to interpret each digital pulse, however it is sufficient to be able to step through a circuit and determine if telemetry signal is present. This enables the **technician to be able to fault find to board level or if necessary to component level.**

7.9.9 Measuring Amplitude of a Signal

The amplitude or, signal level as it is commonly known can be determined by making use of the screen graticule. By altering the VOLT/DIV control then we can select a suitable scale in order that the level of signal can be determined. For example if the VOLT/DIV is set to 2V/DIV then in the example shown the peak to peak voltage is 6V.

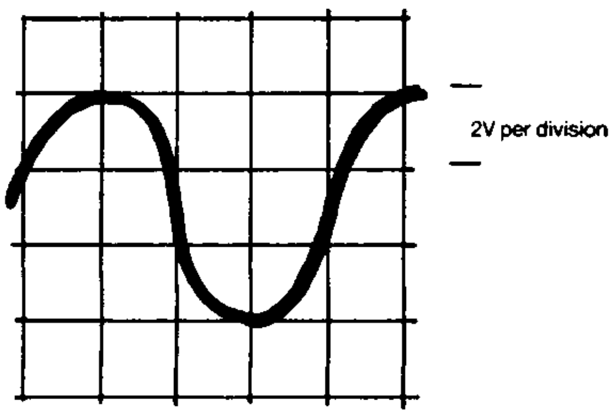


Figure 7.15

Typical VOLT/DIVISION settings may range from 5 VOLTS /DIVISION to 5mV/DIVISION.

7.9.10 Summary

It is not the intention of this chapter to discuss every function available on oscilloscopes. There are many types available and the technician would be required to read the operators manual for the particular oscilloscope he/she intends to use. However, the basic principles discussed in this section apply to all oscilloscopes.

7.10 Self Diagnostics

Many ROV systems now incorporate a surface computer that carries out a self diagnostics programme. This enables the operator to monitor signals at various points in the system.

A typical self diagnostics programme is included in the Hydrovision Diablo ROV. The following pages are available in a typical data display system.

a) **Multiplexer information:** Up link and down link data for each channel can be displayed showing each individual data 'bit'. When a function is operated the data can be seen to vary accordingly.

b) **Main display:** This page is normally displayed during diving operations and provides the pilot with vehicle heading, vehicle depth, pitch and roll, oil pressure and temperature.

c) **Thruster demand and gain:** The amount of thruster power that is being used is displayed graphically. Also the thruster gain is displayed as a percentage, it is possible to adjust the gain to suit the conditions during the dive.

d) **DC voltages:** The DC voltages at the control outputs are displayed both digitally and graphically. It is also possible to 'null' the trim controls to zero volts in order to eliminate thruster spin when no input is received from the joystick.

It can be seen that it is possible to diagnose areas of faults without touching the ROV. This can make the fault finding procedure less time consuming The software also allows the operator to re-programme multiplexer channels, for example if some extra equipment is to be fitted to the vehicle a channel can be set up without any physical re wiring taking place.

CHAPTER 8 HYDRAULIC SYSTEMS

8.1 Introduction

Remotely Operated Vehicles are, as previously stated divided into three classes. **Eyeball, Workclass** and **Large Inspection Class**. The latter two are normally dedicated to work tasks and pipeline inspections. Due to the physical size of the vehicle and the weight of the equipment fitted to the ROV, the power/size developed by the thrusters is critical to their operation. For this reason manufacturers make use of hydraulics as their source of power.

8.2 Hydraulic Principles

Hydraulics can be defined as the transmission of power created by pushing on a confined liquid. Figure 8.1 illustrates a simple hydraulic press, carrying out exactly the same task as a mechanical lever. A force of 10lb is applied to a piston of an area of 1 square inch, the pressure is defined as Force per Unit area, or:

Pressure = Force / Area

Then it follows that a pressure of 10lbs per square inch is developed in the fluid throughout the container. By simple calculation we can see that the pressure developed in the container will in fact support a load of 100lb supported on a piston area of 10 square inches. In comparison with the mechanical lever, we can see that exactly the same task can be carried out by a fluid based system.

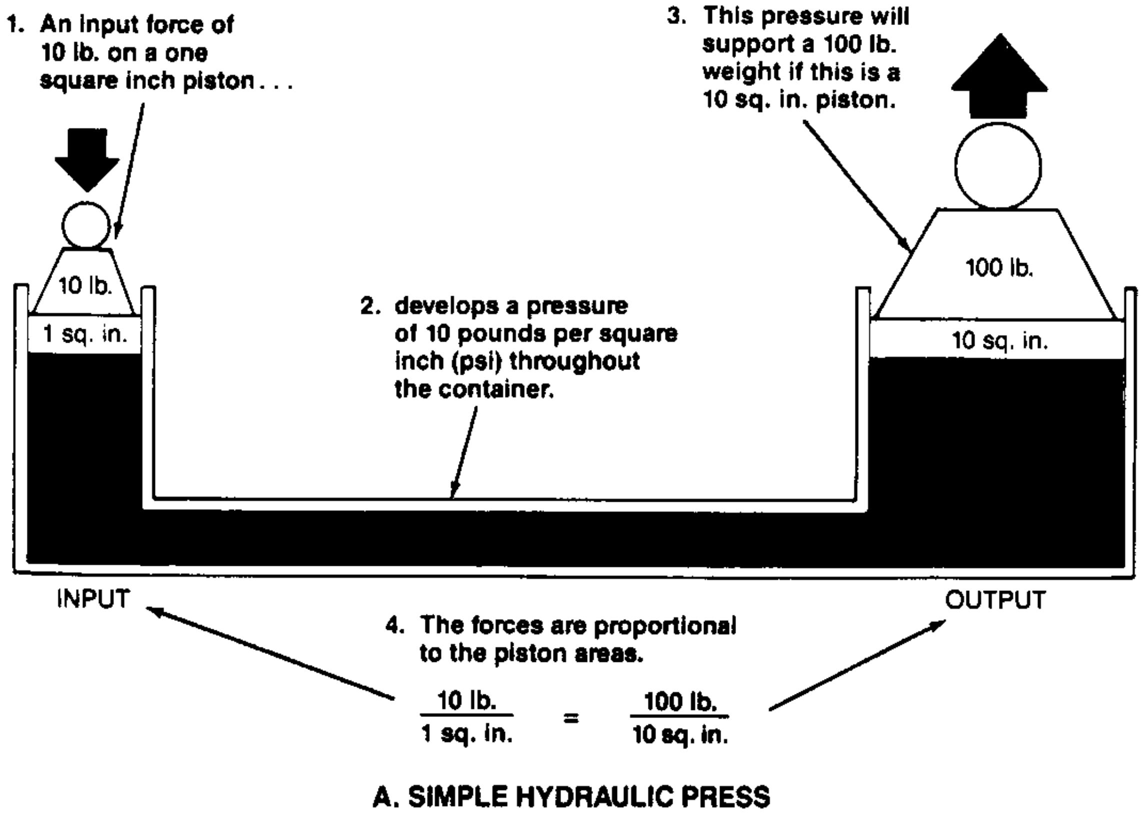
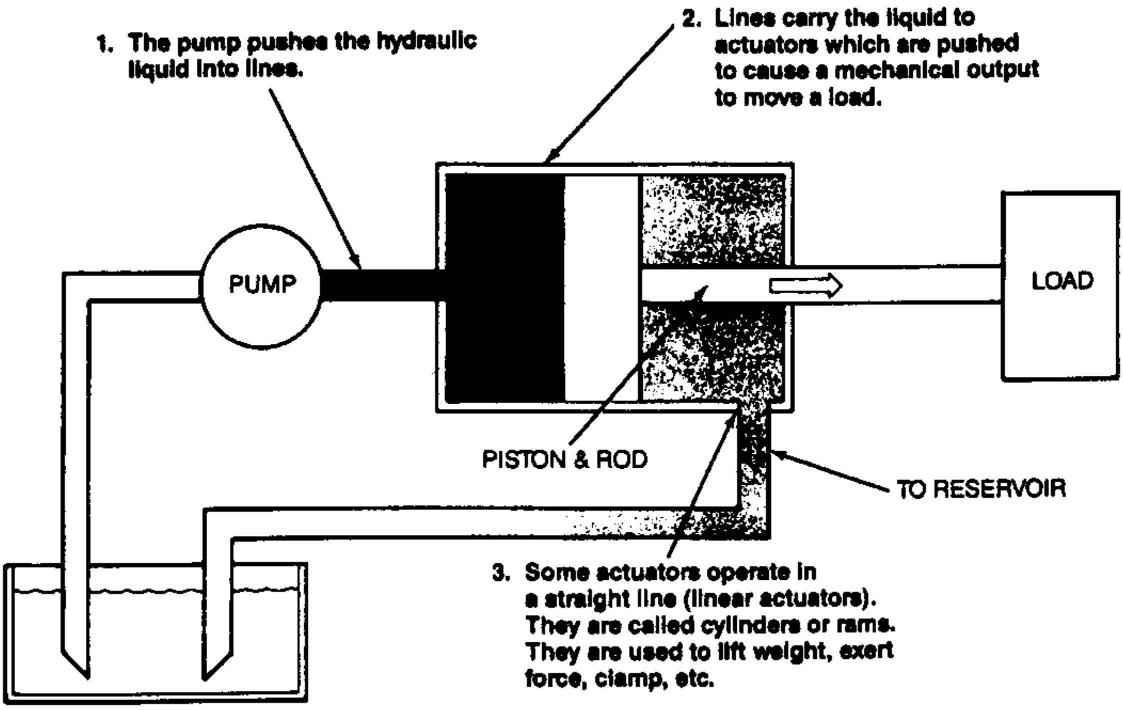


Figure 8.1

A basic hydraulic system requires a pump to develop the oil pressure, a valve to control the flow of oil to the actuator, which in turn carries out the work required by the system. Figure 8.2 illustrates a basic system of this nature.



A. LINEAR ACTUATOR

Figure 8.2

8.3 Advantages of Hydraulics

Hydraulic systems have several advantages over non-fluid based systems.

8.3.1 Variable Speed

The speed of the actuator is dependent on the volume and flow rate of the oil being supplied to it. This can be achieved by either using a flow control valve, or by altering the delivery of the pump, i.e. how much oil the pump supplies to the actuator over a given time.

8.3.2 Reversible

It is possible to reverse a hydraulic actuator instantaneously without causing any damage to the system. A directional control or reversible pump provides the reversing control, whilst a pressure relief valve protects the system from excess pressure.

8.3.3 Overload Protection

A pressure relief valve protects the system from excess pressure brought about by an overload or torque, force in the actuator. For example should an ROV thruster become fouled and seized, then the flow would cease and the pressure build up. The pressure relief valve will activate and allow the oil to flow back to the tank, thus protecting the system from damage.

8.3.4 Stalling

If an electric motor stalls during an operation due to overload, it is likely that a fuse will blow, thus preventing instant re-start. If a hydraulic system stalls, then the Pressure Relief Valve will divert the oil back to tank for the period of time that the system pressure remains in excess of normal working pressure. Once normal pressure is resumed the system will continue to operate as normal. Stalling, therefore, does not pose the same problem in a hydraulic system, as it does in a purely electrical or mechanical system.

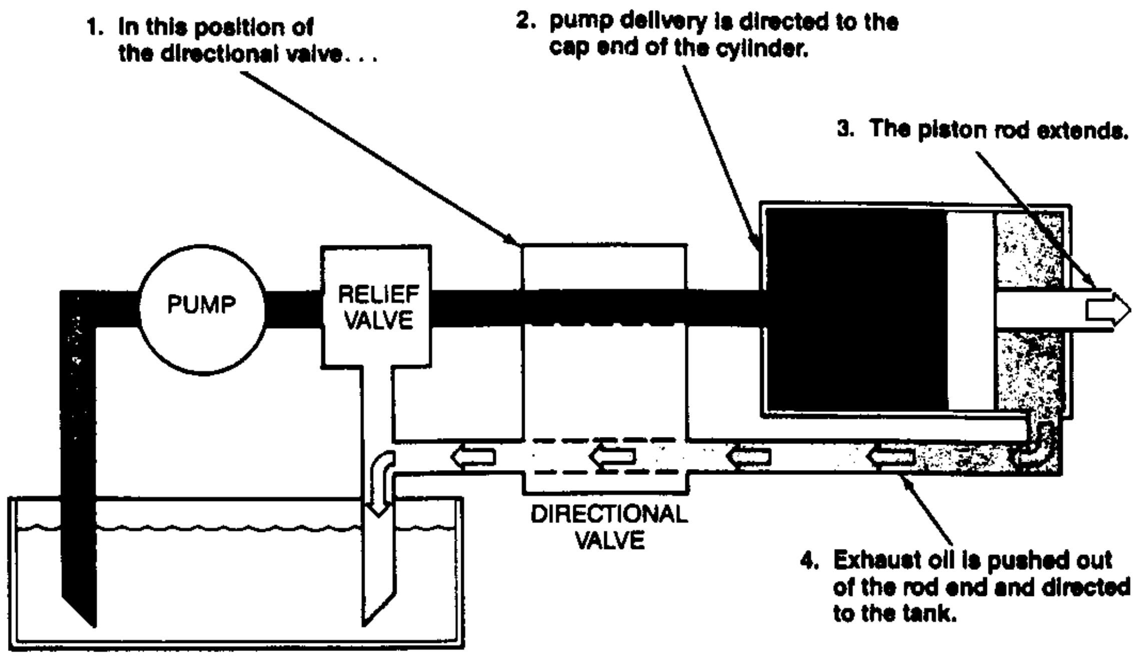


Figure 8.3 a

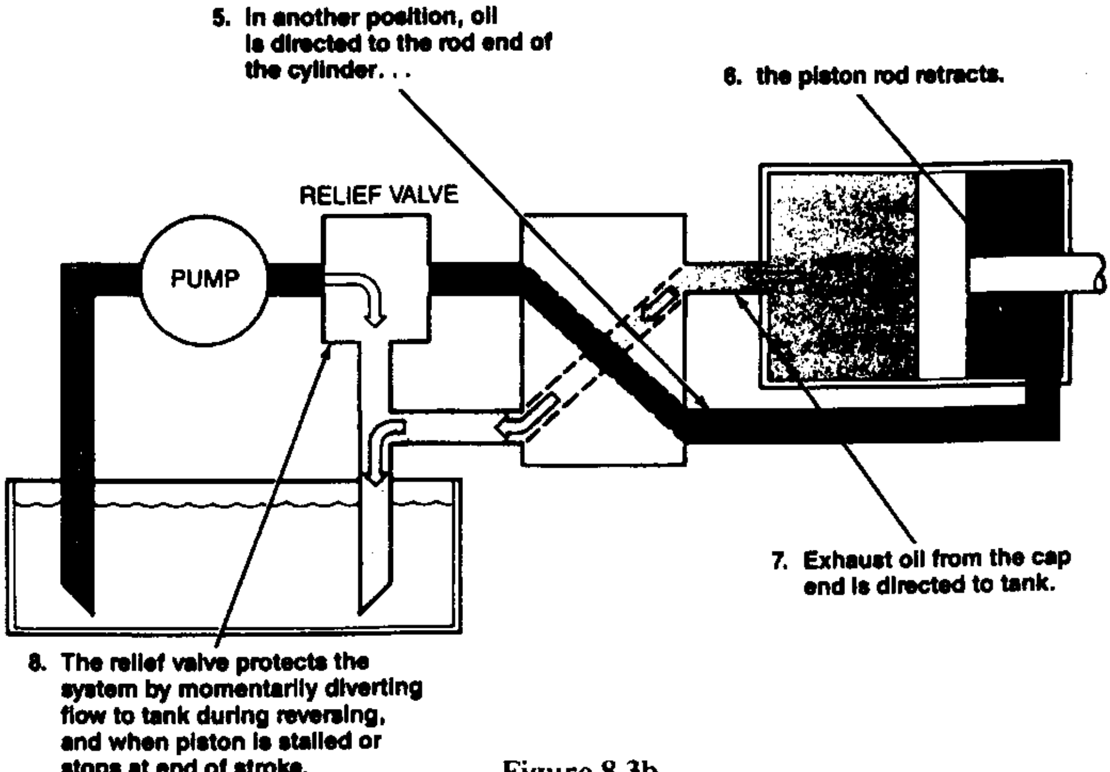


Figure 8.3b

8.4 Pressure

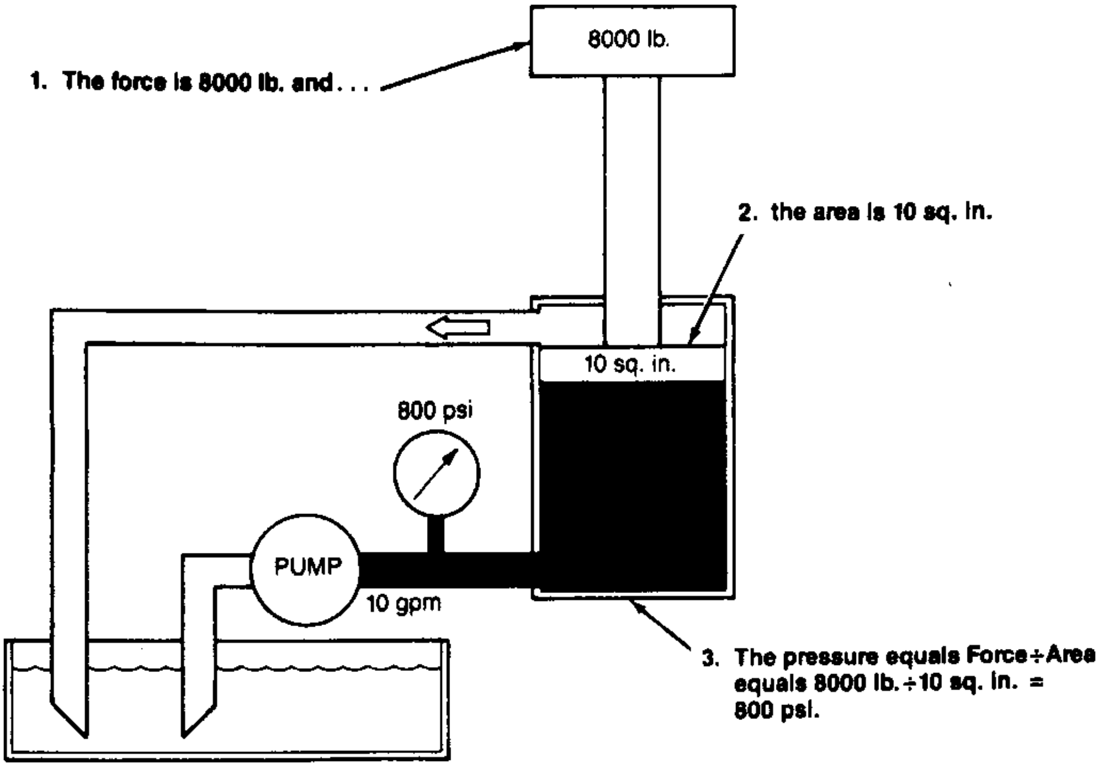
Pressure is created whenever the flow of liquid is restricted. This may be brought about by a restriction in the piping, or the presence of an actuator with an applied load. Figure 8.4 illustrates the effect of a load on oil pressure. An 8000lb load supported by a 10 square inch piston creates a pressure of 800 PSI Pressure. Force and Area are linked by the following formula.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$\text{Pressure} = \frac{8000\text{lb}}{10\text{Sq in}}$$

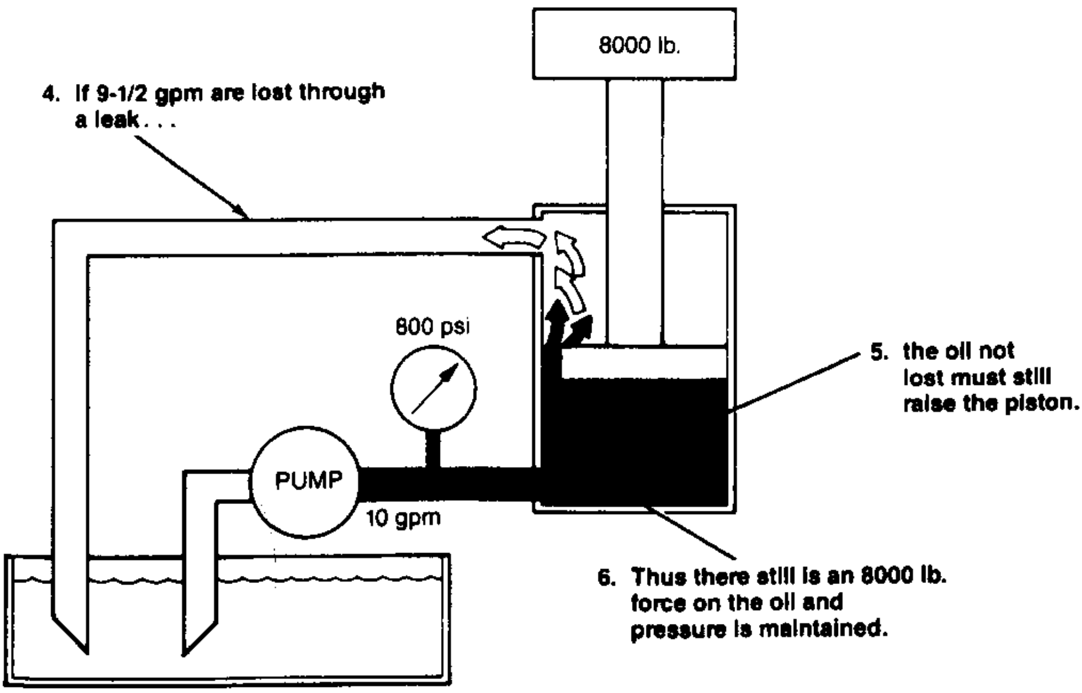
$$\text{Pressure} = 800 \text{ PSI}$$

It follows that if the load is uncreased then so is the pressure. Figure 8.4 (B) illustrates the effect of a leak on the system past the piston. The Force and Piston Area remain unchanged and so the pressure remains the same. However the oil flow passses the piston at a rate of 9.5 gallons per minute. As the pump output flow is 10 gallons/mins then it leaves on 0.5 gallons per minute to move the piston. The overall effect is that the piston and therefore the load will move much slower.



A. NO LEAK IN SYSTEM

Figure 8.4 a



B. LEAK IN CYLINDER

Figure 8.4b

8.5 Flow

As discussed in the previous section, it is pressure that gives the actuator its force. However, it is the flow of oil that gives the actuator its movement, flow is created by the action of the pump.

8.5.1 Measurement of Flow

There are two ways in which flow can be measured.

Velocity - The average distance that the oil particles travel per unit and time.
Units - Feet per second or metres per second

Flow Rate - Is a measure of the volume of fluid passing a given point in a given time.
Units - gallons per minute or litres per minute

8.5.2 Flow and Pressure Drop

In order for liquid to flow, there must be a state of unbalanced force to cause motion. when fluid flows through a pipe of uniform diameter there will always be slightly less pressure down stream with respect to the pressure up stream. This is due to friction in the pipeline, and must be taken into account during the design of the system. Figure 8.5 illustrates pressure with respect to flow through a uniform pipeline.

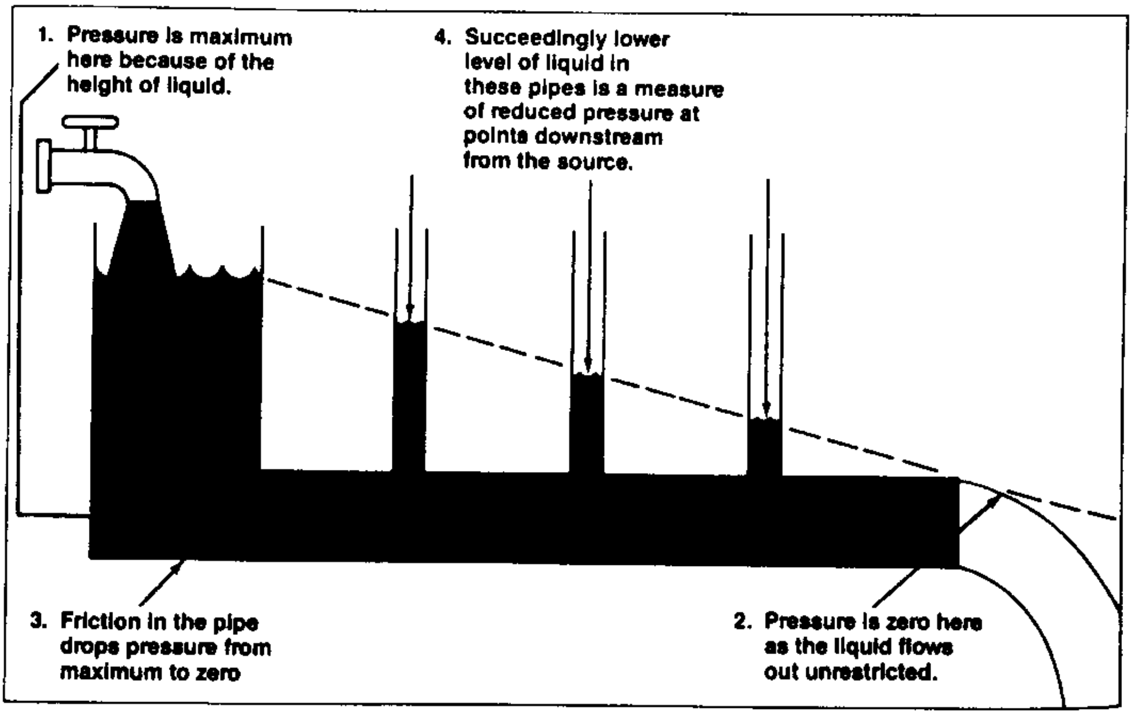


Figure 8.5

8.6 Hydraulic Calculations

By applying the basic laws of physics it is possible to determine the main components required by a hydraulic system.

8.6.1 Determining Pipe Size

By applying one of two formulas it is possible to calculate the size of hydraulic lines required. If gpm and velocity is known, it is possible to calculate the cross Sectional Area of the flow line.

$$\text{Cross Sectional Area (square feet)} = \frac{\text{gpm} \times 0.3208}{\text{Velocity (fps)}}$$

N.B. fps = feet/second

The Velocity in fps can be calculated by using the formula:

$$\text{Velocity (fps)} = \frac{\text{gpm}}{3.117 \times \text{area}}$$

8.6.2 Work and Power

Work is carried out whenever a force acts through a distance.

i.e. Work = Force x Distance

e.g. A 10lb load is moved through a distance of 5 feet.

Therefore Work = 10lb x 5 feet

Work Done = 50 ft/lb

In practice we must take into account the rate at which work is done. This is referred to as power.

$$\text{Power} = \frac{\text{Force} \times \text{Distance}}{\text{Time}} \quad \text{or} \quad \frac{\text{Work}}{\text{Time}}$$

8.6.3 Horsepower in a Hydraulic System

One horsepower is described as being power required to lift 33,000lb, 1 foot in 1 minute. In a hydraulic system speed and distance are represented as gallon/minute, and force is represented as pressure.

$$\text{Horse Power} = \text{gpm} \times \text{P.S.I} \times 0.000583$$

$$\text{Horse Power} = \frac{\text{gpm} \times \text{Psi} \times 0.583}{1000}$$

$$\text{or hp} = \frac{\text{gpm} \times \text{PSI}}{1715}$$

We can now calculate the exact horse power of a system using this formula, however this formula assumes that the system is 100% efficient. In practice a typical hydraulic system is only about 80% efficient. For this reason we have to calculate on effective horsepower to compensate for losses.
The equation is as follows:-

$$hp = gpm \times PSI \times 0.000583$$

has to be modified to approximately

$$hp = gpm \times PSI \times 0.0007.$$

N.B. 0.000583 is approximately 80% of 0.0007.

Thus horsepower can now be represented

$$h.p = \frac{\text{gallons}}{\text{minutes}} \times \frac{\text{pounds}}{\text{Sq Inches}}$$

As 1 gallon = 231 Cubic inches

12 inches = 1 foot

$$\text{Power} = \frac{\text{gallon}}{\text{minute}} \times \frac{231\text{in}^3}{\text{gallon}} \times \frac{\text{Pounds}}{\text{in}^2} \times \frac{1\text{ foot}}{12\text{ in}}$$

$$= \frac{231}{12}\ \text{ft lb / min}$$

This gives the equivalent mechanical power of one gallon per minute flow at 1 PSI of pressure. We can express this as a horsepower by dividing by 33000 foot pounds per minute.

$$\frac{\frac{231}{12}\ \text{ft lb / min}}{\frac{33000}{1}\ \text{ft lb / min}} = 0.000583\text{hp}$$

Thus 1 gallon per minute flow at 1 PSI equals 0.000583 hp

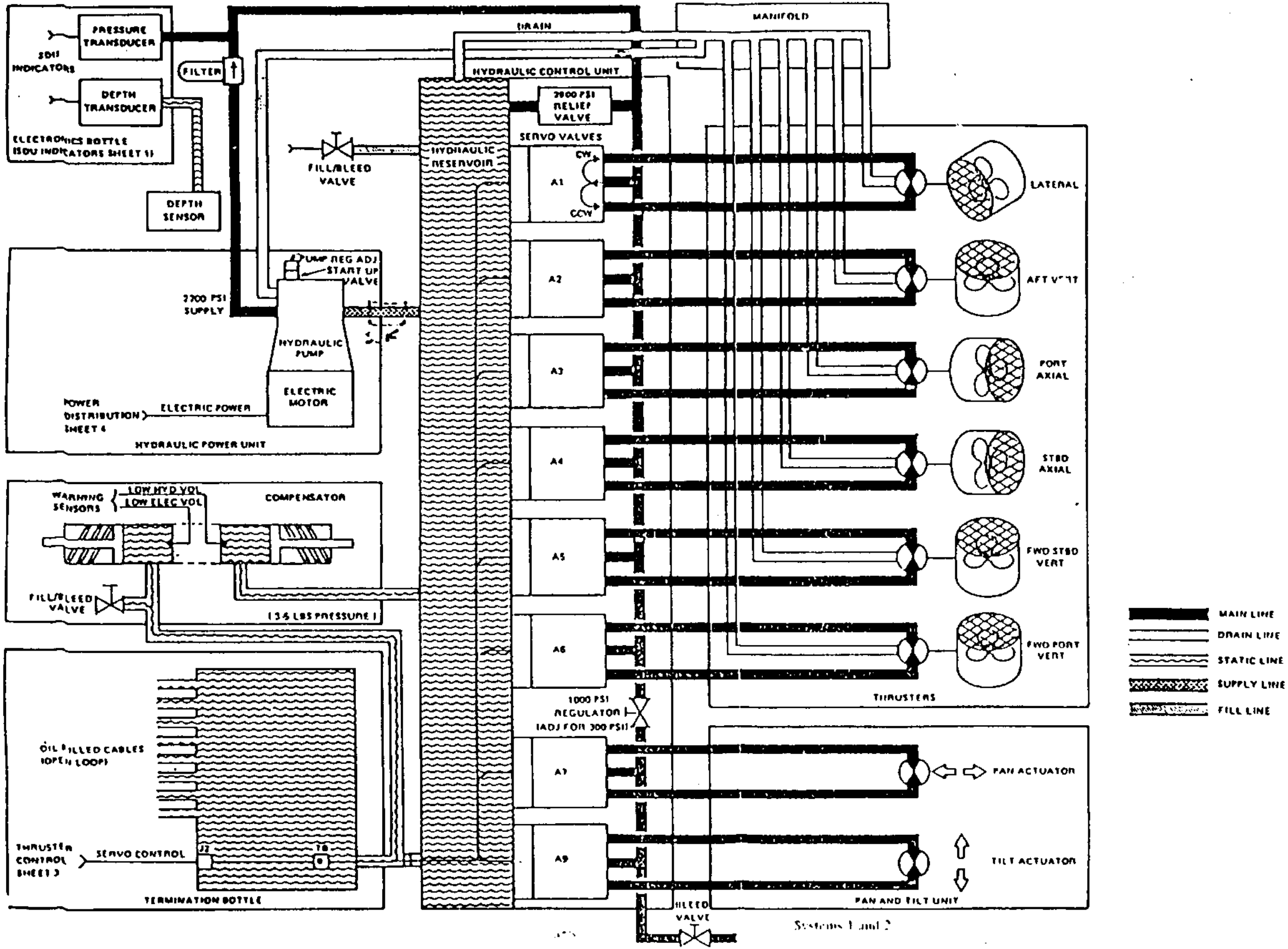
8.6.3 Horse Power and Torque

Torque can be defined as a rotating or twisting force. There are two torque - power formulas most commonly used.

$$\text{Torque} = \frac{63025 \times hp}{rpm} \qquad hp = \frac{\text{torque} \times rpm}{63025}$$

8.7 Basic Hydraulic System

Figure 8.6 shows the basic layout of the hydraulic system of a typical Workclass ROV. It is the intention of this section to discuss the various components that make up the system.



Systems 1 and 2

Figure 8.6

8.7.1 Hydraulic Pump

The hydraulic pump is directly coupled to an electric motor and converts mechanical energy into hydraulic horsepower. The principle of the operation is that an increasing volume is generated on the intake side and a decreasing volume (with increasing pressure) on the output side.

8.7.1.1 Pump Displacement

The flow capacity of a pump can be defined as the displacement per revolution, or simply the output of oil in gallons per minute. Displacement is expressed in cubic inches per revolution.

8.7.1.2 Pump Delivery

The delivery of the pump is dependent upon two factors:-

a) Load Conditions

b) Drive Shaft Speed

The pump will actually deliver more oil than it's specified rating, if it is running under no-load conditions. It follows therefore that the delivery will reduce under excessive load conditions.

The amount of oil being delivered is also dependent upon the speed that the shaft turns. In order for the pump to perform according to it's specifications, the drive motor must operate at the correct speed.

8.7.2 Types Of Pump

The most common types of hydraulic pump found in industry are positive displacement pumps. A positive displacement pump delivers specific amounts of fluid per revolution, stroke or cycle. These pumps may be of fixed displacement, in order to adjust this parameter, certain internal components have to be adjusted.

Some pumps have the facility to vary the size of the pumping chamber by adjusting external controls, these pumps are known as variable displacement pumps.

8.7.2.1 External Gear Pump

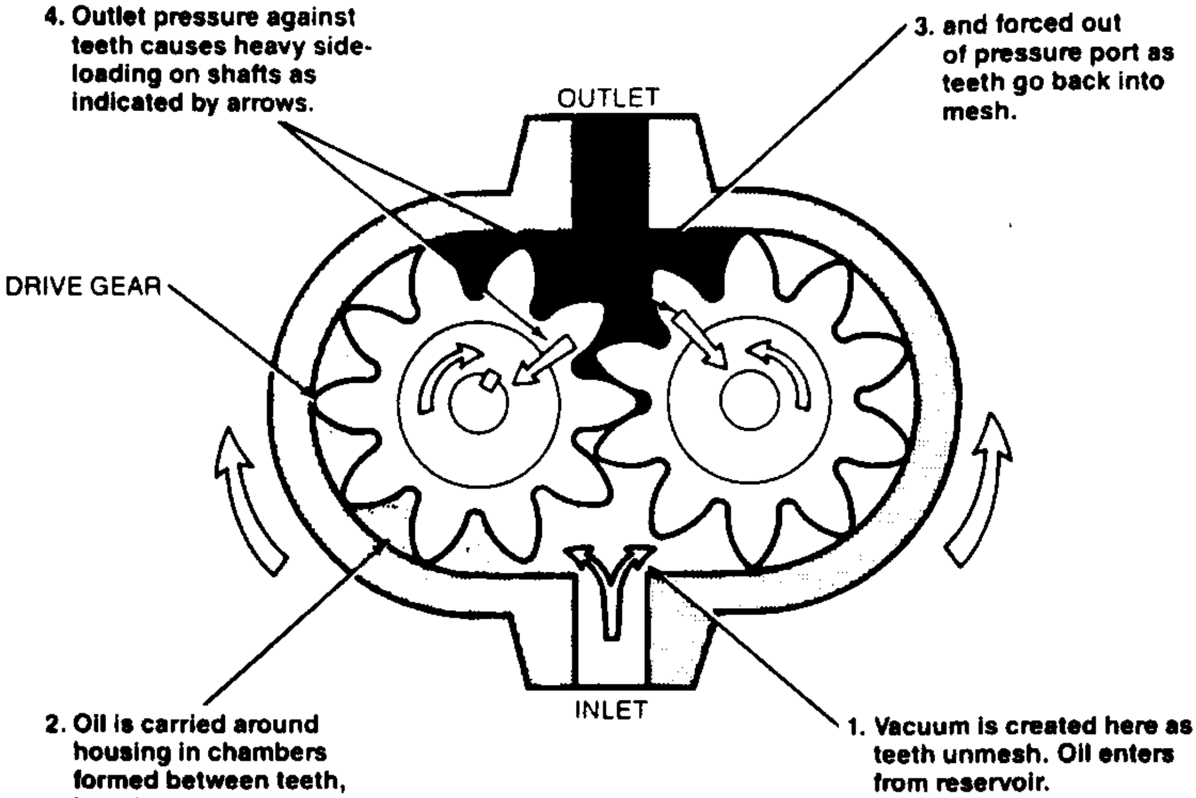


Figure 8.7

As the teeth of the two gears un mesh a partial vacuum is created, thus, drawing oil into the unit. The oil becomes trapped between gear teeth, and as the teeth mesh together the oil becomes pressurised. Gear pumps can be mounted in tandem, or through drive which allows separate inlet and outlet parts, thus, creating two separate isolated systems, possibly with two different types of hydraulic oil. This system does occur in certain ROV systems, typically where the manipulator hydraulic system is isolated from the main system.

8.7.2.2 Vane Pumps

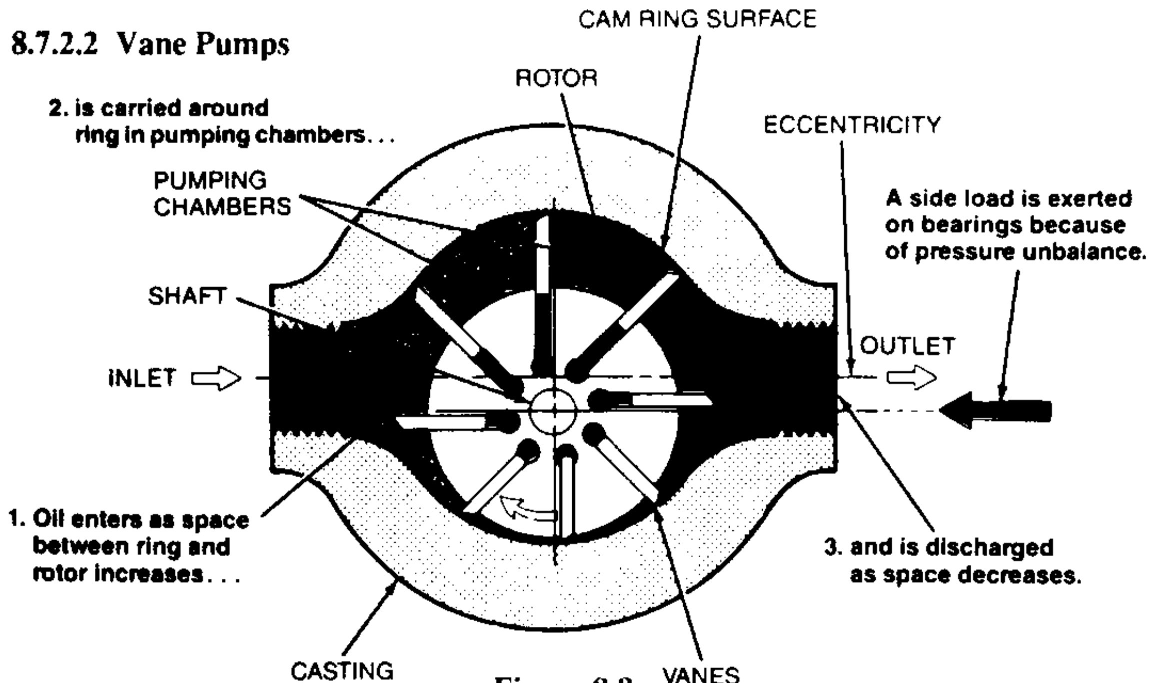


Figure 8.8

Figure 8.8 illustrates the operating principle of the vanes pump. The unit consists of a slotted spindle. The slots contain moveable vanes which are 'thrown' against the outer casing of the pump body. The eccentricity of the spindle is such that a vacuum is created on the inlet side, and as the volume between the vanes decreases, then the oil pressure increases. Due to the vanes being in constant contact with the casing, they are subject to constant wear. As the vanes wear down, then they extend further from their slots and eventually replacements is necessary.

The vane pumps covers low, medium and high volume ranges and can operate at pressures up to 3000 PSI. They are highly efficient with a low noise level and a long life.

8.7.2.3 Piston Pumps

Piston pumps are commonly used on ROV's and operate on the principle that when a piston in a bore retracts it draws fluid in and when it moves out it expels fluid from the bore.
There are two types of piston pumps:

a) Radial Piston Pumps

Radial Piston Pumps consist of a cylinder block inside a reaction ring. (see fig 8.9). The cylinder block contains bores in which free moving pistons are housed. The cylinder block is offset in such a way that as it spins, the pistons are subject to centrifugal force. As the pistons move out, fluid is drawn into the cylinders. As the distance between the cylinder block and reaction ring decreases, then the pistons move in towards the centre forcing out fluid in the process.

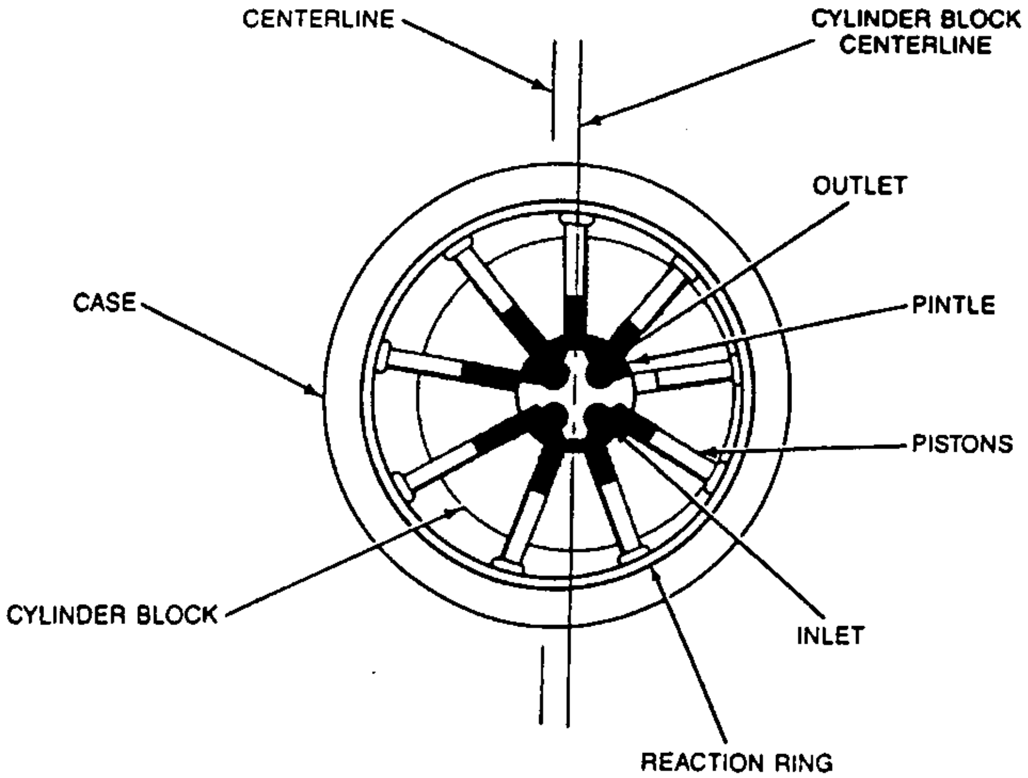


Figure 8.9

b) Axial Piston pumps

Figure 8.10 shows a simple axial pump. The cylinders rotate parallel to the axis of rotation of the cylinder block. The swash plate is at an angle that determines the length of the piston stroke. The larger the stroke is, then the more oil is drawn to the bore and the larger the displacement becomes.

The ports are arranged so that as the pistons pass the inlet, they are drawn back and as they pass the outlet they are forced out. The displacement of the pump is determined by the number of pistons and the length of the stroke.

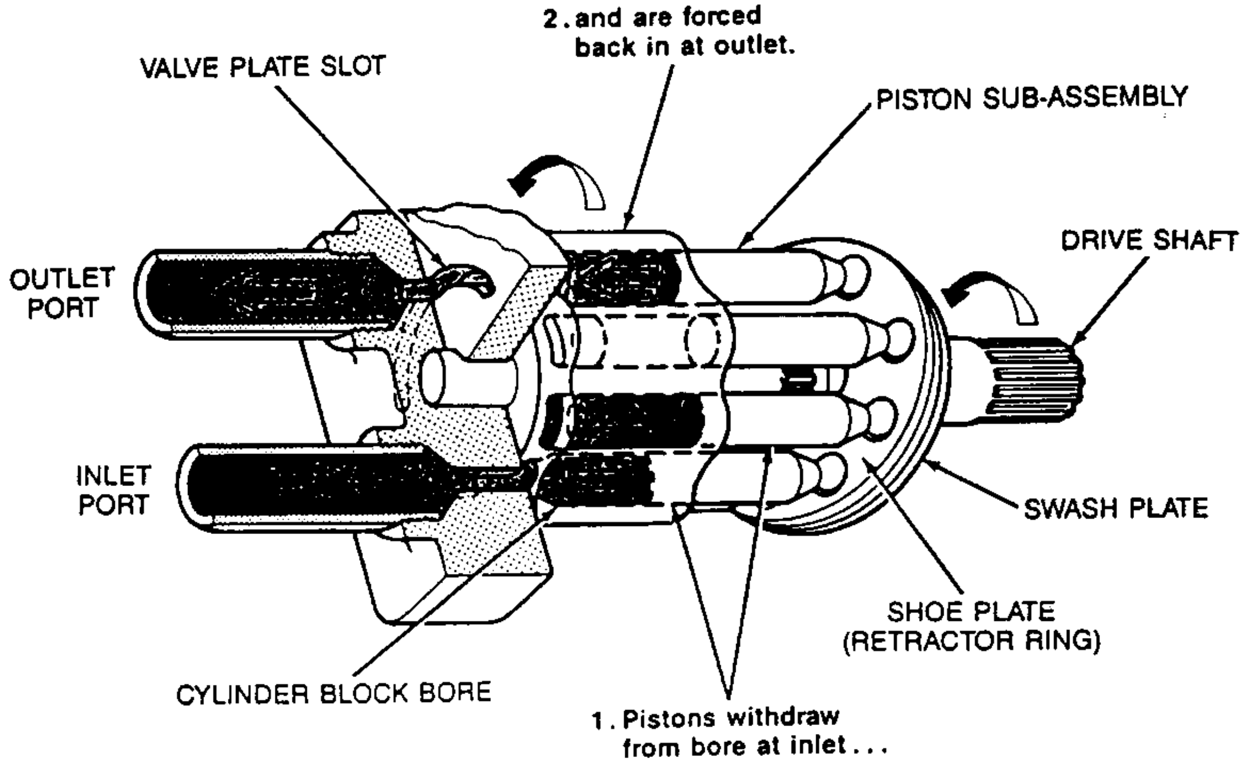


Figure 8.10

Some pistons are designed in such a way that oil is allowed past the piston rings and into the casing to facilitate lubrication of internal bearings. For this reason there has to be a part, known as a case drain, to allow oil back to the tank.

8.8 Hydraulic Valves

Introduction

Figure 8:6 illustrated a basic layout for an ROV hydraulic system. It can be seen that the thruster motors will require a variable flow speed and direction, in order to meet their requirements. The manipulators contain linear actuators, which require only a variable direction, but normally only a constant flow rate.

8.8.1 Directional Valves

Directional valves feature in the ROV Hydraulic system in more than one form. They have the ability to start, stop and control the direction of fluid flow.

8.8.1.1 Classification of Directional Valves

Directional valves are classified according to certain characteristics as listed below:-

a) Number of flow paths
   e.g. two way, three way.

b) Actuation method
   e.g. mechanical, pneumatic, electrical

c) Internal valve element
   e.g. Poppet, spool, piston, ball

d) Size - Size of flange or part connections

e) Connections - Pipe thread, straight thread or flanged

8.8.1.2 Check Valve

Check valves feature in almost all hydraulic systems including ROVs Basically they allow the flow of fluid in only one direction.

Figure 8.11 shows a check valve serving as an in line one way valve. A spring holds the poppet in the normally closed position. Fluid pressure forces the poppet against the spring, thus allowing flow in the appropriate direction. When the pressure ceases, the poppet returns to its seat and prevents any undesired back flow of oil.

Typical Uses On ROV

As on many hydraulic systems, a check valve is often used directly after the pump to prevent back flow of oil, in the event of excessive pressure building up in the system.

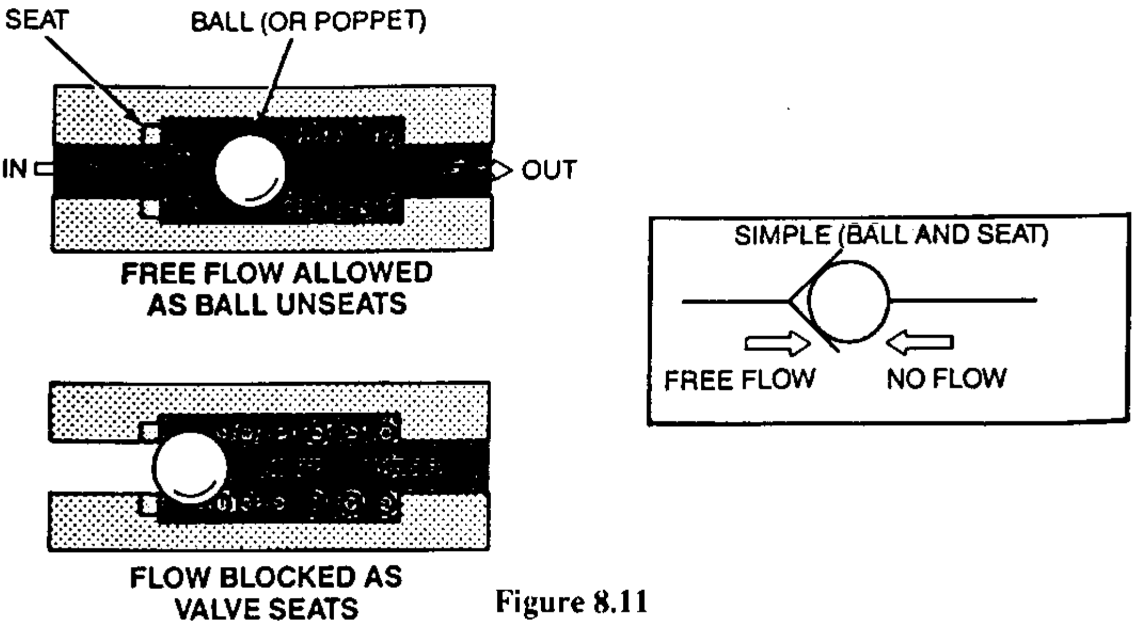


Figure 8.11

8.8.1.3 Two Way Directional Valves

Two way directional valves are commonly found in what is termed the **Hydraulic, Control Unit** (HCU). This unit consists of a 'bank' of two way directional valves, which control devices such as manipulator arms, and camera pan/tilt units. The H.C.U generally operates at a lower pressure than the thruster hydraulic system, typically 1000 - 1200 PSI. As previously mentioned, the H.C.U may be completely isolated from the main system, by incorporating two directly linked gear pumps into the system (see section 8.7.2.1)

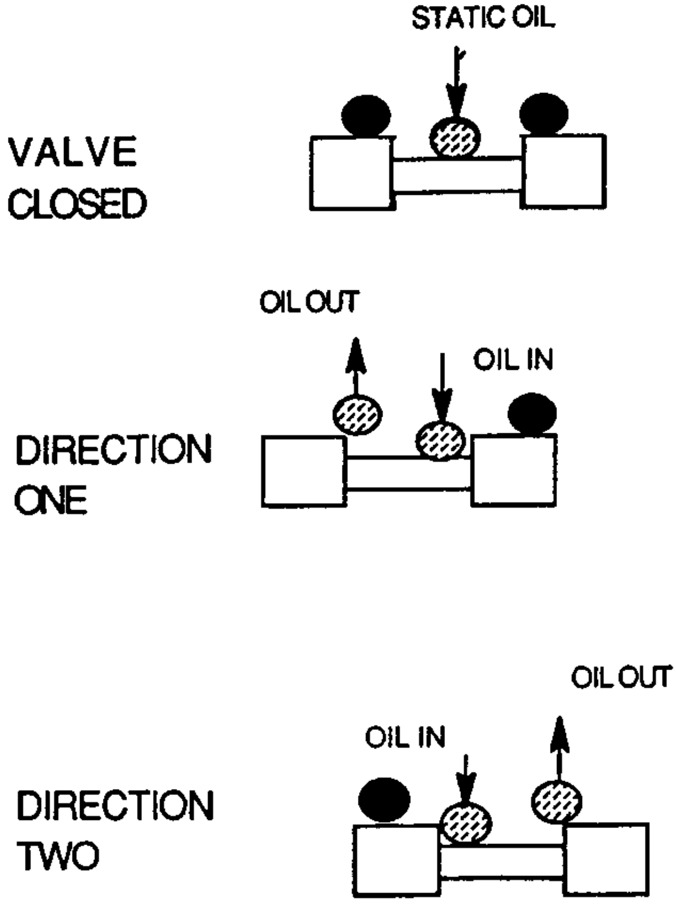


Figure 8.12

8.8.1.4 Actuation of Directional Valves

There are several methods generally used in industry to actuate the spool movement. They include, pneumatic, mechanical and electrical actuation. The ROV industry makes use of electromagnetism, and the particular valve is known as a solenoid valve.

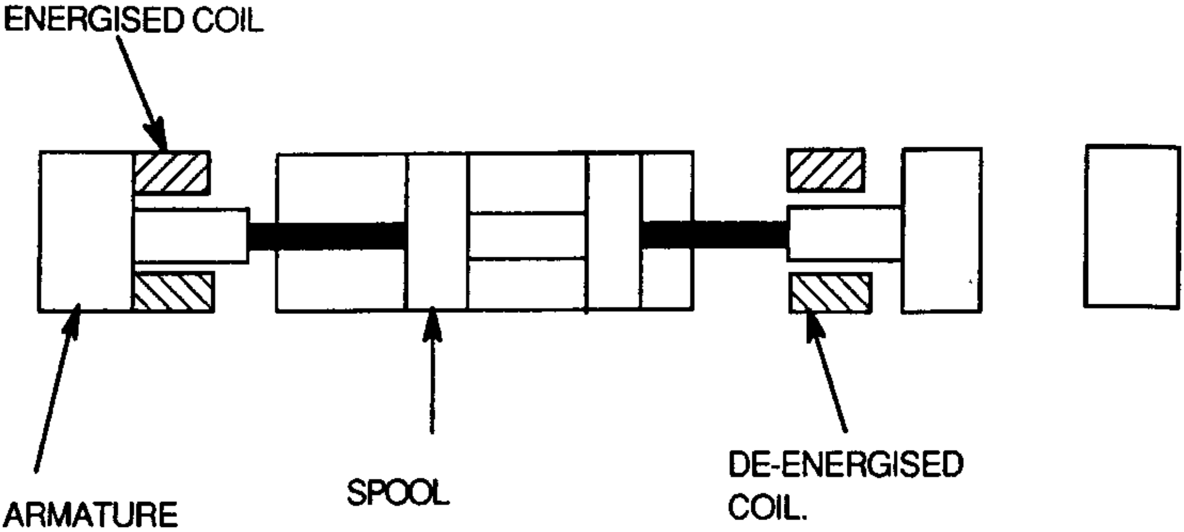


Figure 8.13

Fig 8.13 shows the solenoid valve in an energised state, by applying a voltage, the coil becomes energised, moving the pin against the spool. Normally solenoid valves contain springs, that centralise the spool once the coils are de-energised.

8.8.2 Servo Valves

The servo valve is a directional valve that is capable of being infinitely positioned to provide control of the amount of fluid supplied to the actuator. ROV's make use of these devices to meet the requirements of the thruster motors, which are required to run at variable speed and in either direction.

8.8.2.1 Principles of Operation

Figure 8.14 shows the principle operation of a Electrohydraulic Servo Valve:-

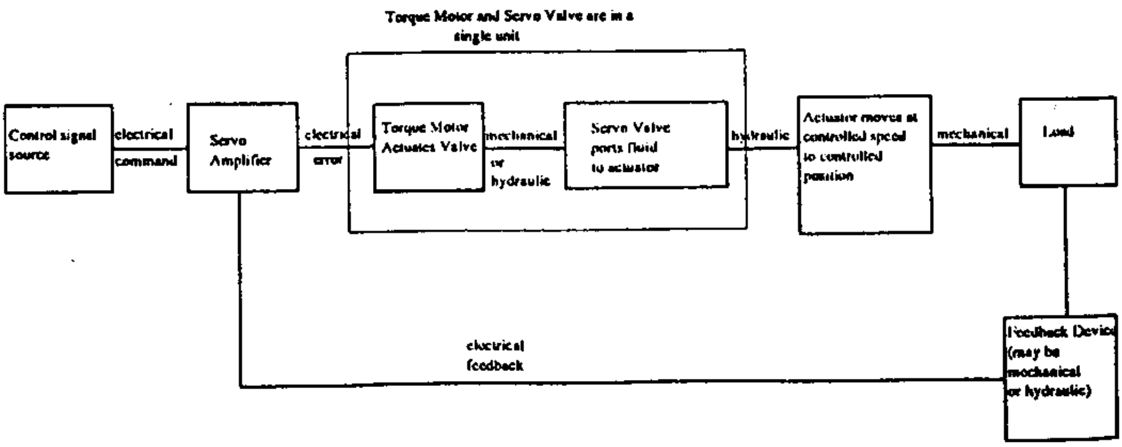


Figure 8.14

A control signal, which may comprise of an analogue d.c voltage is feed to an amplifier, which boosts the signal. This analogue voltage will represent the initial output from the joystick control. The electrical signal is applied to the torque motor, which is mechanically coupled to a spool that controls the fluid rate of flow.

If follows therefore that the load will move at a rate proportional to the electrical input signal. A feed back loop may be incorporated into the system, whereby an electrical signal is applied from the load to the servo amplifier. This feedback signal is compared with the original input signal, and any resulting error is fed to the torque motor, which reacts in such a way as to cancel the error.

8.8.2.2 Torque Motor

Figure 8.15 shows the basic operation of the torque motor.

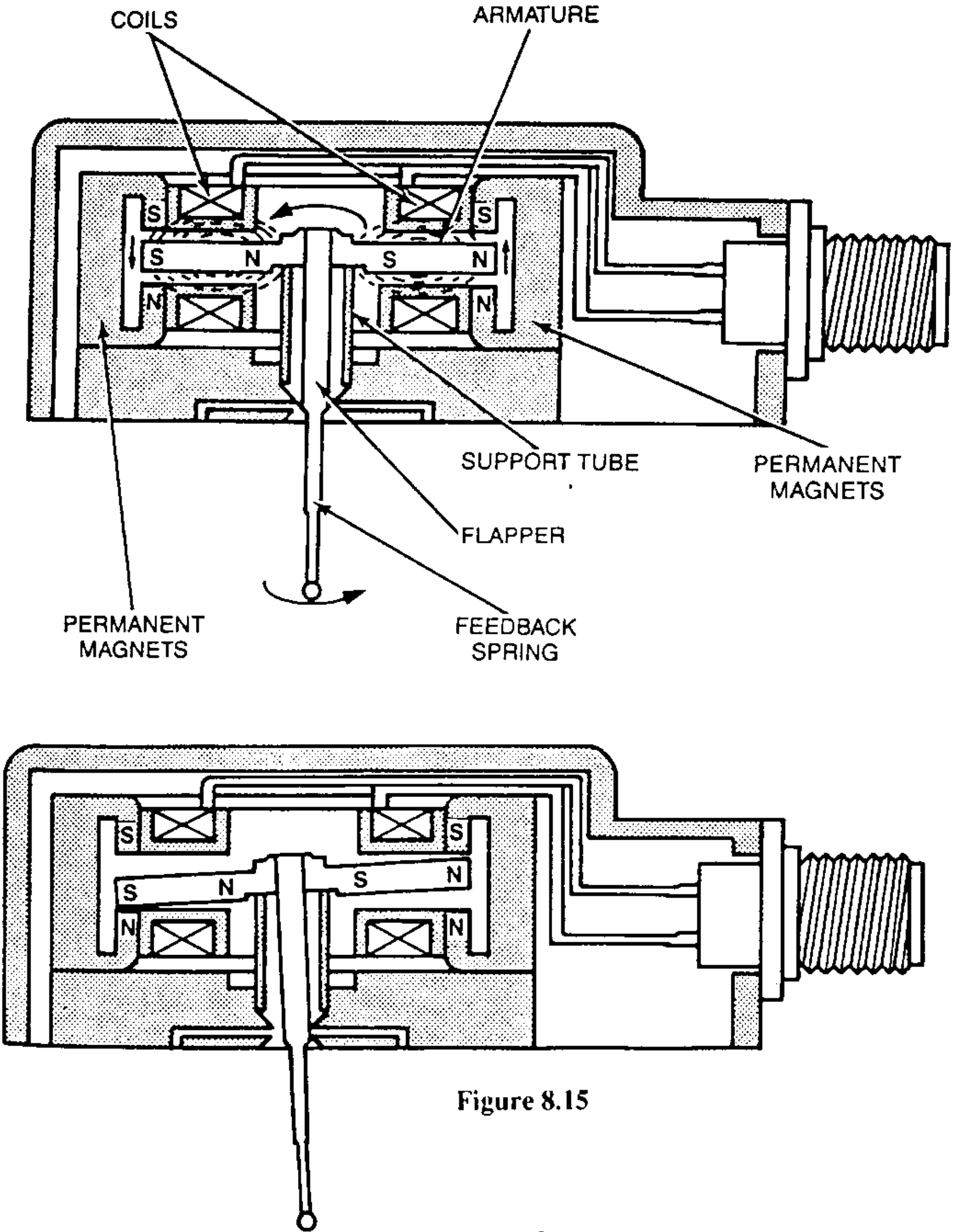


Figure 8.15

The unit consists of a flapper, pivoting on a flexible support tube. The flapper is coupled to armature, which is encased in a permanent magnet. Each armature is surrounded by electrical coils to which the control signal is applied. On application of control signal the armatures are shrouded by a magnetic field, the strength of which is proportional to the input signal. This magnetic field gives rise to the movement of the armatures and therefore the pivoting of the flapper.
The flapper is mechanically connected to the spool as illustrated in the single stage servo valve (Fig 8.16). It follows that the spool will move proportionally to the input signal and thus create a fluid flow of equal proportion.

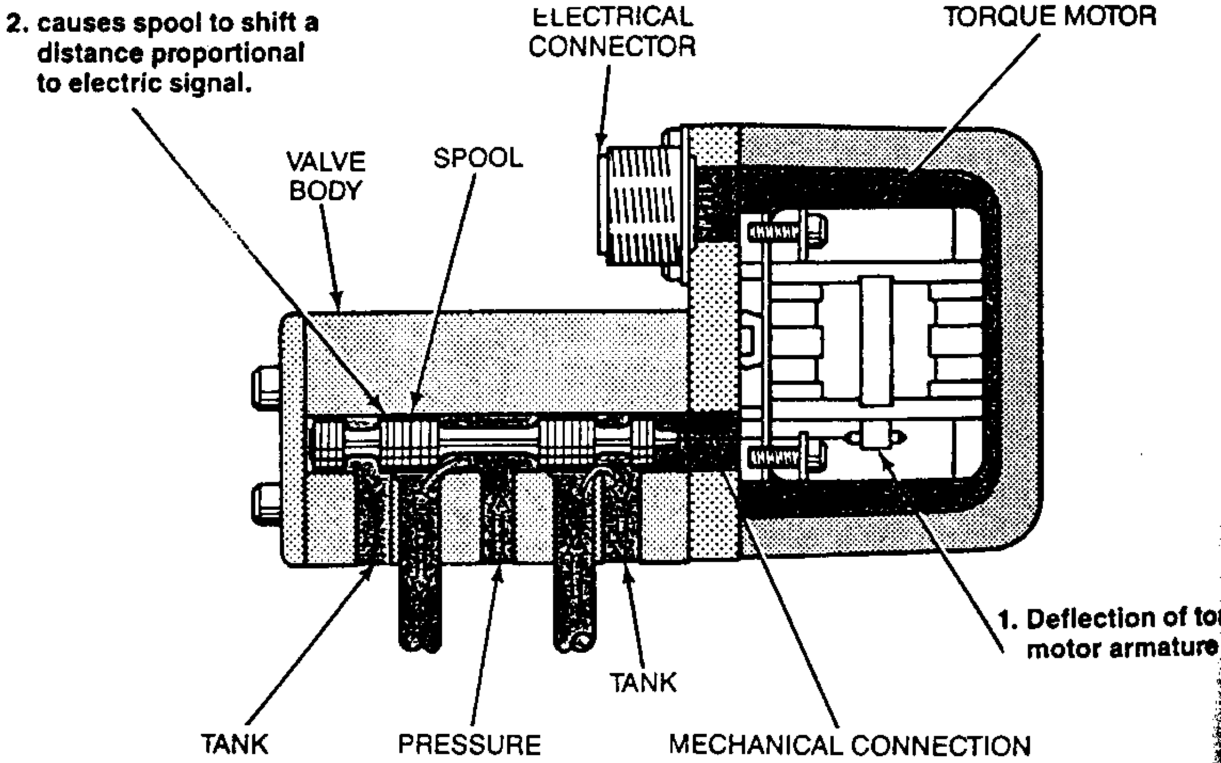
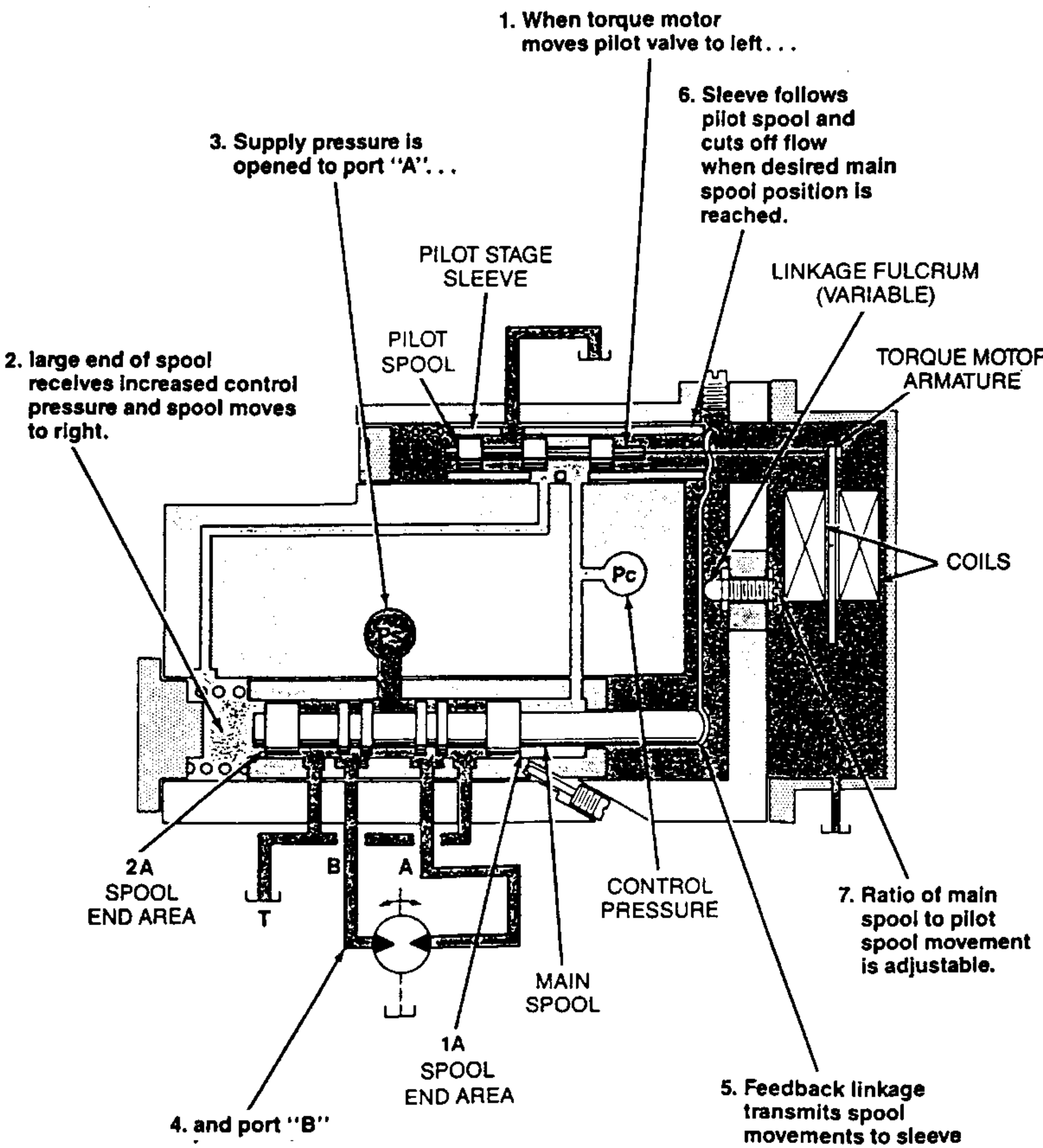


Figure 8.16

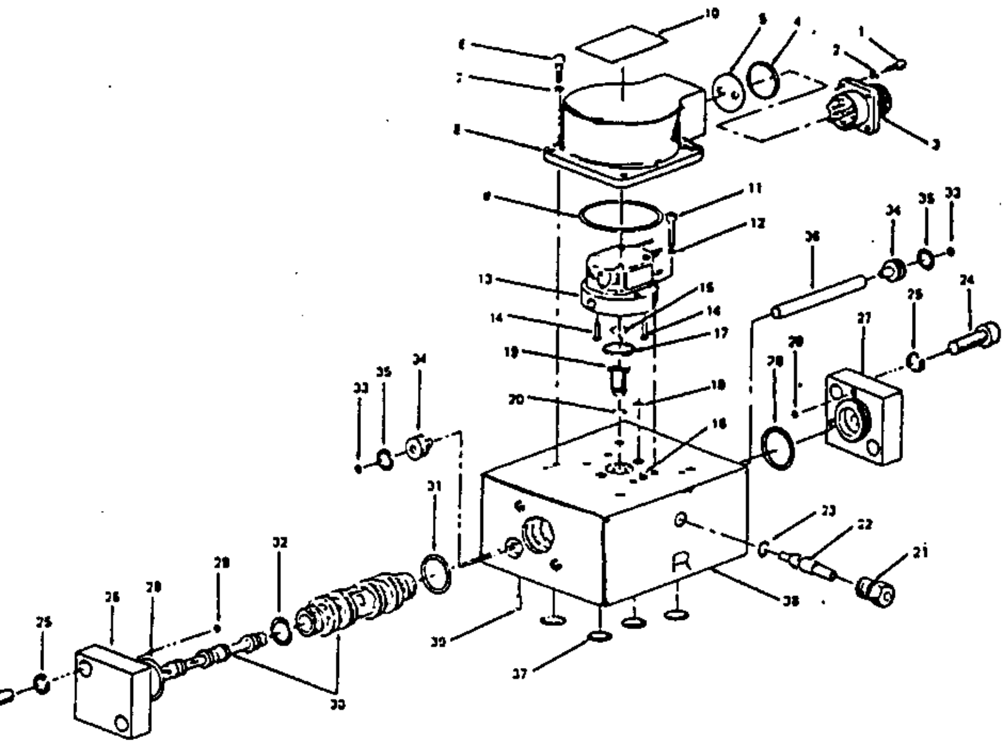
8.8.2.3 Two Stage Spool - Type Servo Valve

In most cases ROV systems require a larger flow rate than could be obtained from a single stage spool valve. For this reason the system makes use of the Two Stage Spool - Type Servo Valves as illustrated in Fig 8.17.



1. When torque motor moves pilot valve to left...
6. Sleeve follows pilot spool and cuts off flow when desired main spool position is reached.
3. Supply pressure is opened to port "A"...
PILOT STAGE SLEEVE
LINKAGE FULCRUM (VARIABLE)
PILOT SPOOL
2. large end of spool receives increased control pressure and spool moves to right.
TORQUE MOTOR ARMATURE
COILS
Pc
2A SPOOL END AREA
T
B
A
CONTROL PRESSURE
7. Ratio of main spool to pilot spool movement is adjustable.
MAIN SPOOL
1A SPOOL END AREA
5. Feedback linkage transmits spool movements to sleeve
4. and port "B"

Figure 8.17 (a)



Item No.	Nomenclature or Description	No. Req'd.
1.	Screw	4
2.	Lockwasher	4
3.	Connector, Elect.	1
4.	O-ring	1
5.	Spacer	1
6.	Screw	2
7.	Lockwasher	2
8.	Cap, Motor	1
9.	O-ring	1
10.	Nameplate	1
11.	Screw	4
12.	Lockwasher	4
13.	Hydraulic Amplifier Assy.	1
14.	Rivet	2
15.	O-ring	1
16.	Pin, Dowel	1
17.	O-ring	1
18.	O-ring	2
19.	Union-Drain Orifice	1
20.	O-ring	1
21.	Fitting, Locking	1
22.	Pin, Eccentric	1
23.	O-ring	1
24.	Screw	4
25.	Lockwasher	4
26.	Cap, End	1
27.	Cap, End	1
28.	O-ring	2
29.	O-ring	2
30.	Bushing and Spool Assy.	1
31.	O-ring	4
32.	O-ring	2
33.	O-ring	2
34.	Inlet Orifice Assy.	2
35.	O-ring	2
36.	Filter	1
37.	O-ring	4
38.	Body	1
39.	Pin, Roll	1

Figure 8.17 (b)
Physical Construction of a typical servo valve

The principle of operation is similar to the single stage valve, except that the flapper is mechanically connected to a pilot spool, which controls the main supply spool. It should be noted in this case that the feedback link from the main spool to the flapper is mechanical. The most common type of servo valve used on ROV's is the MOOF, the specifications and port configuration are available in the appendix section of this book.

8.9 Hydraulic Actuators

8.9.1 Introduction

The hydraulic actuator is the unit responsible for converting the energy stored in the fluid into mechanical energy. They comprise of either motors, or rams; motors providing rotary motion for thrusters, rams producing linear motion for manipulators and camera pan and tilt function.

8.9.2 Hydraulic Rams

Figure 8.18 illustrates the typical construction of a hydraulic ram/cylinder.

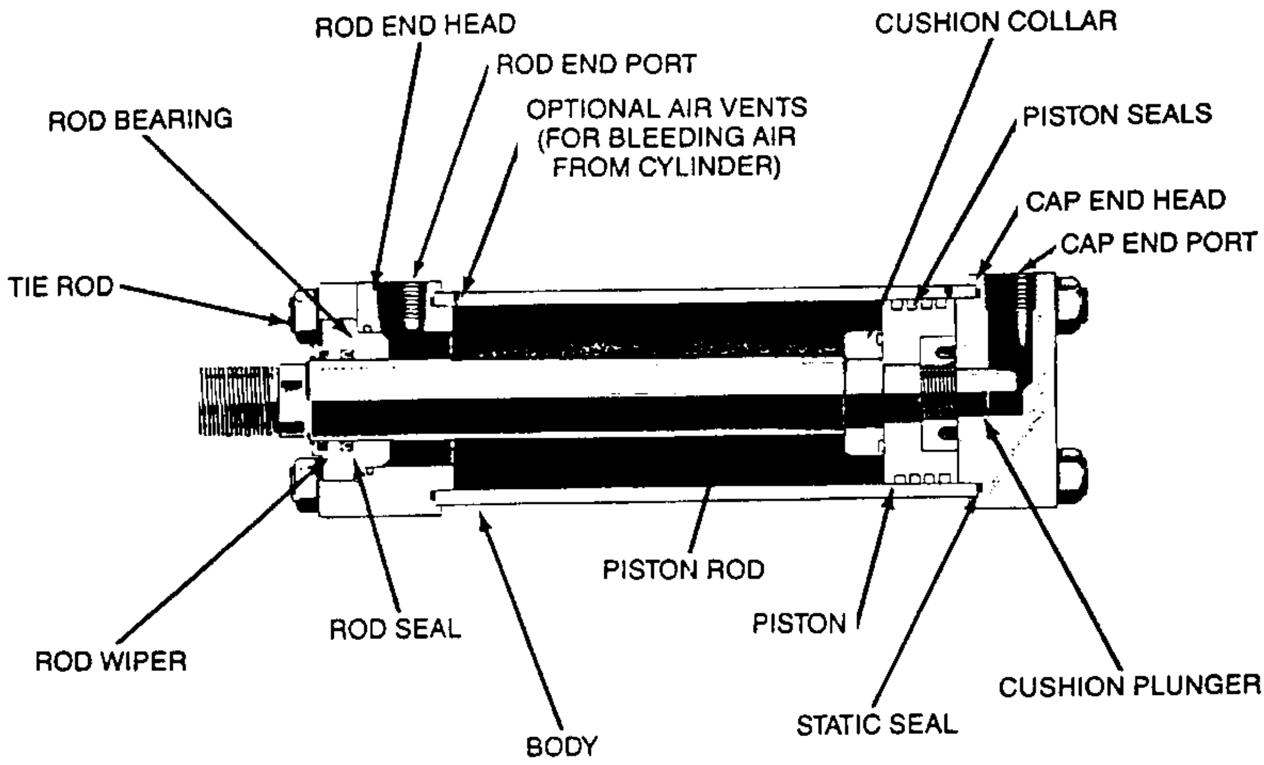


Figure 8.18

The operation of the cylinder is basic in the fact that oil is delivered to either port via the Solenoid Valve, and the pressure acts up on the piston, moving it in the appropriate direction. The piston rod is connected to the 'limb' of a manipulator for example and transfers the movement of the piston rod to the limb.

Figure 8.19 illustrates the various cylinder mounting methods

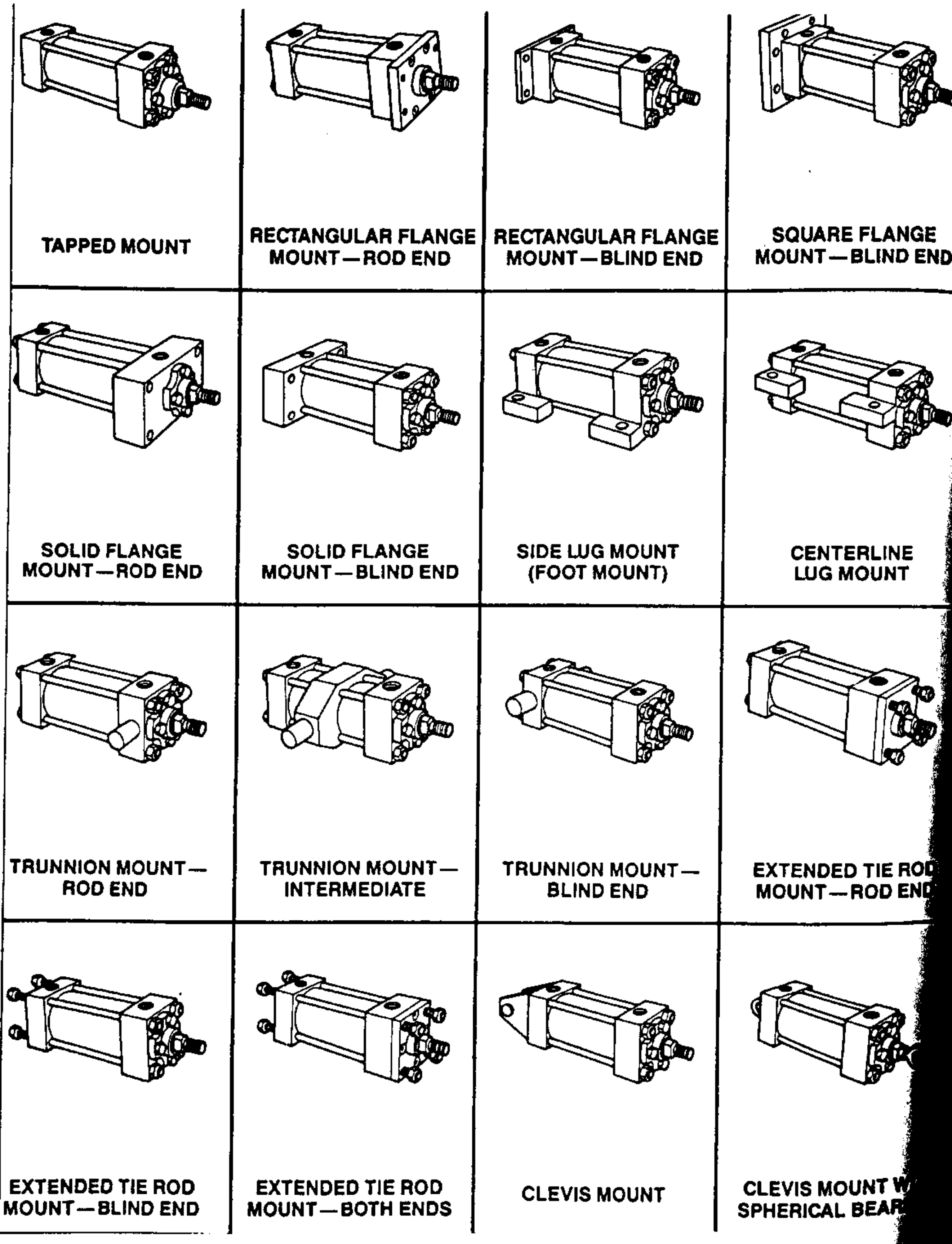


Figure 8.19

The main components of the limb are as follows.

a) Seals - The seal between the piston and the cylinder walls is critical for efficient operation. The seals may be manufactured from cast iron or more commonly rubber. If these fail, then 'creep' will occur when the actuator is on load. This is caused by oil by-passing the seal. It is important to ensure that the rubber material is compatible with the oil, as the rubber may perish.

The integrity of the rod seal is of upmost importance, as this prevents ingress of dirt, or sea water into the actuator. Rod seals may be manufactured from rubber or teflon. The rod seal material must be compatible not only with the oil, but in the case of ROVs it must be compatible with sea water.

b) Cylinder Cushions - The cylinder cushions are situated at either end of the cylinder, in order to slow down the movement of the piston at the end of it's stroke. If this was not the case, the piston would hammer against the end cap and suffer possible damage.

c) Ports - The external openings to the cylinder allowing oil to and from the cylinder as appropriate.

8.9.3 Hydraulic Motors

8.9.3.1 Introduction

Motor is the term given to an actuator that provides rotary motion. All motors are common in the fact that pressure is exerted on piston, vanes or gears which are directly coupled to an output shaft.

The motor that we are concerned with most in the ROV industry, is the axial piston motor. For this reason it is this motor that we will base our information.

8.9.3.2 Performance of Motors

The performance of motors is based on the following parameters.

a) Ability of pressure exposed surfaces to withstand force of hydraulic fluid.

b) Efficiency of linkage method used to connect pressure surface with output shaft.

c) Leakage Characteristics

8.9.3.3 Motor Ratings

Motors are rated according to torque, displacement, speed and maximum pressure limitations.

a) Torque - Torque is the turning, twisting function of the output. Motion is a function of force, and if sufficient torque is present to overcome friction, motion will occur.

b) Displacement - Is the amount of fluid required to turn the motor 1 revolution, and it is expressed in cubic inches per revolution (Cubic in/rev).

c) Running Torque - The running torque of a motor is the actual torque a motor can develop to keep the load turning. Running torque is a percentage of theoretical torque.

d) Starting Torque - The starting torque is the torque required to start the load turning. Once again it is considered to be a percentage of theoretical torque.

e) Speed - Speed is the rotational velocity at a specific pressure that the motor can maintain without sustaining damage. It is a function of volume of delivered fluid and displacement.

f) Slippage - Slippage is the leaking of fluid across the motor without any work taking place.

8.9.3.4 Axial Piston Motors

Axial piston motors are probably one of the commonest type found on ROV systems. They fall into the class of High Speed, Low Torque Motors. Figure 8.20 shows the construction of a typical in line axial piston motor.

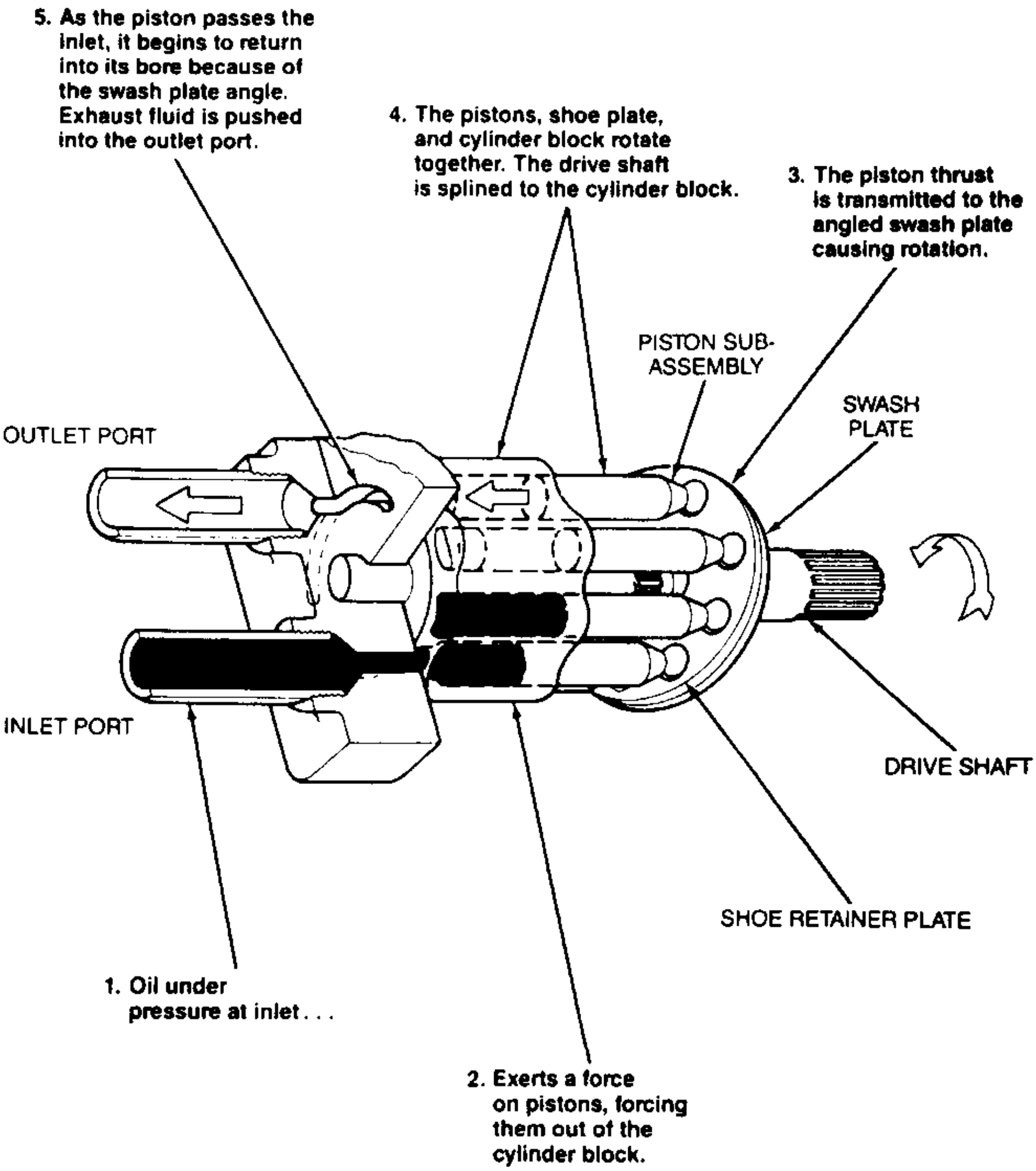


Figure 8.20

Fluid pressure acts up on the piston ends which transmit the pressure to the swash plate. The angle of the swash plate is such that a rotational movement is developed. The torque of the motor is proportional to the area, number of pistons and the angle at which the swash plate is positioned. The motors may be of fixed displacement or variable displacement. The variation of displacement is brought about by externally adjusting the angle of the swash plate.

8.10 Contamination Control

8.10.1 Introduction

It can be said that about 70% of hydraulic breakdowns are due to contamination of hydraulic fluid. Contamination can be defined as the presence of solid particles in the hydraulic fluid. It is essential therefore to try and minimise this occurrence in the best possible manner.

8.10.2 Effect of Contamination on System

The following factors have to be taken into account when looking at how contamination effects the system.

a) Purpose of Hydraulic Fluid -

- To Cool and dissipate heat

Contamination forms a sludge on the reservoir walls and thus prevents effective heat transfer.

- To Transmit Power

Contamination blocks small orifices and consequently restricts the flow of oil to relevant units.

- Lubrication

This can lead to disastrous consequences. All hydraulic components have tolerances which allow a certain amount of oil to flow through them for lubrication. For example, a certain amount of oil passes the piston rings in the axial motor in order to lubricate the shaft bearings. Build up of contamination in the cylinders will prevent this and lead to possible seizing of the shaft.

b) Mechanical Clearances

The clearance between hydraulic components can be defined as follows.

- 5 micrometers for high pressure units
- 15 to 40 micrometers for low pressure units

Note - one micrometer is one millionth of a meter.

Figure 8.21 shows the typical clearance value for various hydraulic components

	μm	In.
Gear pump (Pressure loaded) Gear to side plate Gear tip to case	 1/2-5 1/2-5	 0.00002–0.0002 0.00002–0.0002
Vane pump Tip of vane Sides of vane	 1/2-1* 5–13	 0.00002–0.00004 0.0002–0.0005
Piston pump Piston to bore (R)** Valve plate to cylinder	 5–40 1/2–5	 0.0002–0.0015 0.00002–0.0002
Servo valve Orifice Flapper wall Spool sleeve (R)**	 130–450 18–63 1–4	 0.005–0.018 0.0007–0.0025 0.00005–0.00015

Figure 8.21

c) Modes of Failure

Particles that bring about contamination vary in size. It is this fact that determines the degree of failure in a hydraulic system.

- Catastrophic Failure

Brought about by large particles jamming a component. For example a particle may lodge between the teeth of the two crown wheels in the motor. This would cause complete seizure of the motor and result in the ROV becoming immobilised.

- Intermittent Failure

This may occur in components such as relief valves. The contaminant may prevent the poppet from re-seating properly and the valve would temporarily dump back to tank. As soon as the contaminant is flushed away, normal operation will be resumed.

- Degradation Failures

Degradation failures are caused by erosion of components by fine contaminants. This process may continue until catastrophic failure occurs if not checked by a maintenance procedure. (See chapter 12).

8.10.3 Summary of Contaminants

The table shown in fig 8.22 summarises the various contaminants in the ROV hydraulic systems.

Contaminant	Character	Source and Remarks
Acidic by-products	Corrosive	Breakdown of oil. May also arise from water-contamination of phosphate-ester fluids.
Sludge	Blocking	Breakdown of oil.
Water	Emulsion	Already in fluid or introduced by system fault or breakdown of oxidation-inhibitors.
Air	Soluble Insoluble	Effect can be controlled by anti-foam additives. Excess air due to improper bleeding, poor system design or air leaks.
Other oils	Miscible but may react	Use of wrong fluid for topping up, etc.
Grease	May or may not be miscible	From lubrication points.
Scale	Insoluble	From pipes not properly cleaned before assembly.
Metallic particles	Insoluble with catalytic action	May be caused by water contamination, controllable with anti-rust additives.
Paint flakes	Insoluble, blocking	Paint on inside of tank old or not compatible with fluid.
Abrasive particles	Abrasive and blocking	Airborne particles (remove with air filter).
Elastomeric particles	Blocking	Seal breakdown. Check fluid, compatibility of seal design.
Sealing compound particles	Blocking	Sealing compounds should not be used on pipe joints.
Sand	Abrasive and blocking	Sand should not be used as a filler for manipulating pipe bends.
Adhesive particles Lint or fabric threads	Blocking Blocking	Adhesives or jointing compounds should not be used on gaskets. Only lint-free cloths or rags should be used for cleaning or plugging dismantled components.

Figure 8.22

8.10.4 Prevention of Contamination

As a general rule ROV's incorporate 2 filters into the system, they are Low Pressure Suction Filters and High Pressure Filter. The Low Pressure Filter is located after the tank and before the pump which is designed to remove any particles that may be sucked from the tank by the pump. High pressure filters, as the name implies removes any contamination after the pump on the high pressure side.

Figure 8.23 illustrates a typical high pressure filter

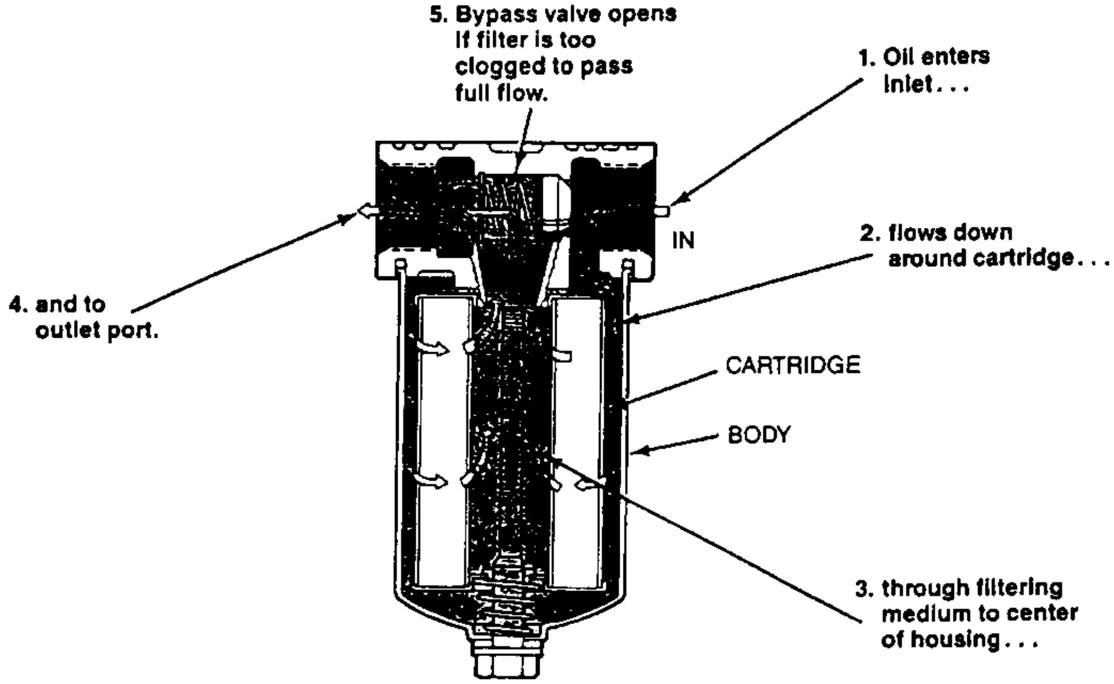


Figure 8.23

It is not the intention of this chapter to go into detail on filter changing as that is amply covered in chapter 12 on Mechanical Maintenance.

8.11 Hydraulic Fluids

It has been mentioned previously about the properties required from a hydraulic oil. However it is useful to have an appreciation of which oils should be used in the system to suit the particular environment in which the ROV is working.

8.11.1 Viscosity

Viscosity can be defined as a measure of a fluids resistance to flow, or an inverse measure of its fluidity. It is generally viscosity that determines which oil is used in the system. It can be said if a fluid flows easily, then its viscosity is low, a fluid that does not flow easily is said to have high viscosity.

8.11.1.1 Choosing the Right Viscosity

One has to make a compromise when choosing oil of the optimum viscosity. A high viscosity oil is desirable for maintaining a seal between mating surfaces, however there are disadvantages.

- High resistance to flow
- High temperature caused by friction
- Increased power consumption due to friction
- Sluggish operation
- Air becomes easily trapped.

If we overcome these factors by using a low viscosity oil, the following problems may occur.

- Excessive Internal Leakage
- Pump efficiency decreases, slowing down actuator speed.
- Break down of oil film between moving parts gives rise to frictional wear.

8.11.1.2 Measurement of Viscosity

The viscosity of a given oil can be determined by measuring the flow rate of oil at a given temperature. This value is termed the Kinematic Viscosity and has been catalogued by the International Standards Organisation (ISO) for a variety of oils at different temperatures.

Figure 8.24 illustrates the ISO figures for oils at 40°C.

ISO Viscosity Grade	Midpoint Kinematic Viscosity cSt at 40°C	Kinematic Viscosity Limits cSt at 40°C Minimum	Maximum
ISOVG2	2.2	1.98	2.42
ISOVG3	3.2	2.88	3.52
ISOVG5	4.6	4.14	5.06
ISOVG7	6.8	6.12	7.48
ISOVG10	10	9.00	11.0
ISOVG15	15	13.5	16.5
ISOVG22	22	19.8	24.2
ISOVG32	32	28.8	35.2
ISOVG46	46	41.4	50.6
ISOVG68	68	61.2	74.8
ISOVG100	100	90.0	110
ISOVG150	150	135	165
ISOVG220	220	198	242
ISOVG320	320	288	352
ISOVG460	460	414	506
ISOVG680	680	612	748
ISOVG1000	1000	900	1100
ISOVG1500	1500	1350	1650

Figure 8.24

From this we see that one must bear in mind the conditions that the ROV is required to operate. For example whilst working in the Arctic regions a low viscosity oil is required, e.g. ISO VG 30. When working in hotter climates, for example in Far Eastern waters, the vehicle may require oils of viscosity of around ISO VG 10.

Typical Oils are as follows:

BP	HLP 10
ESSO	NUTO H10 or UNVIS J13
SHELL	TELLUS RIO or TELLUS TIS
TOTAL	AZOLLA VG10

8.12 Manipulators

8.12.1 Introduction

Constant improvement in technology have given rise to ROVs carrying out more and more subsea tasks that were at one time reliant solely upon divers. In order to carry out these tasks, ROVs have to be fitted with robotics arms, commonly known as manipulators. All manipulators work on a master/slave principle, the pilots control being the master and the manipulator being the slave. Manipulators can have anything up to nine functions.

8.12.2 Principles of Operation

Manipulators are found on all classes of ROV - small 'eyeball' class are equipped with single function electronic manipulators, their purpose for example would be to carry a CP Probe. As vehicles increase in size, the tasks become more complex, where stronger and more functional manipulators are required. For this reason manipulators of this nature are hydraulically powered.
The functions are normally only required to operate at a fixed rate and therefore solenoid valves will be used to control the flow of oil. Normally each function will have its own dedicated valve, which will be one of a series of identical valves, collectively known as the Hydraulic Control Unit or H.C.U.

Figure 8.25 shows the layout of the Slingsby Engineering Ltd TA009 Seven Function Manipulator.

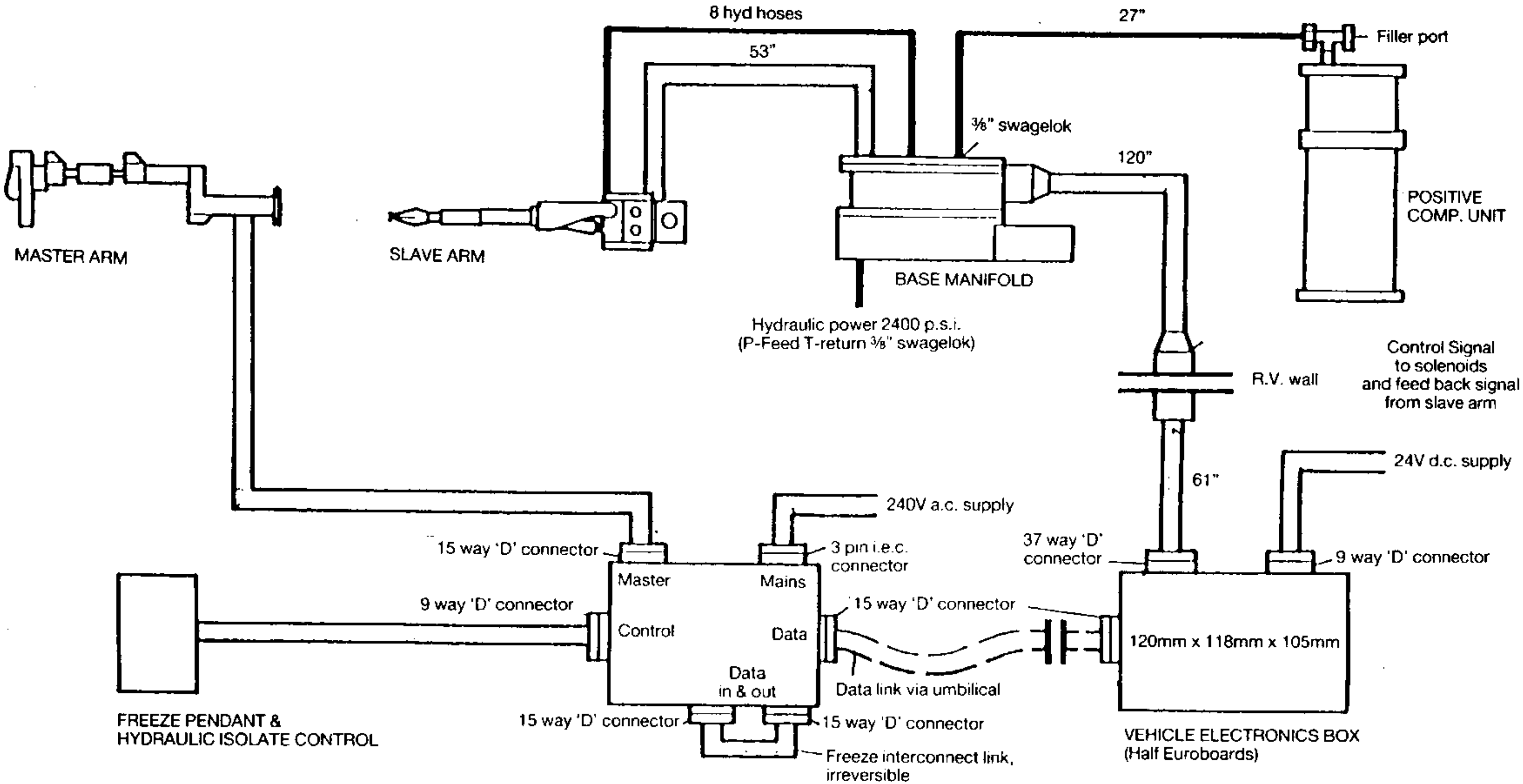


Figure 8.25

PICTORIAL SYSTEM ASSEMBLY

Figure 8.26 shows the location of the relative feedback potentiometers on the master and slave arms.

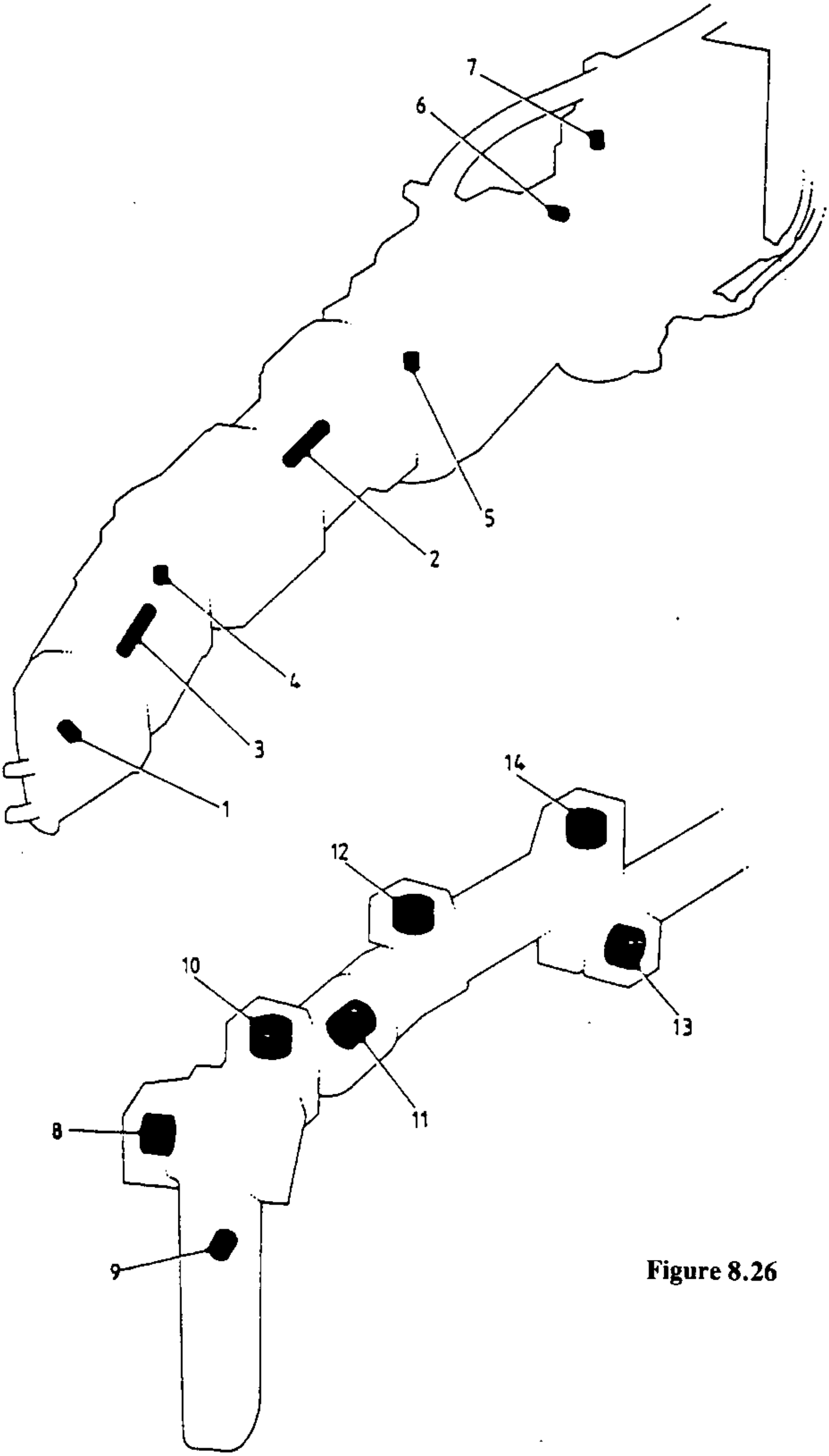


Figure 8.26

POTENTIOMETER LOCATION DIAGRAM
SLAVE/MASTER ARM

8.12.3 7 Function Manipulator

The TA009 Manipulator consists of two main groups of components which constitute a basic 7 function, closed loop positional feedback master slave manipulator system.

The Master Arm and its associated power supply and amplifiers are the minimum components required in the master arm group. (See Pictorial System Assembly).

The Slave Arm, Valve Pack, Positive Compensation System, Underwater Cable Assembly and Slave Electronics Unit are the minimum required components in the slave arm group. (See Pictorial System Assembly).

The system is designed to be capable of operating in a variety of installation situations. Typically, a remote piloted submersible, or manned submersible configuration may be used as the Transporter Package.

A number of product options to the basic manipulator are available.

Among these are:-

a. Continuous Wrist Rotate
b. Tool Grip Jaws
c. Force Feedback
d. Tool Lock Mechanism
e. Freeze Facility
f. Parallel Jaws
g. Self Contained Multiplexer.
h. 8th Function Extender
i. Teach and Repeat Microprocessor based control
j. Hydraulic Power Pack
k. Special Tooling Interface
l. Debris Cutters.

The seven functions available in the standard system are, as configured in the human arm.

1. Shoulder Slew (left/right)
2. Shoulder up/down
3. Elbow pivot (left/right)
4. Forearm rotate
5. Wrist Pivot (left/right)
6. Claw rotate
7. Claw open/close

The following is a brief overview of the system operation. It is described with the assumption that a basic system and freeze facility are fitted in a modern Type ROV. Other installations would operate the same in principle.
The motion of the manipulator is governed by the master arm system which is a scaled-down version of the slave arm (underwater arm). Each position feedback joint, on both master and slave arms, has a 5 kilohm servo potentiometer mounted on it, the spindle of which is directly coupled to the motion of the joint itself. Refer to the mechanical assembly drawings for further details.

Thus, to take a particular joint, a signal is available from both the master and slave arms and these are nominally pre-aligned at the commissioning stage to cover the same length of travel on the potentiometers, and hence to give nominally the same voltage range, as all potentiometers have ± 5V d.c. between the terminals. Some variation exists in the forearm rotate, claw rotate and claw open/close functions as the master arm is configured with rotary actuation potentiometers and the slave arm with linear actuation potentiometers. The electronic systems perform gain adjustment to ensure matching of voltage swings, in these particular cases.

Both master and slave signals are fed to the vehicle electronics control box, the surface master arm signals being carried via the optional 'Freeze' control card and the system or vehicle data link. The control box electronics performs a comparison between the two signals and if an error exists between the two, supplies a drive signal to the relevant hydraulic servo valve (proportional control valve) in the slave arm. This serves to drive the slave arm joint to the required master arm position, the electronics control monitoring continuously and progressively reducing the drive signal until the two arm signals correspond. At this point, the slave arm and master arm are in the same position, for that particular joint. Taking all seven degrees of freedom together and all operating at the same time (if required) this means that whatever position or attitude is taken up by the master arms, within the mechanical constraints of the system, the slave arm will be driven until it assumes a corresponding position.

A 'freeze' switch is released, the electronics cause the slave arm to track slowly, over a 10 second period, to any new position that the master arm may have adopted. A hydraulic isolate valve is fitted to the system and is used to switch hydraulic power to the arm.

Figure 8.27 shows the capabilities of the Slingsby Engineering Ltd 9 Function Manipulator.

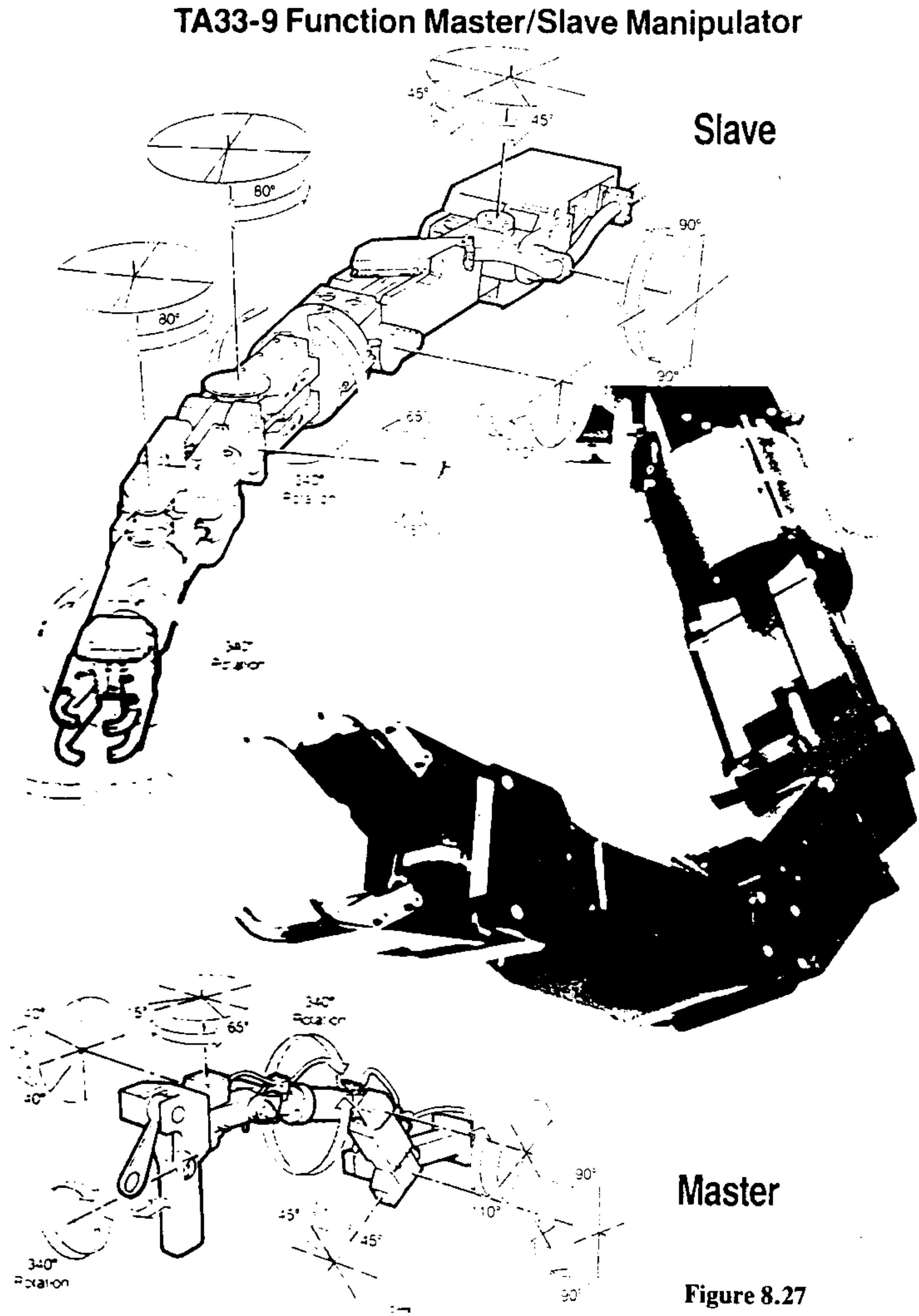
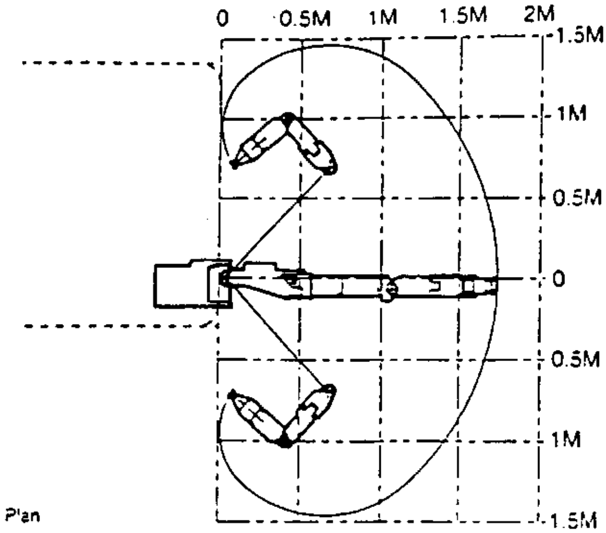
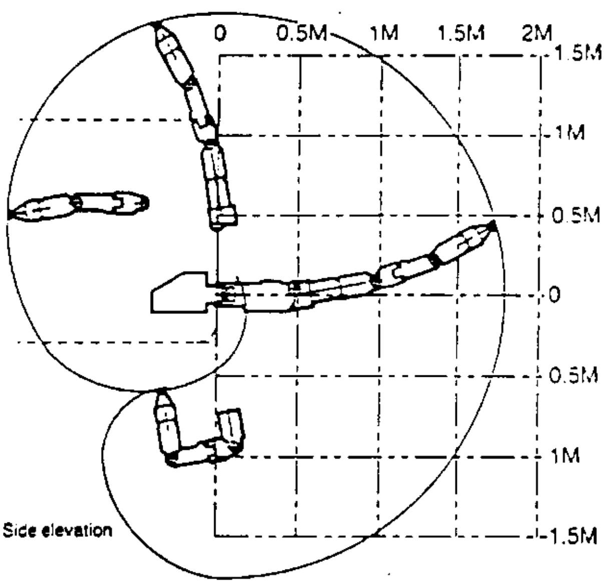


Figure 8.27

TA33 – Operating Envelope





Specification

Shoulder – Up/Down
±90°
Shoulder Slew
±45°
Elbow
110°
Forearm Rotation
340°
Upper Wrist Pitch
80°
Wrist Yaw
+15°
−65°
Lower Wrist Pitch
80°
Claw Rotation
340°. Continuous Optional
Rotation Torque
108. Nm 80 ft. lb.
Claw Open/Close
150mm (6 in.)
Maximum Reach
1·75m (69 in.)
Maximum Lift at Full Reach
34kg (75 lb.)
Hydraulic Supply
138/206 bar (2000/3000 p.s.i.) 2 gpm.
Weight of Slave Arm
88 kg (193 lb.) In Air. 56 kg (123 lb.) In Water
Weight of Installation
110 kg (242 lb.) In Air. 70 kg (154 lb.) In Water

Figure 8.28

The TA33 is a nine function master/slave manipulator designed primarily for subsea use on manned or remotely operated vehicles, as well as being suitable for use in almost any hostile environment.

The TA33 offers unrivalled dexterity combined with the ruggedness essential for remote subsea operations. Hydraulic and electrical service lines run within the arm structure to avoid the possibility of damage or snagging.

Designed as a general purpose subsea manipulator, the TA33 is particularly suited to difficult cleaning and inspection tasks on structures where access is limited, such as welded nodal joints.

The TA33 is a development of the proven TA9 seven function manipulator, now accepted as the offshore industry standard master/slave system, and therefore has the advantage of a well established spares and technical back-up service.

8.12.4 Conclusion

This chapter has provided an overview of hydraulic theory and the components commonly found in ROV systems. The maintenance of the system is covered in chapter 12.

9.0 Introduction

Work class ROVs all make use of hydraulic power. The hydraulic systems thus employed use pressure fittings to connect together the high pressure pipe work and hoses used to connect together the various components. High pressure fittings are produced by several different manufacturers but *SWAGELOK* design and make a range of re-usable fittings that are very popular throughout the industry. These fittings will be used to illustrate the types of fittings available.

9.1 Selecting Fittings

Before any fitting is selected the tube outside diameter must be known and the fitting thread size must be either, selected for new work, or matched to existing fittings where modifications or maintenance is required. The next consideration is the working pressure. For hydraulic systems this may be as high as 3000 p.s.i. and any fitting used must be able to withstand this pressure without leaking.

9.1.1 Thread Size

Due to design considerations there are a number of different thread sizes and types available. The thread may be tapered or parallel

a) Tapered threads are designed so that a pressure-tight seal is made on the threads. When using these types a sealant such as *StripTeeze* or *Swak* is required. These are manufactured to BS 21.

b) Parallel threads are used where a pressure-tight seal is not made on the threads. The seal is usually made either metal-to-metal or with a gasket against the face of the female part. There may be 3 variations on the sealing arrangement all being covered by BS 2779.

   i) The first variation is a Male Parallel With Bonded Gasket Seal. In this case a composite washer, usually metal and elastomer, is used to seal against the face of the female port. A machined taper directly behind the male thread centres the gasket.

   ii) One variation is the Female Parallel. This type seals against the face of the female port metal-to-metal or with a gasket.

   iii) The third variation is the Female Parallel Gauge. A gasket, metal or fibre, is used inside the female port against a flat surface. The mating male component exerts a load on the gasket sealing the connection. BS 1780 (1985) is an additional specification for this type.

There are a number of different threads use for hydraulic applications some of the more usual types are:-

a) American Standard Pipe Thread (NPT)

b) American Standard Unified Thread

c) ISO 7/1

d) ISO 228/1

e) BSP

f) BSPT

g) DIN

h) JIS

i) BSPP

9.1.2 Pressure Rating

It can be stated with confidence that Swagelok fittings are all rated to the maximum working pressure of standard tubing. In their literature they state that Swagelok fittings provide a leak proof seal on all tubing connections. The onus is, however, on the individual to ensure that he selects the correctly rated fitting for the job in hand.

9.2 The Swagelok System

These fittings are comprised of four precision-made components, all manufactured to very stringent tolerances and under rigid quality control procedures. The consistency and quality of these matched components is the reason that Swagelok can be so confident in their being "fit for purpose". The four components are:-

The nut

The back ferrule

The front ferrule

The body

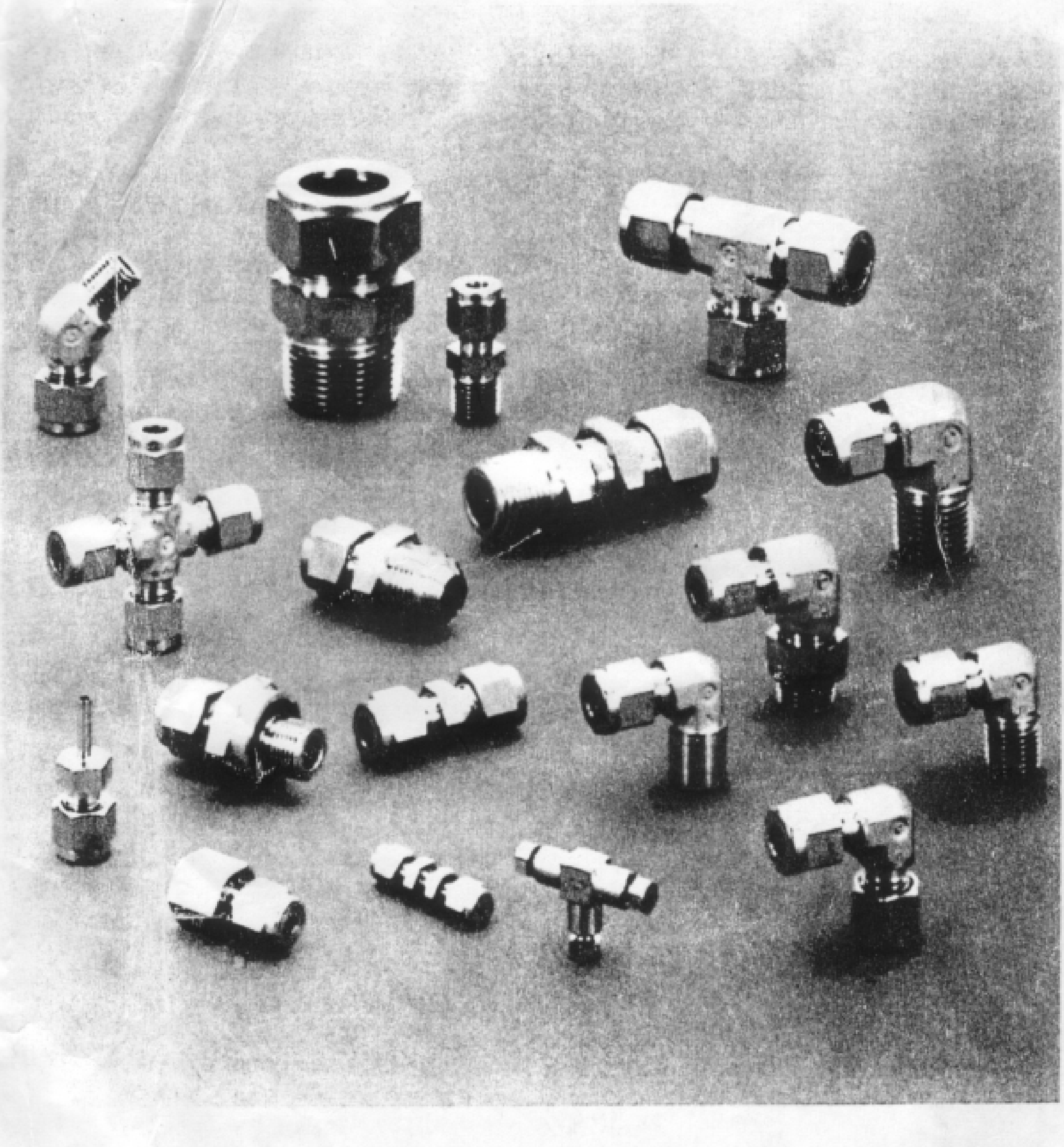
Special courses and training is provided by Swagelok on demand to teach the correct and safe use of their fittings. A selection of Swagelok fittings are shown in Figure 9.1

9.3 Advantages of Tube Fittings

The reasons for concentrating on these types of mechanical pipe fittings in this chapter are:-

Tube fittings are easier to install than threaded pipe
Labour costs can be significantly reduced
Welding, with the associated special procedures, is eliminated
No specialist tools are required

Figure 9.1



CHAPTER 10 ROV HOOK UP, PRE/POST DIVE CHECKS

10.0 Introduction

It is the intention of this chapter to outline the mobilisation of a typical ROV system and discuss the principles behind the pre and post dive routine.

As the name implies the pre and post dive checks take place immediately before the vehicle is deployed and as soon as it arrives back on deck. It cannot be emphasised enough how important a task the pre and post dives are. They form an integral part of the planned maintenance procedure in the fact that they identify any malfunction immediately and can therefore minimise any vehicle downtime. For this reason it is important that a standard routine is laid down in the form of a check list that is made available to all ROV personnel, especially newcomers to the system.

Becoming competent at carrying out a pre and post dive check is a skill that develops only with practice. It is important to include every item on the list and a very important point is to be totally aware of the fact that the hydraulics have a limited running time in air.

10.1 ROV Hook Up

ROV hook up basically refers to the mobilisation procedure that takes place at the beginning of the of the contract, the task usually takes between twelve and twenty four hours depending on the class of vehicle and the nature of the job.

Mobilisation takes place initially in the base and will involve testing the system, carrying out a full inventory of spares and consumables and selecting a suitable crew to suit the nature of the operation. Once this has been carried out the system will be transported to the vessel or installation by supply ship or helicopter depending on the class of ROV being used.

The actual positioning of the control cabin, workshop, winch and crane requires a certain amount of liaison with the authorities on board as there are many safety factors that have to be taken into account.

Once in position the ROV team can start to connect up the appropriate cabling between the relative units.

10.1.1 Deck Cabling

Deck cable is armoured, zone two rated cable that carries the necessary signals between the control cabin, winch and workshop. Typical examples of these cables are as follows:-

a) Main power cable to supply the winch and crane power packs.

b) Domestic power supply to the workshop.

c) Cable to route power, control, video and optical fibre signals from the control cabin to the winch fixed junction box.

d) If necessary any purge hoses between all the units.

e) Communication link between control cabin, winch and crane.

f) Vessel or rig supply to the power distribution unit.

During this procedure the cables will be routed in the safest manner possible and once again close liaison with the vessel or installation crew will be necessary.

The umbilical is also connected to the ROV during this procedure. During the transportation the ROV is disconnected from the umbilical, the loose conductors being secured to the winch which has a dedicated travelling container.

Once in location the conductors are reconnected, a task that can be quite time consuming depending on the system in use. The final stage in the operation is the testing of the system and ensuring that all the equipment in the control cabin is hooked up correctly.

Once the tests have been satisfactorily completed the control cabin, winch, workshop and crane are welded to the deck. On completion the welds are inspected and require to be certified before the operations can proceed.

10.2 Pre and post Dive Checks

Figure 10.1 illustrates a typical pre and post dive check list for a Scorpio system. It can be seen that the checks include the whole system and therefore any faults or defects can be identified immediately.

The list begins with integrity checks that ensure that the vehicle has not suffered any physical damage or that any equipment that is fitted to the vehicle has not worked loose. These checks may alter slightly depending on what equipment is fitted to the ROV.

It can be seen that a generator is also included in the list. It may be the case that the system is working on a ship that does not have a suitable source of power and therefore the ROV company is required to supply a generator. If this is the case then it is the responsibility of the team to ensure its safe operation.

Once the integrity checks are complete it is safe to power up the ROV. The communication between the pilot and deck officer is via hardwire comms with a microphone headset used by the deck officer. The pilot will be operating the functions from the control cabin whilst the deck officer observing the vehicle . An efficient method of communication is essential to ensure that the hydraulic power pack is not running for too long a period in air. Good communication procedures takes time to develop, the basic skills of which are discussed in Chapter 14.

During the dive checks it is the responsibility of the deck officer to ensure that the procedure does not endanger any personnel who may be near by. They have the right to intercept anyone who they feel to be putting themselves or the vehicle at risk.

SCORPIO PRE AND POST DIVE CHECK LIST

Post Dive No: Date Submersible:

Pre Dive No: Date

Post	Vehicle Integrity Checks	Pre
	Frame free from damage	
	Cables & connectors secure	
	Pod straps,caps & Plugs OK	
	KELLUM & Pennent correct	
	Fixed buoyancy & Ballast OK	
	Thruster & props correct	
	Manipulator secure & correct	
	Cable cutter secure & correct	
	Pan & Tilt & camera correct	
on	Lens cover -	off
	Lights secure	
	Sonar correct, comp full	
	Hyd. Term Secure & 80% full	
	Hyd. Fill Vv & Drain Plug OK	
	Hyd. motor secure	
	Hyd. Comps (x2) 80% full	
	Umb. Term. OK & Comp 80%	
	TCU oil ind full, & cap secure	
	TCU Vv closed & capped	
	HCU oil ind. full, cap secure	
	Optics J/B comp diaphm full	
	Xenon flasher secure	
	Emergency pinger secure	
off	Still camera & flash secure	on
	Sonardyne transponder OK	
	Ancillary eqpt. fitted & secure	
BALLAST FITTED kg	ADDITIONAL BUOYANCY kg	

Post	GENERATOR CHECKS	Pre
	Fuel level	
	Water level	
	Anti-freeze correct	
off	Oil level	on
	Generator running	
	Record running hrs	

Post	WINCH CHECKS	Pre
	Oil level in reservoir	
	Reset footage ctr	
	Brake operation	
	Buoy'cy floats ready	
	Comms working	
	Start winch	
	Test all functions	

Post	CRANE CHECKS	Pre
	Oil level in reservoir	
	Hook & Shackles OK	
	Lift wire OK	
	Start crane	
	Test all functions	

Post	VEHICLE POWER ON	Pre
	Power ON - OCU	
	Hyd. Wng Lt ON	
	Leak indicator test lts	
	Power ON - Veh	

Post	VEHICLE POWER ON	Pre
	Flux gate to SLAVED	
	Leak locator to OPR	
	Reset cable twist ind.	
	Depth ind. to zero	
	Auto depth to MAN	
	Auto hdg to MAN	
	Veh lts check	
	Video system check	
	Sonar system check	
	Power ON - HYD.	
	Check HYD pressure	
	HYD temp(100F max)	
	Thrusters functions OK	
	Pan & Tilt OK	
	Manipulator OK	
	Tools function OK	
	HYD - OFF	
	HDG - OK with ship?	
	Climb/dive rate ind - 0	
	Pitch ind veh atitude	
	Ancillary eqpt check	
	Emrgy Pinger test OK	
off	Xenon flasher	on
	Check RCU	

Figure 10.1

10.3 Dive Logs

The pre dive and post dive log sheets are retained by the company and contribute towards the records that are kept regarding the vehicle's history Another important log is the ROV dive log. The dive log records all the events that occur from the moment the ROV leaves the deck until the moment it comes back again. By carrying out this process it is possible to keep record of the total number of hours that the vehicle has been operating as well as recording specific events that occur during the dive. Fig. 10 2 illustrates a typical dive log.

SUBMERSIBLE DIVE LOG			
			Sheet of
DIVE NO:	DATE:	SUBMERSIBLE	SHIP/PLATFORM
CHARTER:	JOB NO.:	SEA STATE	WIND:

OPERATION TEAM		LOCATION:	LAT:
Ops Controller			LONG:
Surface Officer		DIVE TASK:	
Pilot		EXTRA EQUIPMENT FITTED:	
Observer			
Winch		BOTTOM CONDITIONS:	
Crane			
Deck		VIDEO TAPE NO.:	DIVE DURATION:

Time	Video counter	Event

Figure 10.2

CHAPTER 11 ELECTRICAL MAINTENANCE.

11.0 Introduction

A planned maintenance procedure (PPM) is, in the long term a cost effective way of ensuring the efficient operation of the whole system. If PPM were not in place then breakdown would eventually occur and lead to time consuming remedial maintenance during which the vehicle would be on DOWN TIME. Down Time refers to the time that the system is effectively off hire due to breakdown.

Adhering to a PPM. is the responsibility of all ROV personnel and all practices should be suitably logged. A well organised logging procedure will reflect the systems overall performance and will, in certain situations aid the technician in locating faults. Maintaining the log is normally the responsibility of the Sub Engineer as he works solely with that particular system as opposed to certain personnel who are contractors and will constantly be moving between different systems. The Sub Engineer will ensure that the logs are kept up to date and compile any 'handover' documentation that is required to be given to the new team on crew change.

A certain amount of time may be dedicated each day to carrying the routine maintenance. It is the intention of this chapter to outline the various electrical maintenance tasks that may be carried out as part of the maintenance procedure.

11.1 Cables, Connectors and Penetrators

As a general rule the vehicle electronics tends to be a very reliable part of the system. All the circuits are housed in watertight pressure vessels and require little maintenance. However the connectors and cables that interlink the various pressure vessels are exposed to the harsh environment and are susceptible to damage and wear. For this reason it is imperative that the technician be fully aware of the correct methods of handling and maintaining such devices.

11.1.1 Connectors and Penetrators

Connectors and penetrators form the interface between the internal electronics of the ROV and the external cabling interconnects the various pressure vessels. The efficient operation of these devices depends on their ability to prevent water ingress to the current carrying conductors. Figure 11.0 illustrates a typical connector and penetrator unit.

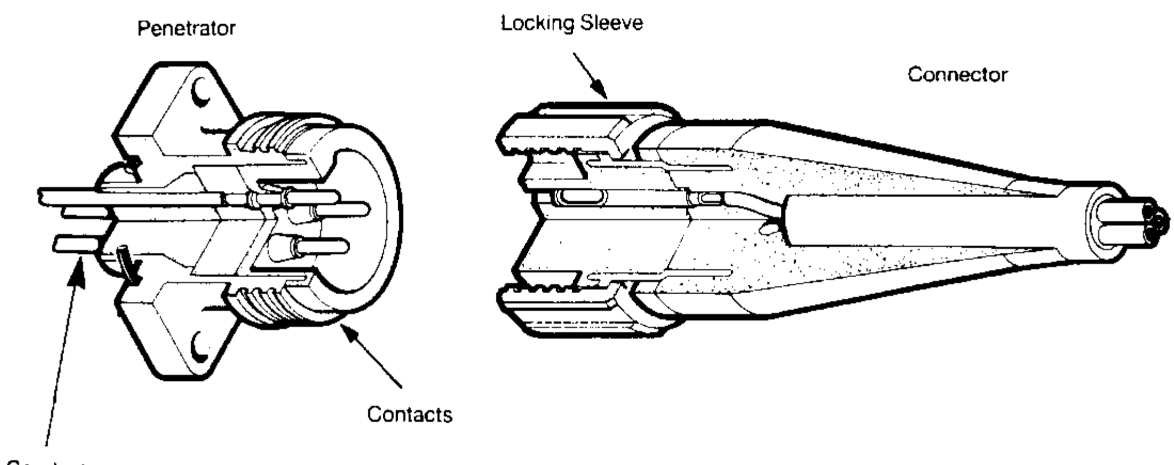


Figure 11.0

11.1.1.1 Penetrators

The penetrator forms the interface between the internal electronic circuitry and the connector. Penetrators are normally manufactured from high quality stainless steel and are bolted or screwed into the actual pressure vessel. The seal between the two mating faces is created by a rubber 'O' Ring and it is the degree of integrity of this 'O'Ring that prevents water ingress to the pressure vessel.

The number of internal conductors and therefore contacts can vary between one and anything up to seventy depending on the requirements of the interconnection. The contacts are normally gold plated to ensure a high degree of electrical conductivity. All conductors and contacts are chemically bonded into a synthetic rubber matrix which offers a high degree of insulation and resistance to water ingress.

Penetrators and connectors are manufactured in either male or female configuration and a list of the many available types are included in the appendices of this handbook.

11.1.1.2 Connectors

Connectors are directly attached to the cable and have internal conductors and contacts that are bonded in the same manner as in penetrators. The may have a locking sleeve that adds to the rigidity of the unit. The main purpose of the locking sleeve however is to prevent the connector being accidentally pulled out of the penetrator during operations. It is important to realise that the sealing properties are **not** created by the locking sleeve and excessive over tightening will only lead to damage and eventual breakdown of the unit.

11.1.2. THEORY OF OPERATION.

Figure 11.1 illustrates the principle of operation of a single pin connector mating with a female penetrator.

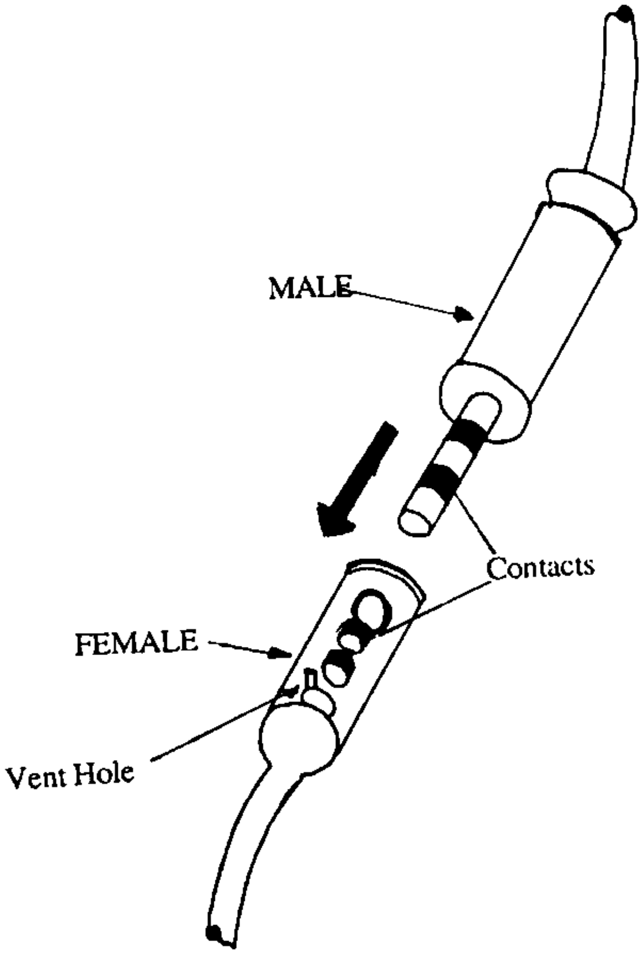
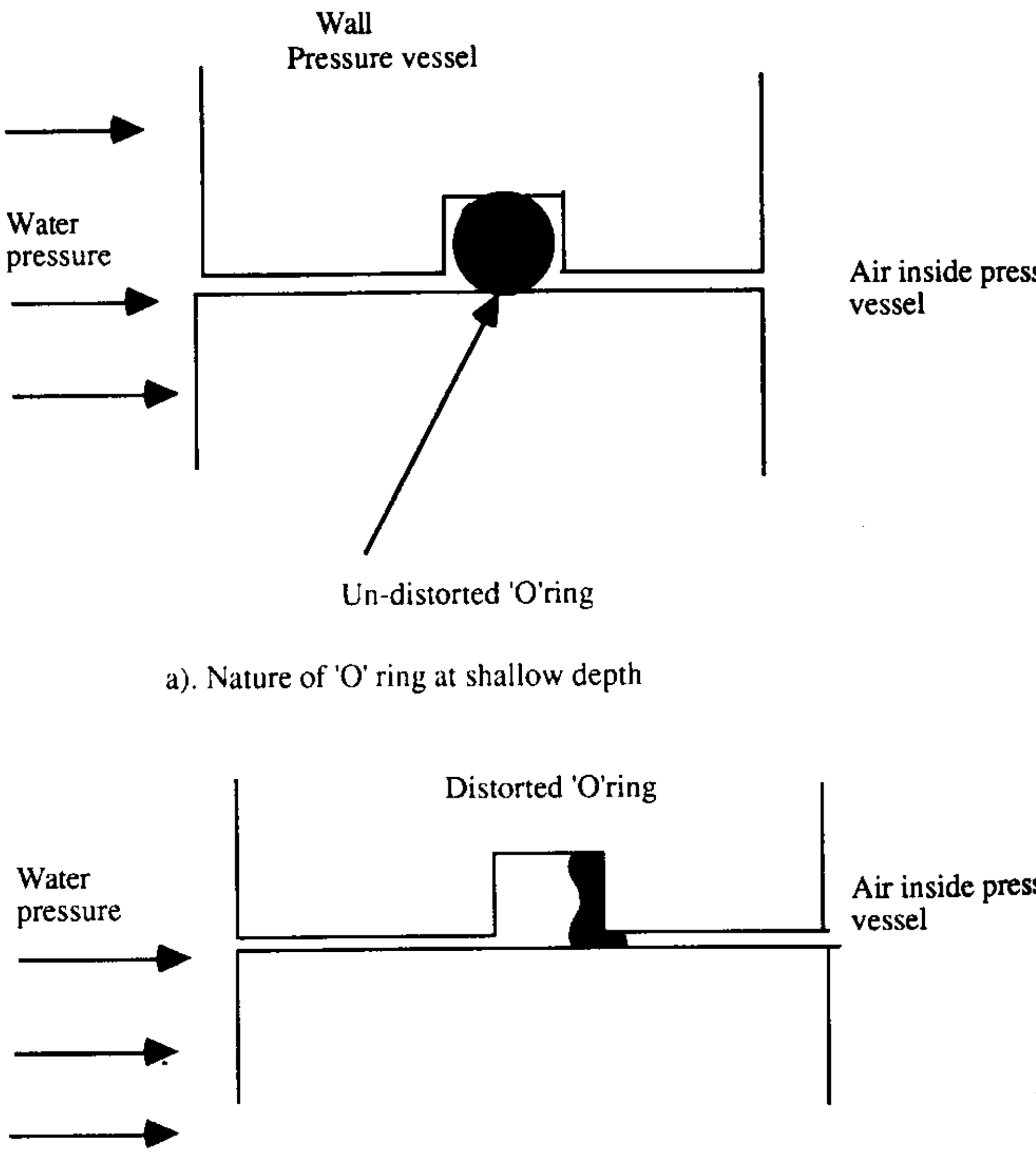


Figure 11.1

The male pin is flared at the tip and is therefore oversized with respect to the inside diameter of the female socket. This ensures that air and water is forced out through the vent hole. It follows that as the vehicle increases in depth then the surrounding water pressure will increase. This has the effect of forcing the rubber sealing faces together and thus, increasing the sealing effect. It is imperative therefore that the integrity of the sealing faces is maintained at all times as any breakdown will result in water ingress.

11.1.2.3. 'O'RING SEALS.

O Rings operate on a similar principle to the connectors and penetrators. They form a mechanical seal which is illustrated in figure 11. 2



a). Nature of 'O' ring at shallow depth

b). Nature of 'O'ring at depth

Fig 11.2

It can be seen that as the external pressure increases the O Ring becomes mis shapen and is forced into the gap between the two surfaces. It follows therefore that a greater seal exists when the vehicle is at greater depths, however when working in shallow depths water ingress may occur if the two faces are not firmly bolted together.

11.1.3 Maintenance of Connectors, Penetrators and 'O' Rings.

The efficient operation of sub sea connectors is totally dependent on how well they are maintained. It cannot be emphasised enough how important it is that the correct methods are used when carrying out connector / penetrator maintenance as failure to do so may result in many hours of unnecessary breakdown.

11.1.3.1 Connectors and Penetrators

Whenever a connector and penetrator are unmated the following procedure should be followed.

a) Inspection of contacts.
Electrical contacts are susceptible to corrosion . A defect of this nature would indicate that there has been a possible ingress of water through a faulty or improperly mated connector. Contacts may also become mis-aligned due to the connector being 'forced' during the mating process. Contacts should also be inspected for evidence of 'arcing'. Arcing occurs when the contact is improperly mated in the female receptacle, this gives rise to the current 'jumping' across the gap and causing the contact to burn.

b) Inspection of synthetic rubber.
The rubber should be inspected for evidence of water ingress. Any sign of moisture on the rubber surface is unacceptable and the problem should be addressed immediately. The possible causes of water ingress are improper mating of the connector and penetrator, rubber becoming mis-shapen due to over tightening of the locking sleeve and, in extreme cases the rubber becoming cracked or perished. In extreme cases of water ingress an electro-chemical reaction may take place resulting in a deposit forming around the sealing faces.

c) O Ring Seal.
Connectors that make use of an O Ring to create the seal require the O Ring to be thoroughly inspected whenever the unit is un-mated. The O Ring should be inspected for obvious signs of damage, lack of integrity and perishing. It is not uncommon for an O Ring to be mislaid and the unit reassembled without the O Ring being in place. For this reason it is imperative that the technician checks that it is correctly in position before assembly.

11.1.3.2. Assembly Procedure

Once the above inspection has been carried out the following procedure should be undertaken when assembling the connector and penetrator.

a) The contacts and sealing faces should be cleaned with a suitable electrical solvent cleaner in order that all traces of dirt are removed. It may be necessary to use Q Tips in order to remove any traces of dirt from the O Ring groove. On some vessels or installations there may be a source of compressed air available which can assist in the cleaning of the connector.

b). Once the contacts, connector and penetrator are clean it is necessary to lightly grease the connector. It is normal practice to apply a **thin film** of **Silicon Grease** to the mating parts in order to provide lubrication. If this was not carried out then the mating parts would become dry and difficult to un-mate. The excessive force that would have to be applied to un-mate them would lead to possible damage or distortion of the unit.

c). The connector should be mated to the penetrator, taking great care as to align the two mating units correctly. Most connectors have a locating lug that prevents any misalignment taking place. Some connectors and penetrators are manufactured with one pin, called a polarising pin, of different size which assists in correct location. Figure 11.3 illustrates some typical subsea connectors that are found in the ROV industry.

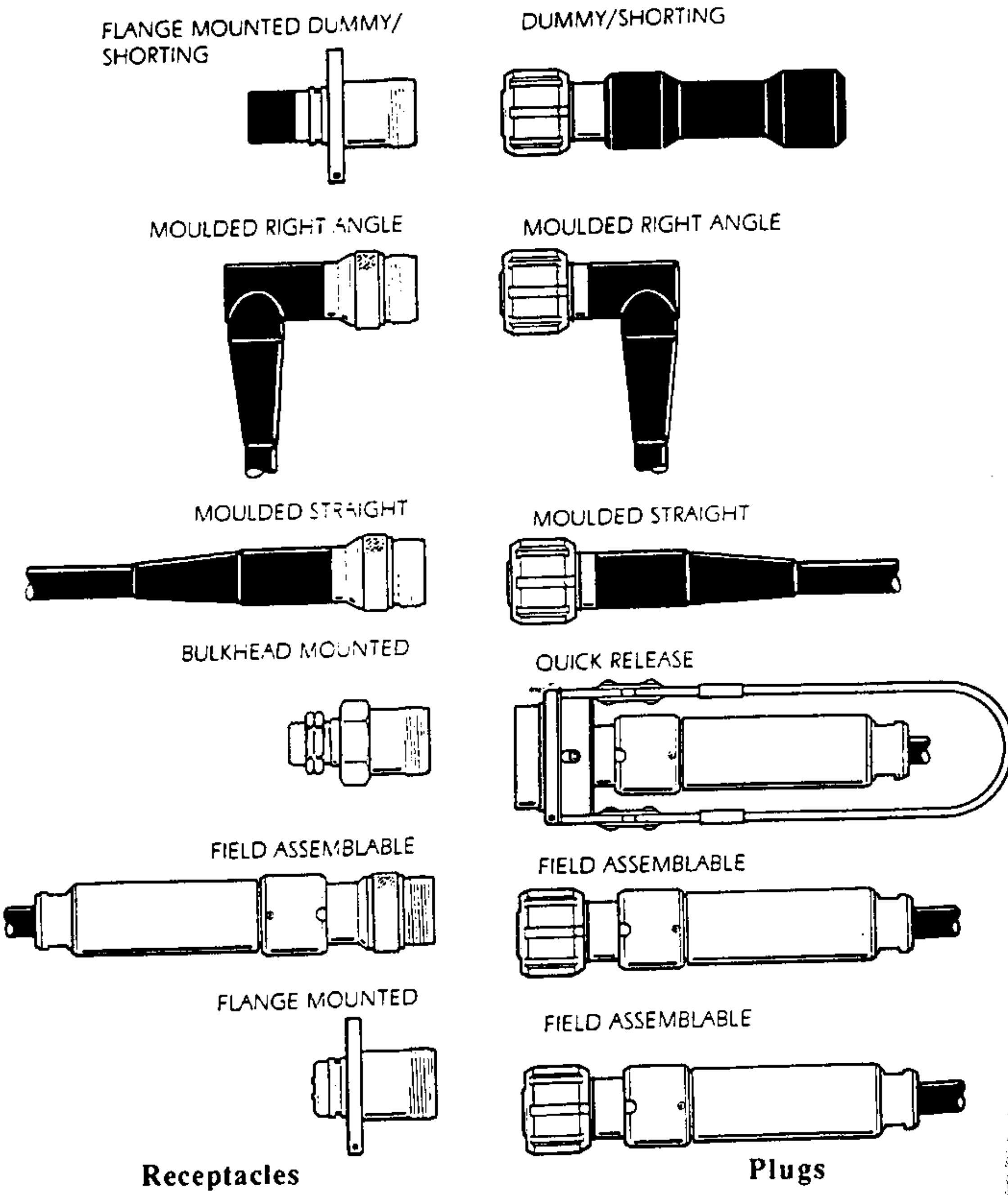


Figure 11.3

d). When adjusting the locking sleeve great care must be taken to prevent over tightening. If this occurs then the connector is liable to warp thus destroying the sealing properties. It is therefore only necessary to **hand tighten** the locking sleeve and no attempt should be made to use spanners or strap wrenches. Occasionally it may be necessary to use a tool of this nature to undo a connector locking sleeve. This is because the unit may have been subject to extreme pressure and this has had the effect of tightening the connector. It may also be the case that the connector is somewhat inaccessible to the hand an a tool is required to release the locking sleeve.

11.1.3.3. GREASING.

It is important to fully appreciate the reason behind applying Silicone Grease to sub-sea connectors. As previously stated it is used purely as a lubricant and does not create the seal. There are many misconceptions that exist throughout the industry, some claiming that if a large quantity of grease is applied then the greater is the sealing effect of the connector.

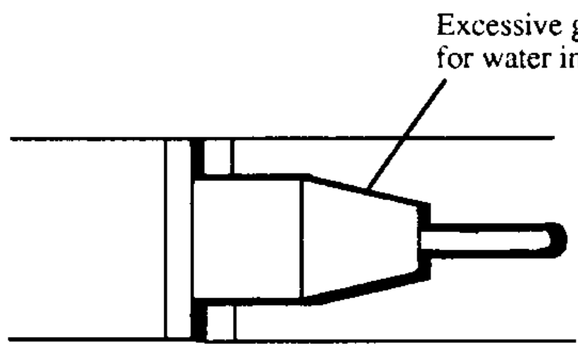


Fig 11.4

Figure 11.4 illustrates the effect of over greasing,.in this situation the grease prevents the connector and penetrator from mating correctly. The grease actually allows a path for water,that may be under pressure, to access the contacts.

11.2. SUB-SEA CABLES.

Sub-sea cables are especially designed to withstand excessively high pressures to which they are subjected to in their working environment. They are manufactured from a resilient synthetic rubber that offers a high degree of protection and electrical insulation to the conductors within. Sub-sea cables contain varying numbers of conductors depending on the specific task. It must be stated however that if they do not fall into a structured maintenance procedure then they are very susceptible to failure and consequent breakdown of the system.

11.2.1 Possible Cable Defects

The following defects are likely to occur without regular maintenance taking place.

a) Breakdown of outer sheathing.
During operations the cables are constantly exposed to drag caused by the movement of the vehicle through the water. If they are not properly secured then they become susceptible to wear. In extreme circumstances cables may become snagged on a manipulator or even sucked into a thruster. To overcome this problem it is important to ensure that all cables are securely fastened with Ty- Raps to the vehicle frame.
In some extreme cases the insulation may perish causing the rubber to crack and expose the conductors within. For this reason it is important to inspect all cables on a regular basis.

b) Breakdown of internal conductors.
Extreme cable movement can also lead to the conductors within the cable breaking down, particularly near the connectors which tends to be the most sensitive point. Once again it is possible to detect these occurrences by regular testing of the cable.

11.2.2 Testing Sub Sea Cables

In order to monitor the integrity of the internal conductors we can measure the insulation between each one using a MEGGER METER. This has the effect of measuring the resistance between each conductor whilst connecting a high voltage to the conductors. (see chapter 7 Use of Test Equipment). Ideally the insulation should be infinite between conductors, however ingress of moisture combined with either connector or conductor damage can lead to an insulation breakdown that will require repair to be carried out.
NOTE: WHENEVER AN INSULATION TEST IS CARRIED OUT THE CABLE SHOULD ALWAYS BE DISCONNECTED FROM THE PRESSURE VESSELS OR ANY ELECTRICAL CIRCUITRY.

11.3 Maintenance of Umbilicals

Umbilicals are susceptible to both fatigue and overloading which can eventually lead to the breakdown of the internal conductors. These factors may arise from poor piloting techniques which may lead to the umbilical becoming twisted or kinked. Damage may also occur due to mismanagement of the umbilical during the launch and recovery process. When the vehicle is passing through the splash zone the umbilical may tend to 'snatch' due to there being insufficient 'slack' available whilst latching and un-latching.
All these factors can result in the R.O.V. team having to carry out what is known as a RETERMINATION. Retermination can be a lengthy and tedious process, however it is important to follow the correct procedure in order to minimise the vehicle 'down time'.
The following sections outline the process for the re-termination of a typical armoured umbilical.

11.4. CABLE SPLICING.

A situation may often arise in which a sub-sea cable requires repair to be carried out in the field. This may be due to insulation break down between the internal conductors or , in extreme cases, the severing of the cable by a thruster. In either case the cable can be re-joined using either the quick splice method or the long splice method. Normally spare cables will be available and the damaged one can be instantly replaced with a serviceable one. In this case time will allow the damaged cable to be repaired using the long splice method. However it may be the case that the repair requires immediate attention, in this case the quick splice method would be used.

11.4.1. LONG SPLICE.

The long splice method makes use of specially manufactured potting compounds to form a rigid, water tight joint. It is the setting time of such compounds that restrict this method to longer periods of maintenance. Figure 11.5. illustrates the procedure of staggering the cable prior to splicing and the methods of joining individual conductors.

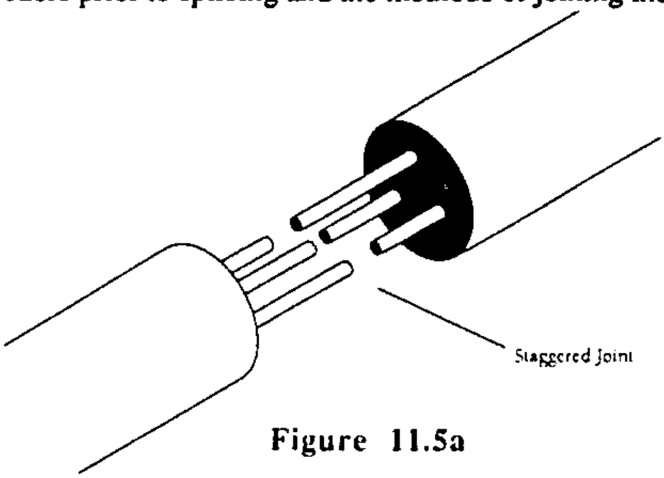
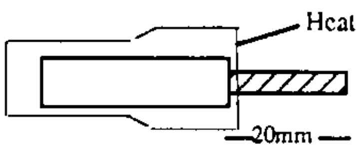
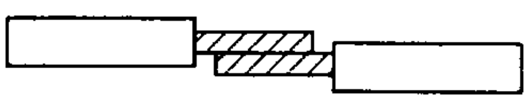


Figure 11.5a



a) Cable with heat shrink attached prior to soldering



b) Conductors are tinned and may lie side by side

c) Conductors may be butted togrther

NOTE: By butting the joints as shown in diagram 'c' we effectively minimise the risk of piercing the heat shrink with the edges of the conductors. This may occur when they are laid side by side as in diagram 'b'.
When butting a joint however the strength factor is minimised, obviously this is irrelevant if the joint is to be potted.

It can be seen that the cores of the cable are staggered where they are joined in order to maintain uniform thickness. Staggering also prevents the soldered joints from coming into contact with one another. Each soldered joint is normally covered with 'heat shrink' to add to the insulating properties. Once this stage has been completed the cable cores and the outside insulation is cleaned with a degreasing agent. The cable is then mounted in a mould into which the potting compound is poured.

There is a wide variety of potting compounds available, each having slightly different properties. The main difference between the compounds is the specific depth rating and the guaranteed life span of the compound. Once the compound has been poured into the mould the joint requires to be left to set for approximately 8 to 10 hours.

11.4.2 Short Splice

The initial joining together of the conductors is the same for the short splice as it is for the long splice. The only difference with this method is the fact that no form of potting compound is used. Instead an insulating rubber tape known as self amalgamating tape is used. When the tape is stretched it actually bonds with itself to form a strong waterproof joint. The tape is wound around the conductors, starting from the centre of the conductors and working outwards. Between each layer of tape it is common practice to coat each layer with a resin that sets and forms an electrically insulating and waterproof coating over the tape.

11.5 Sub Sea lamps

The quality of Sub sea lighting is crucial to all ROV operations, the principles of this subject have been discussed in chapter 16. For this reason a correct maintenance procedure is essential if this quality is to be upheld.

The most common problem that occurs with sub sea lighting is the burning out of the actual filament. There are a variety of lamps available to the industry, the main difference being the power rating. They are mounted in a housing which offers protection and a water tight environment in which to operate. It follows therefore that the housing contains an 'o'ring seal which requires to be inspected whenever a lamp is maintained.

Lamps may burn out due to one or more of the following reasons.

a) Water ingress to the lamp connector.

b) Breakdown of the 'o'ring seal allowing the actual lamp to become exposed to sea water.

c) Mis handling of the lamp during installation.

d) Being operated for too long a period in air.

If water ingress takes place within the lamp connector then the connector should be undone and thoroughly inspected for damage. If necessary the cable should be replaced with a serviceable one.

If the 'o'ring seal breaks down then it to should be replaced, if water does make contact with the lamp connectors then a short circuit is likely to occur as well as corrosion and breakdown of the actual contacts.

It is imperative that the lamps are not touched during installation as moisture from the skin can lead to 'hot spots'on the bulbs surface that can cause the glass to crack. For this reason the bulbs are supplied surrounded by a piece of foam that should be used to hold the lamp during installation.

It is important to realise that sub sea bulbs require to be water cooled. Should they be run in air for too long then they may overheat and burn out. During dive checks therefore the lamps should only be operated for a few seconds.

CHAPTER 12 MECHANICAL MAINTENANCE

12.0 Introduction

Throughout this handbook attention has been constantly drawn to the necessity for a planned maintenance procedure. So far we have discussed maintenance as regard to the electrical side of the RO, it is now the intention to discuss the routine maintenance procedures that should be carried out on the mechanical units of the ROV. It follows therefore that this chapter will concentrate largely on the maintenance of hydraulic systems, the basic principles of which have been covered in Chapter 8.

Maintenance of hydraulic systems is carried out on the basis of how long the system has been operating, this information may be obtained from the Sub Engineers log book or an 'hours run' meter that may be incorporated into the control console.

Each unit will have a specified period of time that it can operate for, after which it will be required to be removed from the system and serviced. As a general rule the units that require to be serviced will be swapped for a serviceable one. The actual servicing may require specialist test equipment and will therefore be sent ashore to a suitable servicing engineer. However, it is the responsibility of the ROV team to ensure that the day to day running of the system is maintained and that if any units are to be removed, they are done so in the correct manner.

12.1 Hydraulic Oil Level

The function of hydraulic oil is initially to transfer energy throughout the system and thus give rise to work being done by the actuators. It also provides lubrication and cooling to certain moving components. It is imperative therefore that the fluid be maintained at an optimum level at all times otherwise serious detrimental effects could take place throughout the system.

12.1.1 Loss Of Pressure

The total energy that is present in the hydraulic fluid is made up of potential energy and kinetic energy. The potential energy relates directly to the system pressure and it follows that if the optimum oil level decreases due to leakage then the energy stored in the fluid will be lost. This will become evident in the fact that system power will be reduced and the pilot may experience difficulty in controlling the vehicle.

12.1.2 Lack Of Lubrication

In extreme situations the optimum oil level may be reduced to such an extent that insufficient lubrication takes place. Situations may arise where certain high speed components may seize. This may be the case with the pump which contains components such as pistons, gear wheels and bearings. Insufficient lubrication of these components could lead to excessive heat being generated and eventual seizure thus resulting in system failure.

12.1.3 Sea Water Ingress

Should the situation arise where virtually all the systems oil is lost then this will result in the ingress of sea water. If this should occur it will become necessary to flush the whole system out with fresh oil.

The ingress of sea water is caused by a positive pressure existing outside the system with respect to the inside, if this should occur it can lead to such problems as corrosion within the system.

Any ingress of water to the system can be detected by draining off a sample of oil from the lowest point , the oil will have emulsified and will have a 'milky' appearance.

12.1.4 Determining The Oil Level

As a general rule the oil level is monitored via the systems electronics and is displayed at the surface unit. A transducer is mounted on the system which produces an electrical signal proportional to the oil level, this is passed via the system telemetry to the surface. Should the oil fall below a certain level an alarm will be activated indicating to the operator that a leak may be present. Normally there will be two alarms, the first being activated at 66% of the total oil level. This alarm may be over-ridden and will allow the operators time to recover the vehicle before complete oil loss occurs. The second alarm will be set to activate at a much lower value, for example 33%, this alarm cannot be over-ridden and will cause the system to completely shut down. The oil level can also be monitored when the vehicle is on deck by noting the position of the compensators.

12.1.5 Compensation

As a general rule the ROV has several junction boxes which, when subject to extreme pressure would probably implode. This is overcome by filling each box with pressurised static hydraulic oil. The internal oil pressure is maintained by a piston that is exposed to the external sea water pressure. The piston is directly coupled to the oil system via a spring that maintains the oil pressure at 3 to 5 PSI above the external sea water pressure. It follows that the pressure inside the junction box is positive with respect to the external sea water pressure, thus preventing the implosion of the junction box.

This method of compensation is applied to the main hydraulic system. Should an oil leak occur the internal positive pressure will give rise to the oil being forced out as oppose to sea water being allowed in. As the oil level drops the alarms will be activated and the operators can recover the vehicle, hopefully before any sea water enters the system.

Whilst the vehicle is on deck it is possible to monitor the oil level by noting the position of the compensator piston. It is common practice to monitor the oil levels throughout the system in this manner during the pre and post dive checks. (see Chapter 10).

12.1.6 Oil Filling

The frequency of which the system requires filling with oil depends upon the leakage factor of the various hydraulic units. However the method for filling the system remains common for all ROVs. It is common practice to fill the system at the lowest point in order to minimise the trapping of air. The system is filled from a pressurised container which has a dedicated hydraulic fitting to couple to the oil inlet.
Before connecting it is vital to ensure that the filler point is thoroughly clean in order to minimise the ingress of dirt into the system. Many systems make use of 'quick fit' connectors which simply snap on to the oil inlet. This minimises the use of spanners and consequently saves time.

12.1.7 Air Bleeding

Whenever the system is filled with oil it is necessary to bleed air out of the system. This is normally done from the highest point in the system. However it may be the case that there are various bleed points around the system located in the appropriate positions. The bleed point may consist of a cap that when slackened allows the trapped air to escape. The bleed point should remain in this state until oil flows freely from the fitting. It may be necessary to bleed the system on a regular basis especially if a major oil change or refit has taken place.

12.1.8 Oil Filter Change

Oil filters should be changed whenever an oil change is carried out. Most filters require the element to be changed and therefore a spare should always be kept in stock. The operators should never be tempted to run the system without a filter element as this could lead to major breakdown due to contamination of the major units. Before changing the filter or any unit for that matter it is important to drain the system oil as the positive pressure would result in a large loss of oil.

12.1.9 Dielectric Oil

As previously mentioned all junction boxes are oil filled, however the junction box may house conductors or transformers that would not be compatible with standard hydraulic oil. In this case it is necessary to use an oil that is inert. Dielectric oil has high insulating properties and is used in such enclosures. This oil is sometimes called transformer oil and is compensated in the usual manner. It is important that the insulation properties of the oil is constantly monitored, this can be done by draining a sample of the oil from the enclosure and checking for signs of water. In the case of the electric motor the insulation is monitored electrically, in this case a resistance reading is displayed at the surface unit and gives an indication to the integrity of the dielectric oil.

12.2 Component wear

It is common practice to have specialised engineers carry out the servicing of individual hydraulic units. The task may require the use of specialist equipment and skills that does not fall within the requirements of the ROV personnel. However, a basic understanding of which components are susceptible to wear could help the operator in the diagnosis of basic faults. We will now consider the components of the basic hydraulic units that are prone to wear.

12.2.1 Hydraulic pumps and motors

Hydraulic pumps and motors contain either gears,vanes or pistons which are required to operate at high speeds. In each case the principle of operation relies on fine tolerances between the chamber wall and the moving component, any increase in these tolerances can lead to loss of system pressure in the case of pumps and reduced power and excessive 'case' pressure in the case of motors. Pumps and motors are designed in such a way that a certain amount of oil is allowed passed the pistons, vanes or gears to facilitate lubrication of the bearings and shaft seals. For this reason it is possible to measure the output of the case drain over an interval of time, and, by consulting the manufacturers data, determine the integrity of the internal components. For example if the oil is in excess of the specifications it would indicate that the piston rings were worn thereby allowing excess oil into the case chamber.

Another common problem that can arise is wearing of the shaft seals. This is evident by a visual check of the system whilst on deck. Seals have a specified working life as stated by the manufacturer, however this can be drastically reduced if the systems oil becomes contaminated. If any seals are ever removed they should always be inspected for damage and any signs of break down.

12.2.2 Hydraulic valves

Valves generally contain minute components that are responsible for the flow rate and direction of hydraulic oil. For this reason their operation is dependent on the cleanliness of the system oil and the environment in which they have been serviced. Typical faults that could arise from blockages could be:-

a) Blocked relief valve leading to system operating at reduced pressure.

b) Blockage in solenoid valve leading to malfunction of manipulator function.

c) Blockage in servo valve leading to either complete loss of oil flow to thruster motor or reduction in running speed.

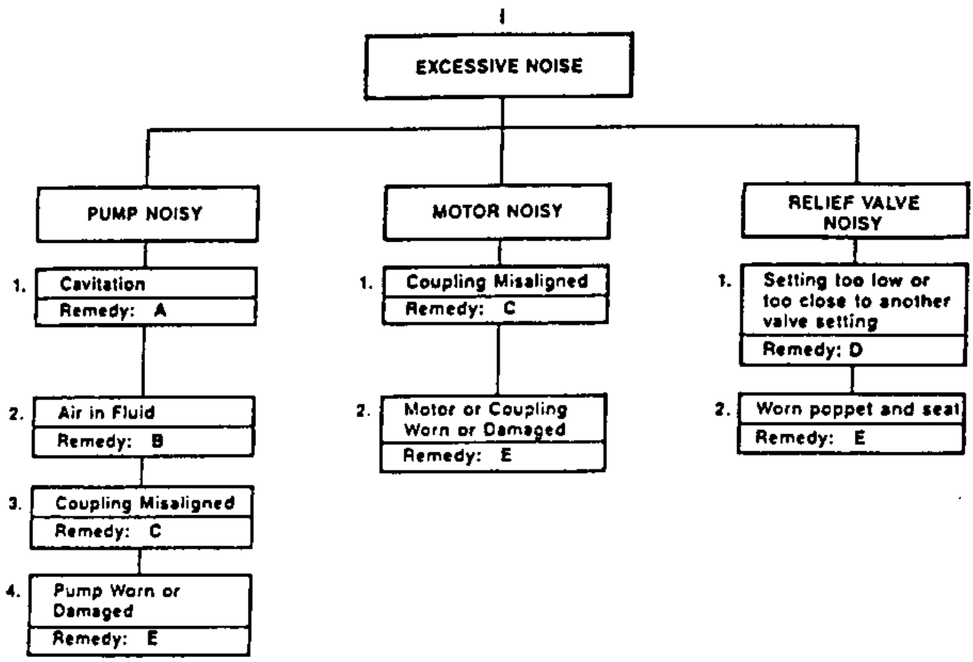
12.2.3 Hydraulic rams

The operation of hydraulic rams depends totally on the integrity of the internal and external seals. Any breakdown in the tolerances can lead to leakage across the piston and therefore reduction in operating performance of the driven unit. For example the operating power of the manipulator may be reduced resulting in it being 'sluggish' in movement.

As with all external seals excessive leakage is easily detected by visual inspection during pre and post dive checks.

12.2.4 Fault diagnostics.

The following tables illustrate typical fault diagnosis procedures for hydraulic systems. Figure 12.1 (a) illustrates the fault finding procedure for a situation for a system that is generating excessive noise.



REMEDIES

A Any or all of the following:
- Replace dirty filters
- Wash strainers in solvent compatible with system fluid
- Clean clogged inlet line
- Clean reservoir breather vent
- Change system fluid
- Change to proper pump drive motor speed
- Overhaul or replace supercharge pump
- Check fluid temperature

B Any or all of the following:
- Tighten leaky inlet connections
- Fill reservoir to proper level
  With few exceptions, all return lines should be below fluid level in the reservoir.
- Bleed air from system
- Replace pump shaft seal
  Also replace shaft if worn at seal journal.

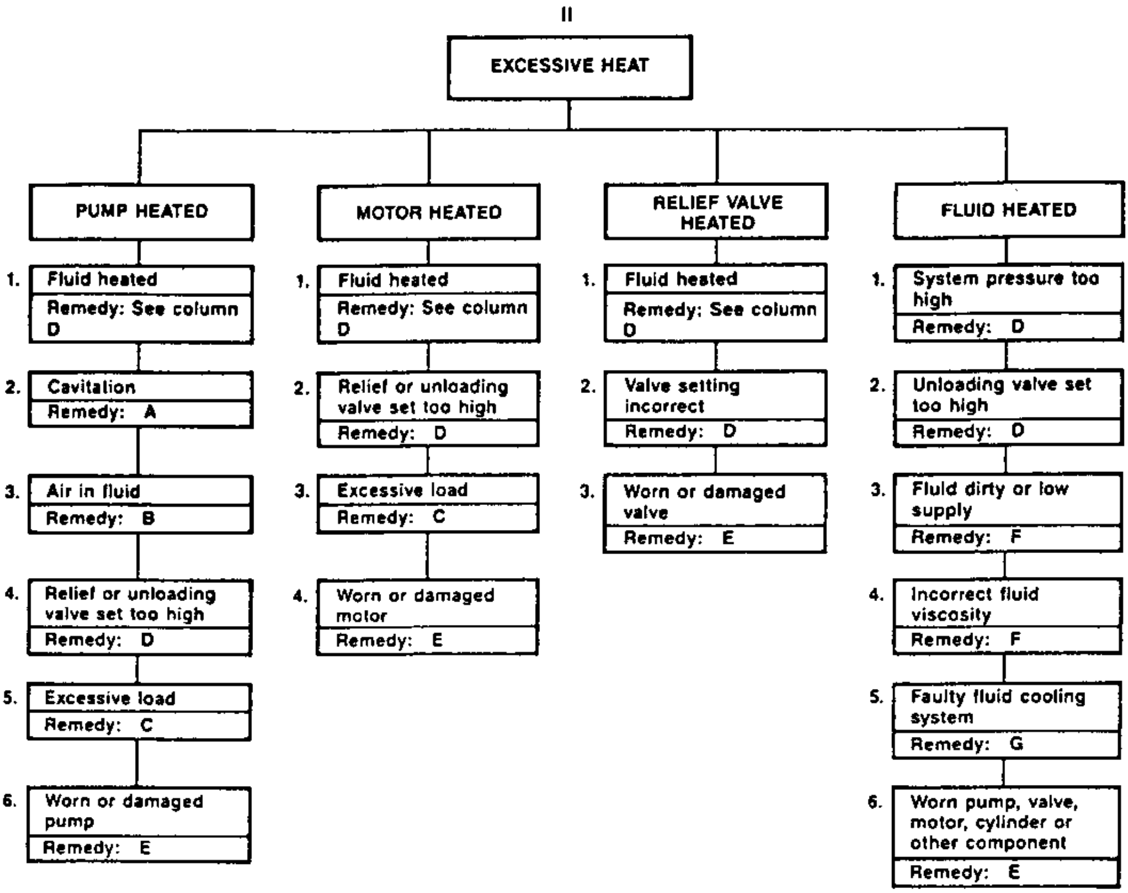
C All of the following:
- Align unit
- Check condition of seals, bearings, and coupling

D • Install and adjust pressure gauge

E • Overhaul or replace defective part(s)

Figure 12.1 (a)

Figure 12.1(b) illustrates the procedure for a system generating excessive heat.



REMEDIES

A Any or all of the following:
- Replace dirty filters
- Clean clogged inlet line
- Clean reservoir breather vent
- Change system fluid
- Change to proper pump drive motor speed
- Overhaul or replace supercharge pump

B Any or all of the following:
- Tighten leaky inlet connections
- Fill reservoir to proper level
  With few exceptions, all return lines should be below fluid level in the reservoir.
- Bleed air from system
- Replace pump shaft seal
  Also replace shaft if worn at seal journal.

C All of the following:
- Align unit
- Check condition of seals, bearings, and coupling
- Locate and correct mechanical binding
- Check for work load in excess of circuit design

D
- Install and adjust pressure gauge
  Keep at least 125 PSI difference between valve settings

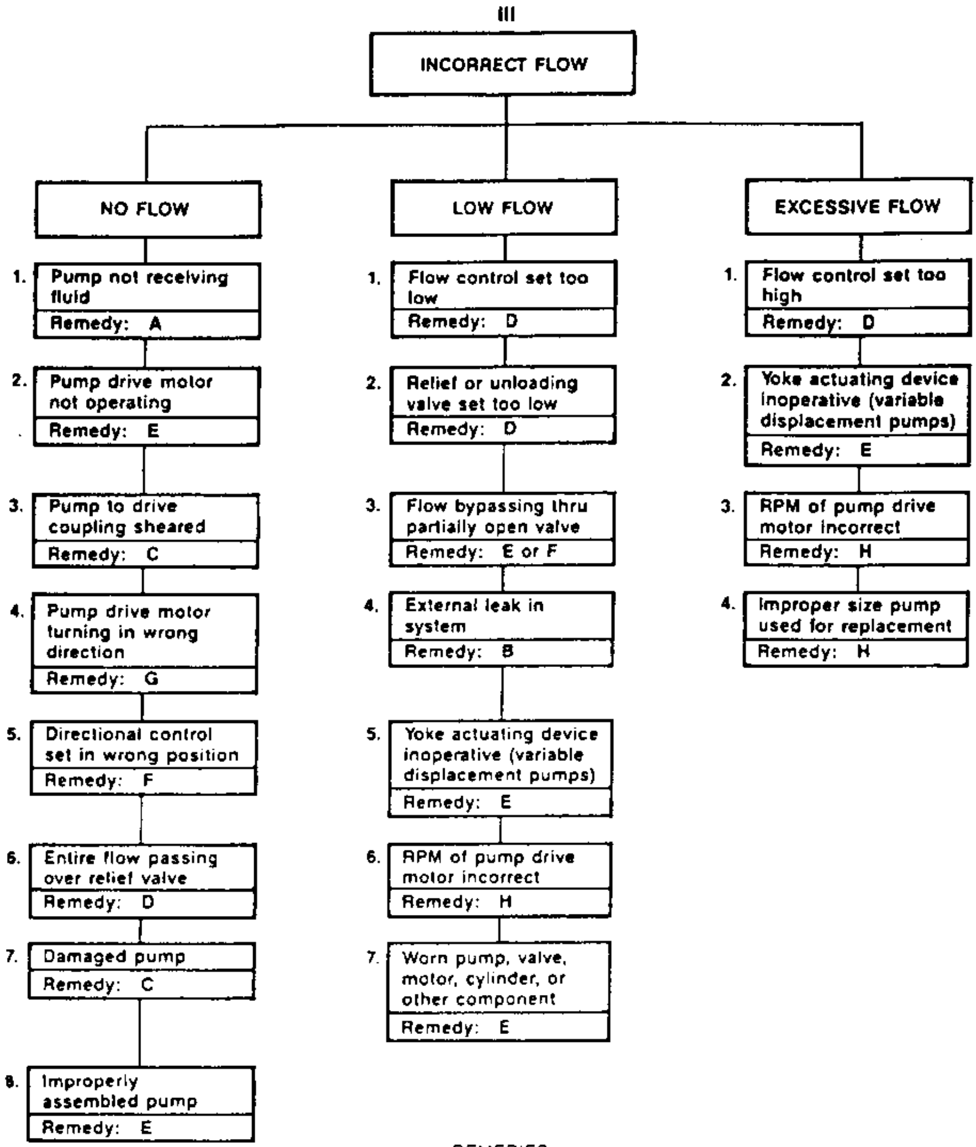
E
- Overhaul or replace defective part(s)

F
- Change filters
- Check system fluid viscosity. Change if necessary.
- Fill reservoir to proper level

G
- Clean cooler and/or cooler strainer
- Replace cooler control valve
- Repair or replace cooler

Figure 12.1(b)

Figure 12.1(c) illustrates the procedure for a system operating with an incorrect flow.



REMEDIES

A Any or all of the following:
- Replace dirty filters
- Clean clogged inlet line
- Clean reservoir breather vent
- Fill reservoir to proper level
- Overhaul or replace supercharge pump

B
- Tighten leaky inlet connections
- Bleed air from system

C
- Check for damaged pump or pump drive
- Replace and align coupling

D
- Adjust part

E
- Overhaul or replace part

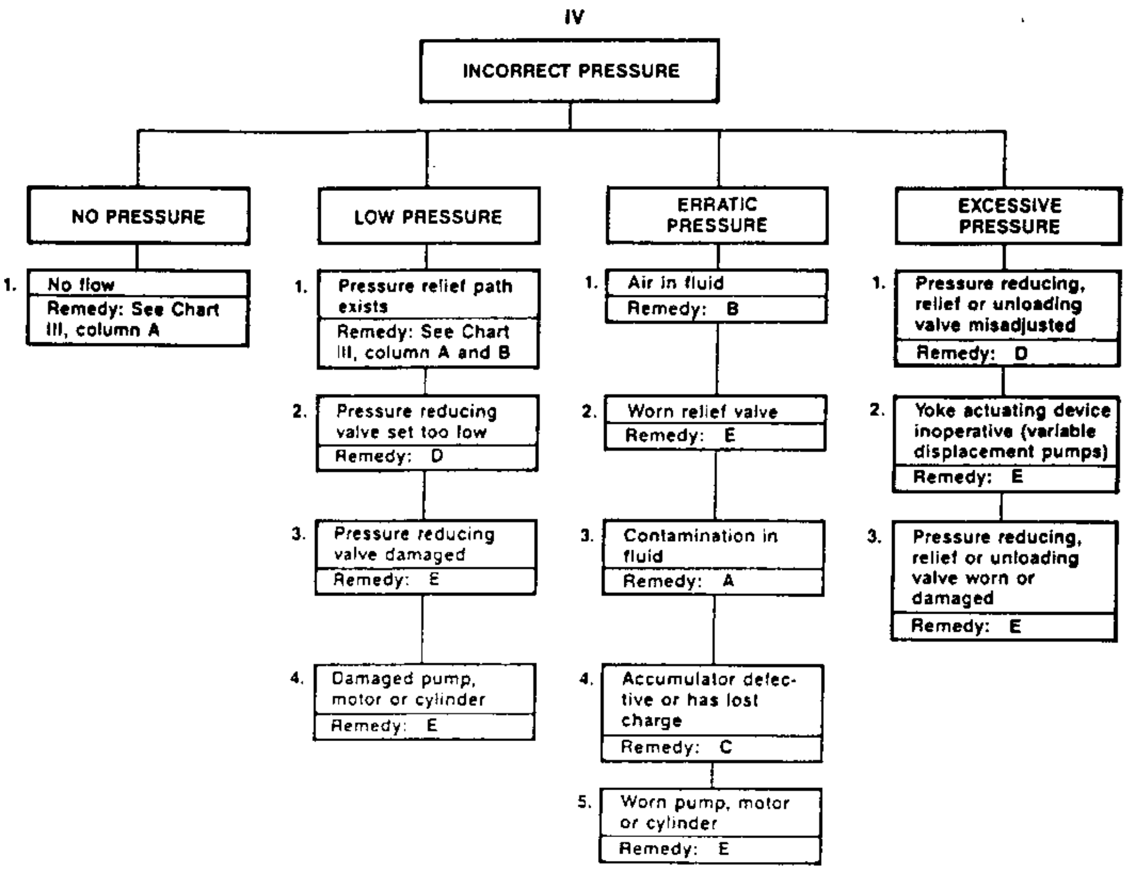
F Any or all of the following:
- Check position of manually operated controls
- Check electrical circuit on solenoid operated controls
- Repair or replace pilot pressure pump

G
- Reverse rotation

H
- Replace with correct unit

Figure 12.1(c)

Figure 12.1(d) illustrates a system operating at an incorrect pressure.



REMEDIES

A • Replace dirty filters and system fluid

B • Tighten leaky connections
Fill reservoir to proper level and bleed air from system

C • Check gas valve for leakage
• Charge to correct pressure
• Overhaul if defective

D • Adjust part

E • Overhaul or replace part

Figure 12.1(d)

12.2.5 Summary

It can be said therefore that the efficient operation of the hydraulics is dependent on the cleanliness of work environment. Should any maintenance be required the ROV should be hosed down with fresh water and the unit in question removed from the vehicle and taken to a clean, dry workplace. A high standard of cleanliness should always be maintained when filling the system with oil so as to prevent ingress of dirt.

12.3 Planned maintenance

Every system should have a planned maintenance procedure that should be correctly adhered to at all times. This would normally be kept in log form or on floppy disc. The principle of the PMP is that it records the running time of all the components. Having this information enables one to ensure that the relevant unit is serviced after the appropriate number of running hours. The running time is determined by the manufacturer and may have slight variation depending on the company. Figure 12.1 illustrates a typical log for the running hours of the main hydraulic system of a typical ROV.

MASTER LOG		HPU MOTOR		HPU PUMP		PORT THRUSTER		STBD THRUSTER		FWD. THRUSTER		AFT THRUSTER		VERT. THRUSTER	
DATE	HOURS	S/No	HOURS	S/No	HOURS	S/No	HOURS	S/No	HOURS	S/No	HOURS	S/No.	HOURS	S/No.	HOURS

Figure 12.2

Figure 12.2. illustrates a typical fault docket which provides some detail of the actual maintenance carried out. Documentation of this nature enables the operator to locate reoccurring faults more easily. For example certain units may break down more often than normal, by consulting the docket it may be possible to detect a trend in the symptoms. This could indicate a fault somewhere else in the system which can be addressed and thereby minimise the overall repair maintenance time.
The fault docket also gives indication as to the spares content on the ROV system. This would normally have a separate log, but in this case it is possible to cross reference between logs.

One of the main advantages of this system is that it makes maintenance easier for the various crews who may work with the system. It follows that it is in everybody's interest to follow the maintenance procedure as it minimises repair maintenance that can prove costly to the ROV companies.

FAULT DOCKET No.					
DATE		DIVE No.		JOB	
CATEGORY					
FAULT SYMPTONS					
REMOVED FROM SYSTEM BY					
REPAIR WORK CARRIED OUT					
SPARES USED					
SIGNED				DATE	
BACK IN SYSTEM					

FAULT DOCKET No.					
DATE		DIVE No.		JOB	
CATEGORY					
FAULT SYMPTONS					
REMOVED FROM SYSTEM BY					
REPAIR WORK CARRIED OUT					
SPARES USED					
SIGNED				DATE	
BACK IN SYSTEM					

FAULT DOCKET No.					
DATE		DIVE No.		JOB	
CATEGORY					
FAULT SYMPTONS					
REMOVED FROM SYSTEM BY					
REPAIR WORK CARRIED OUT					
SPARES USED					
SIGNED				DATE	
BACK IN SYSTEM					

Figure 12.3

CHAPTER 13 EMERGENCY PROCEDURES

13.0.0

The nature of ROV operations is such that despite careful preparation and adherence to proven operational procedures, situations arise that endanger the vehicle and require the crew to take emergency action. The aims of this chapter are to describe common emergencies, to focus on the crucial considerations of navigation, communications, and buoyancy in pre-dive planning and finally to describe actions that should be taken by the crew once an emergency situation has arisen.

13.1.0 The following is a description of possible emergency situations;-

13.1.1

Support Ship Entanglement is perhaps the most common form of emergency situation and often results in the complete loss of the ROV. This can arise where the position of the vehicle relative to the ship is uncertain and the ROV surfaces close to a propeller or thruster, where the ROV entangles with the taut wire of the DP system, or where the relative positions have changed due to a navigation error and the umbilical has moved 'under' the support ship. The key factor in these incidents is often poor communications between the ROV crew and the support ship's master.

13.1.2

Structure Entanglement is also very common but usually results in ROV or diver assistance rather than the complete loss of the vehicle. This often occurs because the pilot becomes disorientated, the vehicle becomes 'snagged', on debris or a structural component such as a pile guide, or the vehicle loses power in precarious circumstances, but may also occur if the support vessel moves position without the ROV crew being informed.

13.1.3

Guide Wire Entanglement is common within Drilling Support activities and can result in the crushing of the ROV as the Blow Out Preventer (BOP) Stack is landed. This can happen, for example, in remote locations where the Drilling Supervisor may only allow a period of time for the crew to disentangle the ROV before recommencing drilling operations due to cost pressures, particularly if there are no other ROVs or Divers available to assist. The most common causes of this are Pilot disorientation due to loss of visibility possibly as a result of disturbed sediments or displaced drilling fluids, and unexpected changes in current strength and direction.

13.1.4

Anchor Chain Entanglement occurs when surveying the anchor chains of Barges or Semi-Submersibles platforms. This is the result of the ROV losing orientation due to disturbed sediments as the chain is lifting, the vehicle then passing under the chain as it lowers trapping the vehicle or its umbilical. This situation is also likely to occur when laying umbilicals and pipelines as the vehicle monitors the touch down point. It is very important, therefore, that these operations are carried out in acceptable weather conditions where there is not excessive 'heave' of the vessel under survey, and that the vehicle is positioned facing into the current wherever possible, so that it benefits from optimum visibility and the prospect of being carried safely away from the work area by the current in the case of a system failure.

13.1.5

Bottom Debris Entanglement occurs when an unseen hazard such as mono-filament fishing line or nylon rope, which tend to be buoyant where they are not anchored, are drawn into the vehicles thruster, or when the vehicle umbilical is 'snagged' around larger items of debris. The best advice is to travel slowly in the vicinity of these hazards and in the event of soft line being taken into the thruster cease or slowly reverse the thruster and attempt to pull the vehicle free using the umbilical winch.

13.2.0

The above mentioned incidents can largely be avoided by **careful planning** of each operation with particular attention being paid to; currents and weather conditions, navigation, communications, and the buoyancy of the vehicle and its umbilical. This section explains the importance of each of these factors.

13.2.1

It is crucial to have an accurate prediction of the **weather conditions and ocean currents** for the maximum expected duration of each dive. These should be available for the pre-dive meetings so that the support vessel can be positioned for maximum safety, and the dive can be planned taking the currents and weather conditions into account. The pre-dive meeting should be attended by the ROV crew, the ships master and any other participating personnel, the plan arrived at will be a result of the prevailing conditions, the surface ship's and ROVs operating parameters and the experience of the personnel.

13.2.2

Consideration of the support ship and the ROVs **navigation systems** is crucial to the planning of the dive because the accuracy of different systems vary considerably. The ships position if determined by Global Positioning Satellite (GPS) may be accurate to within 5 - 10 metres depending on the location and satellite positions, whereas radio systems such as Decca or Pulse 8 are much more accurate, normally within 1 metre. The Hydro-acoustic Position Referencing system (HPR), used to position the ROV relative to the support ship, will also vary in accuracy depending primarily on the depth of the vehicle and the type of transducer fitted (Pinger, transponder or responder). This means that in certain circumstances, particularly on or close to the surface, it may be expedient to judge the relative position of the vehicle, with respect to the surface ship, by eye or by feel and the known direction of the umbilical leading away from the ship. The accuracy of the navigation systems (including the vehicles Gyro or compass) is also a key factor in avoiding entanglements during the dive, as is prior knowledge of the position of likely hazards. When working around structures or guide basis it is also important that the pilot is fully briefed, including the orientation and the position of identification marks and features to enable him to navigate competently.

13.2.3

Communications between ROV crew members and the vessels crew are another important consideration when planning and executing a dive. There have been numerous misunderstandings and 'lack of communications' leading to the loss of ROVs. For example the ROV may surface near an operational ships thruster or main propeller unexpected by the vessels crew, resulting in the ROV being 'sucked in' and destroyed. Alternatively a supply boat may come alongside a platform as the ROV is surfacing, because the Offshore Installation Manager (OIM) has not been informed of the diving operation underway. These circumstances seem all too obvious, but happen all too frequently due to poor communications.

13.2.4

The **buoyancy of a vehicle** and its umbilical can also be a critical factor in avoiding entanglements and easing subsequent rescue attempts. The situation of having an ROV positively buoyant (usually about 30 lbs for a work size vehicle) may well be suitable for a pipeline survey job where the vehicle can reasonably be expected to surface clear of the surface ship in the event of a system failure. It may however be more appropriate to have a 'heavy' vehicle for deep water work so that in the event of a system failure or parted umbilical, it will sink to the bottom where it can be found by the rescue ROV or divers. Considering the buoyancy requirements of the vehicle prior to each job can, therefore, significantly ease any rescue that may be attempted subsequent to an entanglement or parted umbilical situation and needs to be given due consideration at the pre-dive planning stage.

13.3.0

The first time that an ROV operator experiences a **vehicle entanglement** situation can be unnerving. It is important to remember that these situations occur commonly due to the nature of the job and the difficulties encountered in navigating in poor visibility, avoiding unknown obstacles, and accurately predicting weather conditions and ocean currents. Whilst this may be a new and unnerving experience for you it will be familiar to your supervisor who will have seen numerous such incidents previously and will know that they usually have a successful outcome. There is no substitute for experience in these situations but this section will describe procedures that may be followed to ensure the best chance of a successful outcome.

13.3.1

The first thing that a Pilot must do in the case of entanglement is to **inform his supervisor**. If appropriate action is taken early there will be a much greater chance of a successful outcome, whereas uninformed attempts to rectify the situation will invariably make it worse.

13.3.2

If the vehicle suffers a **loss of power on the surface,** the following actions should be taken:

i) Deploy suitable fenders or buoys over the side to minimise contact between the vehicle and the surface platform.
ii) Use the umbilical cable winch to move the vehicle into the recovery position.
iii) Perform the usual recovery procedure.

13.3.3

If **power is lost while the vehicle is submerged** the following actions should be taken:

i) Manoeuvre the surface platform where possible so that the vehicle will not come up under the platform.
ii) Deploy suitable fenders or buoys.
iii) If the vehicle is not rising, use the umbilical winch to haul the vehicle towards the surface.

iv) If it is dark the emergency flasher will activate when the vehicle reaches the surface. Use the umbilical winch to move the vehicle into the recovery position.
v) Perform the usual recovery procedure.

13.3.4

If the **vehicle is on the surface and the umbilical has been severed** the following actions should be taken:

i) Deploy suitable fenders or buoys.
ii) manoeuvre the surface platform close to the vehicle.
iii) Deploy a rescue boat and attach lines to the vehicle.
iv) Haul the vehicle into the recovery position.
v) Perform the usual recovery procedure.

13.3.5

If the **vehicle has become entangled** the following actions should be taken:

i) Replay the 'Black-box' video recorder and with the assistance of the cable twist indicator attempt to determine how the vehicle came to be entangled and the lay of the umbilical.
ii) Determine the degree of entanglement using the video camera.
iii) Plan a route out of the entanglement.
iv) Loosen the umbilical by unwinding the umbilical winch, and attempt to manoeuvre the vehicle out of the entanglement.
v) If step iv) fails attempt to manoeuvre the surface vehicle to free the vehicle.
vi) If step v) fails attempt to pull the vehicle free using the umbilical cable winch. Be careful not to exceed the breaking strain of the cable and to allow for the bend radius and safe working load of the sheave wheel and recovery gear.

13.3.6

If the **umbilical is severed** while the vehicle is submerged the following actions should be taken:

i) Estimate whether the vehicle will surface, float mid-water or remain on the bottom by calculating the resultant buoyancy of the vehicle and its umbilical.
ii) Inform the ship's master and record the ROVs last known position on the charts.
iii) If the vehicle is likely to remain on the bottom arrange for an ROV or diver to attempt the rescue.
iv) If the vehicle surfaces' perform the recovery procedure previously described.
v) If the vehicle is likely to be held mid water then the ocean currents should be predicted and if available an acoustic transducer should be deployed from the surface ship to 'listen' for and locate the vehicle through the activation of its emergency 'Pinger'. The vehicle should be 'tracked' and grappling hooks deployed across its path to attempt to hook the umbilical or vehicle.
vi) On hooking the ROV recover to the surface, immediately attach a line or surface buoy and perform the usual recovery procedures.

It is very important in the above situation to **act quickly** as the ROV can drift away rapidly decreasing the chances of locating and rescuing it. Grappling hooks, charts and other relevant rescue equipment should be made ready and the crew briefed before the diving operation commences.

13.3.7

In circumstances where a **rescue ROV or divers** is required it is necessary to give the Client's Representative and the onshore Operations Manager at least the following information:

i) Last known location.
ii) Circumstances and degree of entanglement.
iii) Depth of ROV.
iv) Background information and manoeuvres already attempted.
v) Likelihood of the vehicle drifting in the ocean currents.
vi) Urgency of the rescue i.e. is the vehicle holding up other platform or drilling operations?

Finally, remember proper planning can often prevent these situations from occurring, but they do still occur from time to time due to unforeseen circumstances. **Keep calm** and follow the relevant emergency procedures issued by your company and you are likely to have a successful outcome. If however, the outcome is the loss of the vehicle, remember that it will be covered by insurance and that it is accepted within the industry that a number will be unavoidably lost due to the nature of the work. These situations are not usually career limiting and can be put down to experience.

CHAPTER 14 COMMUNICATIONS

14.0. Introduction.

ROV personnel will be required to use communication systems at various stages of the work programme offshore. This chapter sets out to indicate the procedures used for both radio and 'hard wire' communications systems.

14.1 Hard Wire Systems.

This is the terminology used to describe the deck to control room wire line communication system. The common configuration is a headset containing a speech activated microphone all connected to a wandering lead which is connected to a deck mounted control box. This method of communication is used daily and all ROV personnel must be familiar with its use. The procedure adopted for speaking on a hard wire system is based on radio procedure but is less formal . For example the Proword "Over" is not used. Radio procedures and Prowords are outlined later in this chapter.

14.2 Radio Communications

Radio communications may be required to communicate between:

a. Deck and control room;
b. Vessel to platform;
c. Vessel to vessel;
d. Vessel to shore.

There are a variety of different radio systems used for these and other purposes offshore. It is not necessary to have an intimate knowledge of these systems but a brief resume, highlighting the points affecting the user will be helpful.

14.3 Radio Communication Modes

Radio communications systems are designed to be either Simplex or Duplex. In a Simplex system it is not possible to transmit and receive at the same time. If one radio on the designated frequency or channel is transmitting it is not possible for any other radio to talk back to the transmitting station until the transmit button is released. This is not the case in a Duplex system where the transmitter and receiver are on different frequencies which maintains the transmitting station's ability to receive incoming signals. Thus on this type of network another station can talk back to the transmitting station even while he transmits.

14.3.1 Radio Frequencies

For a variety of reasons radios use different working frequencies. The common frequency bands and comments on there uses are outlined below.

a. High Frequency (HF). Used for long range communications world-wide. Suffers from interference and is particularly bad for communicating at night. Used for vessel to shore communication when more advanced systems are unavailable. Commonly uses duplex mode.

b. Very High Frequency (VHF). Used for short range, line of sight, communications. Much less prone to interference than HF and clear voice communication is possible 24 hours a day. Used for vessel to vessel, vessel to shore and deck to control room communications. Commonly uses simplex mode.

c. Ultra High Frequency (UHF). Used for short range, usually less than line of sight, and satellite communications. Very clear voice communications are possible 24 hours a day as there is little interference at all. Commonly uses simplex for line of sight and duplex for satellite communications.

14.4 Radio Procedures.

Before using a radio for communication the following must be known: the frequency or channel to use, the callsign of the transmitting station, the callsign of the station called, the person required at the other end and the subject to be discussed. Once this information is known all radio transmissions begin in the same way. There is the call, the text and the ending transmission.

The Call: Polymariner **THIS IS** Stena Mayo
The call consists of the callsign of the station required, followed by the Pro words This Is and the callsign of the station calling. Each callsign may be repeated up to three times if the initial call is made on international channel 16.

The Text: Either: Give me a working Channel; or The message.
The text may be a request for a working channel if the original call was made on international channel 16 or it may be the information to be passed.

The Ending Transmission: **OVER** or **OUT.**
The ending transmission consists of the Proword Over if a reply is required or Out if no reply is expected or required.

14.4.1 VHF Maritime Calling Procedure.

Calling on Maritime frequencies on VHF is the most common practise offshore. The procedure is:

a. Tune to Channel 16 and listen for a quiet period.
b. Make your transmission as outlined above either requesting or stating a working channel in the text.
c. Wait for a response from the station called for up to 10 seconds. If there is no response in this time make your call again.
d. When a response is made change frequency to the working channel and re-establish communications. Do not work on channel 16 which is used only for distress and calling.

14.4.2 How to Speak

Whatever system is used for communication the following should be borne in mind:

a. Always give precedence to distress or urgent calls
b. Do not jam up the channel with un-necessary conversation or chat.
c. Wait to respond until the transmitting station makes an ending transmission. Only try to interrupt if it is most urgent that you do so.
d. Do not swear.
e. Do not stammer.
f. Remember RSVP
    - R Rhythm of speech - as normal but use pauses for effect.
    - S Speed of speech - Slightly slower than normal.
    - V Volume of speech - Slightly louder than normal.
    - P Pitch of speech - Slightly higher than normal pitch if possible.
g. Remember to press the transmit button and allow a short pause before speaking and continue to hold the button down throughout the transmission.

14.4.3 Prowords

Numerous standard phrases, which have internationally recognised meanings, are used in radio voice communications. These phrases are called Prowords. A table of the more useful Prowords follows.

PROWORD	USE OR MEANING	PROWORD	USE OR MEANING
MAYDAY	The distress signal. Used when in imminent danger and immediate assistance is required.	HOW DO YOU HEAR ME?	What is the strength and clarity of my voice transmission?
PAN	The urgency signal. Used where safety is threatened but danger is not judged to be imminent.	READ BACK	Request to the receiving station to read back the message sent. Used to confirm the message has been received exactly as sent.
SECURITE	The safety signal. Mainly used for navigation or meteorological warnings.	SAY AGAIN	A request for all, or a part of the message to be repeated.
ACKNOWLEDGE	Have you received and understood this message?	I SPELL	Used when a word or an abbreviation is spelt out.
ALL AFTER/ALL BEFORE	Used with a key word from the transmission to identify a part of the text.	OUT	Transmission completed and no reply is expected.
OVER	Transmission is completed and a reply is required.	I READ BACK	The receiving station repeats back the message as received to confirm it is correct.
CORRECTION	Cancels the word or phrase just sent. Normally followed immediately by the correct version.	WAIT	The station requires time to consider a reply this allows up to 5 seconds unless followed by a number which indicates the number of minutes.
ROGER	Message received and understood	I SAY AGAIN	Used when a message or phrase is repeated for emphasis.

14.5. Deck Communications.

As stated above hard wire communications are frequently used by ROV personnel. They do have several advantages:

a. Headsets leave the hands free;
b. There is no interference
c. Does not interfere with radio users.

A Typical conversation between; Deck Officer (DO), Crane Operator (CO), Pilot, Vessel Captain (VC), and Dive Control (DC) will illustrate the use of voice procedure on this means.

DO Pilot This is Deck Officer, Pre-dive checks are now complete standby to launch
Pilot Pilot, Roger
DO Bridge This is Deck Officer, Please report the status of the vessel
VC Bridge, Vessel is on station, Heading 110^0, you are clear to launch.
DO Deck Officer, Roger.
DO Dive Control This is Deck Officer Please report status of divers.
DC Dive Control, All divers are out of the water. You are clear to launch.
DO Deck Officer, Roger.

The Deck Officer would then proceed with the launch operation.

CHAPTER 15 UNDERWATER VIDEO

15.0 INTRODUCTION

Remotely operated vehicles could not exist if closed circuit television was not available. In all types of vehicle it give a visual image to the surface showing what the vehicle is looking at and allowing topside staff to navigate around obstacles or inspect components or just generally monitor the underwater situation. There are several different types of cameras available and in this chapter the most popular will be outlined.

15.1 SIT Cameras

The Silicon Intensifier Target camera is used extensively for general navigation and observation. The camera will operate in low light conditions equivalent to night time with a quarter moon showing. This in turn means that floodlights are not required and in turbid conditions better visibility is achieved because there is no back scatter. It is the prime camera on most ROVs and is the pilot's first choice. Osprey Electronics manufacture a compact SIT camera for ROV use which is 100 mm in diameter and approximately 300 mm long. It is rated to 1000 m water depth and contains an automatic iris. The focus is fixed giving a depth of field from 140 mm to infinity. One important operating point is to ensure the lens cover is put in place as soon as the ROV is on deck to protect the target. The picture is in monochrome.

15.2 SDA Camera

The Silicon Diode Array camera is specifically designed to be tolerant to high intensity light and can, for example, be used to observe welding. This would be impossible with other types of cameras as the light from the welding arc would destroy the picture tube. osprey manufacture an SDA camera which is 100 mm in diameter and approximately 350 mm long. It is rated to 1000 m water depth and contains an automatic iris. Focus is by remote control and it is possible to get close up views of an object. This would be required for weld inspection for instance. This camera is used for specialist purposes where high intensity light is to be observed.

15.3 CCD Cameras

This type of colour camera has become the industry standard for all types of inspection and observation where good quality colour video pictures are required. Osprey once again manufacture this type and they can provide two models; one of which has a pan and tilt mechanism built into the head. The overall dimensions are 104 mm diameter and approximately 330 mm long. They are rated to 1000 m and have automatic irises. The focus is by remote control and is from 10 mm to infinity.

15.4 Video Recording

Whatever type of camera is called for in the contract specifications the video information will need to be recorded. There are several different standards for doing this and Fig. 15.1 lays out in tabular form those currently available.

Parameter	S-VHS	Hi-8	VHS	U-Matic	U-Matic HB
Resolution (TV Lines)	>400	>400	260	Colour 250 Mono 330	Colour 270 Mono 370
Signal to Noise Ratio	46 dB	46 dB	43 dB	45 dB	46dB
Max Tape Length (mins)	180	90	240	60	60
Cassette Size (Volume)	500	90	500	1615	1615
Volume per Hour Recording	166	60	125	1615	1615
Cassette Cost	£8.00	£18.00	£4.00	£10.00	£10.00
Cost per Hour Recording	£2.66	£12.00	£1.00	£10.00	£10.00
Signal Input	Composite or S-Video	Composite or S-Video	Composite	Composite	Composite

Figure 15.1

Most operators are stipulating S-VHS (Super Video Home System) because it has good resolution. To utilise this system to its full potential it is necessary to use 2 co-axial cables from the camera as opposed to the usual one . One cable carries the chrominance signal and the other the luminance. The extra cable is not usually used at present. In order to record the video signal from the camera a recording suite must be put together. To indicate how this may be done a diagrammatic layout such as could be used by a Scorpio ROV is shown in Fig. 15.2

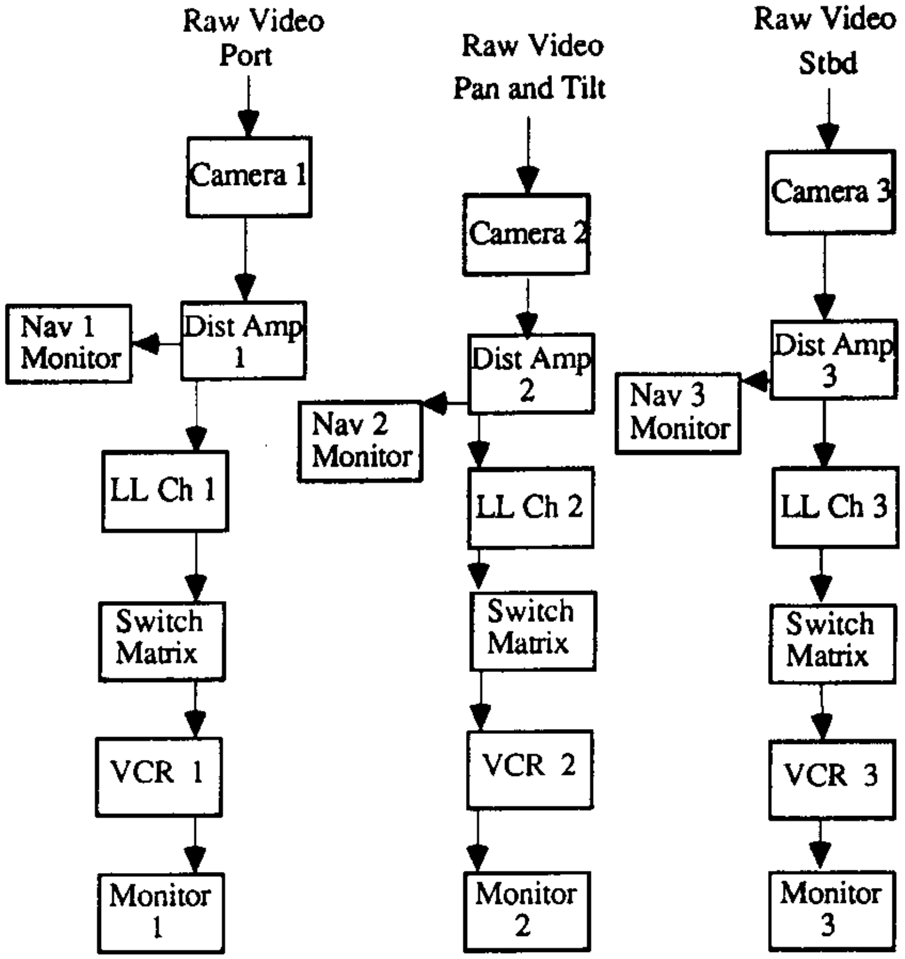


Fig 15.2

15.4.1 Recording Quality

As a result of a study sponsored by several of the offshore oil producers; conducted by R.W. Barrett, M. Clarke and B. Ray for the Marine Technology Directorate, and published in Underwater technology Vol. 18 No. 2 four on site tests were recommended:

a *Check 1 Recorder playback and monitor*
Using a tape pre-recorded to broadcast standards

b *Check 2 Camera and transmission*
Excluding the recorder from the system

c *Check 3 Recorder and transmission*
Using a tape recorded on site in the previous check

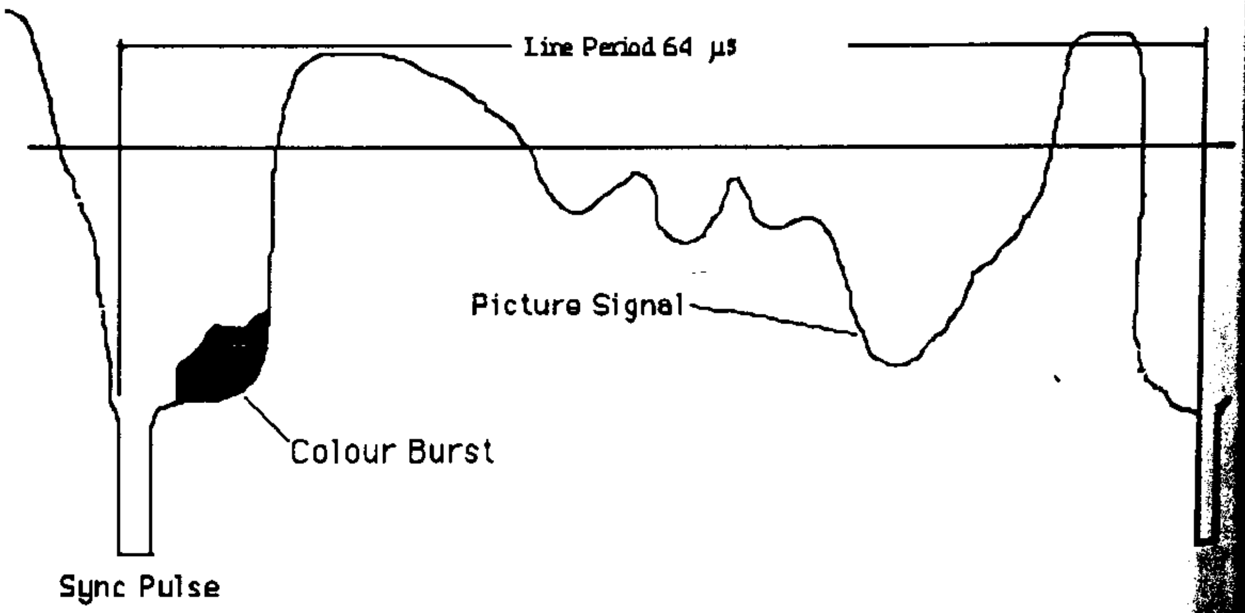
d *Check 3 Camera underwater*
A simple check for specific underwater problems.

These checks can only provide a measure of the video quality at the time they are implemented. They can neither guarantee quality at a different time nor can they take account of possible degradation if components of the whole system are changed or additional items connected to it. They are, however, designed for technicians who are competent in the use of relevant underwater equipment but who have no specialist video or electronic knowledge.

15.5 Video Signal

There are two main video systems in operation, they are PAL (phase alternation by line) and NTSC (national television system committee) which was developed in the United States of America. It is not the intention of this book to go into great detail on these formats as the subject is already well documented, but it is suffice to say that all systems are compatible with both types.
Video signal is an electrical signal that is produced by the camera, that scans the object, and it is proportional to the intensity of light entering the camera. Light is made up of the seven colours red, orange, yellow, green, blue, indigo and violet. However the human eye is most perceptive to red, green and blue, for this reason the camera is designed to detect these three colours which are recombined to form an image of the original object.
The camera is made up of three tubes, each one designed to receive either red, green or blue light and produce an electrical signal which is proportional to the colour strength. The colour is then transmitted on the actual video signal and decoded at the monitor to produce the actual picture.

Figure 15.3 illustrates how video signal appears on an oscilloscope.



Typical Video Level 1 Volt Peak to Peak
Figure 15.3

It can be seen that composite video signal is made up of synchronisation pulses, colour burst, chrominance and luminance.

15.6 Luminance Signal

Luminance is the characteristic used to provide picture detail by varying levels of brightness. Luminance is transmitted on the picture section of the signal.

15.7 Chrominance Signal

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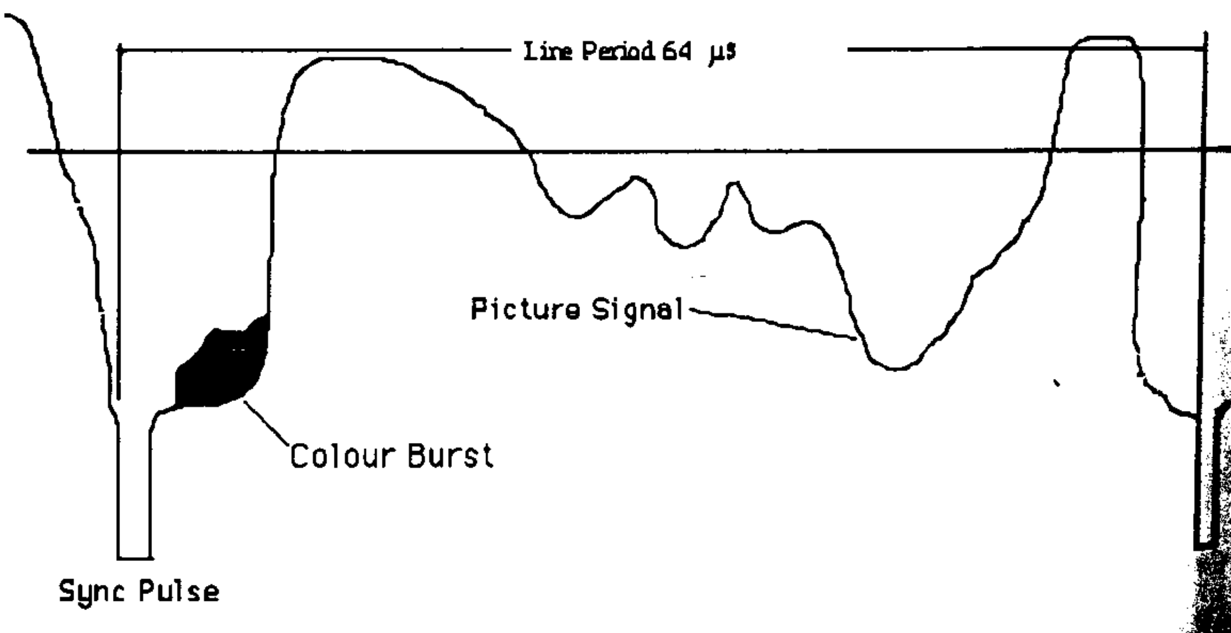

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Luminance is the characteristic used to provide picture detail by varying levels of brightness. Luminance is transmitted on the picture section of the signal.

15.7 Chrominance Signal

Chrominance signal is used to convey the colour information in the video signal. The red, green and blue colours produce an electrical signal that is proportional to the phase shift between them. It is this electrical signal that forms the chrominance signal.

15.8 Colour Burst

Colour burst is added to the video signal to provide synchronisation for the chrominance. This is added immediately after the picture information, before the following synchronisation pulse.

15.9 Synchronisation Pulses

The synchronisation pulses ensure that the receiver operates in step with the vertical scanning of the camera. The TV monitor display is made up of 625 scan lines that are scanned 25 times per second. This means that each line is being scanned at a frequency of 15.625 KHz. It can be seen that the time period between each synchronisation pulse is normally 64μs, the picture information between the two consecutive synchronisation pulses therefore represents the information applied to one scan line.

15.10 Calibration Of Video Cameras

Due to the length of umbilical, ROV systems are subject to the effects of line losses. This can manifest itself in the ROV video system.

The monitors on the system require a certain level of video signal to function correctly, if this is not the case then it may result in extremely poor picture quality.
A situation may arise in which the umbilical may be replaced for a much longer one. For example it may be necessary to incorporate a TMS in to the system, this would require the addition of an armoured umbilical. This would obviously result in an increase in the overall line losses. For this reason it would be necessary to carry out a calibration of the video cameras.

By calibrating the camera we are in fact amplifying the camera output to overcome the line losses. Normally the signal is monitored at the surface using an oscilloscope, whilst the signal is adjusted at the camera output. This may involve the adjustment of a potentiometer which will in turn alter the gain of an output amplifier.

It is important to adjust the gain at the camera end rather than the surface as the video signal will have 'noise' superimposed upon it, by carrying out amplification at the surface we would amplify the noise signal as well. Noise may be derived from the power conductors that lie in close proximity with the video coax.

15.11 Colour Loss

Due to the difference in frequency between the red, green and blue light it follows that colour absorption will take place to a varying degree over a fixed length of umbilical. To overcome this it may be necessary to boost an individual colour with respect to another. As red is of higher frequency than green and blue it follows that it is subject to the highest absorption factor and may need to be amplified at the camera end.

15.12 Typical Faults With Video Systems

The most common faults that arise with video systems are caused by connector breakdown, this may occur at either the ROV or the surface. Should any faults develop it would be wise to check that all the connections are serviceable prior to carrying out any major dismantling.

It may be the case that the video picture becomes impaired due to electrical interference. This can arise if the video system does not have an independent earth from the rest of the ROV electrical system. If this were the case 'current loops' may be induced into the video system from the mains supply and give rise to picture flicker taking place at mains frequency. This fault can be proved by monitoring the video signal on the oscilloscope. It would be found that video signal would be present at a frequency of 50 or 60 Hz.

Many ROV systems make use of fibre optic transmission to convey video signal, this ~~will illuminate~~ any electrical interference. However the physical size of the conductors makes them susceptible to breakdown, especially at the connectors. This can lead to all the associated losses that come with fibre optic transmission and thus result in loss of picture quality.

eliminate

16.0. Introduction

Photography is used extensively offshore as a method of providing a permanent record of the actual state of underwater components and structures. These photographs are in colour and may be stereoscopic. Engineers can then use them for structural analysis and other purposes and they form part of the permanent record for any particular structure. Photography is also one of the prime methods of recording inspection information during annual platform inspections and forms part of the final report for this type of survey. Although video tape recordings are universally used for the purpose of recording information on these same underwater constructions photographs still have an important role to play and ROV personnel must be fully competent in the use of underwater photography. It is appreciated that offshore personnel will probably never need to apply the physics of underwater optical systems directly in a system design way but it is still most useful to have an understanding of the basic principals affecting light in water.

16.1 Light in Water

Light entering the water is affected by reflection, refraction, loss of intensity, loss of colour and loss of contrast in accordance with the laws of physics. These same laws apply when the light enters the camera housing from the water. As photography is basically recording light images onto film a better understanding of these effects will be of benefit for anyone contemplating taking underwater photographs.

16.1.1 Reflection

This is a straight forward effect; whenever a light beam meets a reflecting surface it is reflected, the angle of reflection equals the angle of incidence.

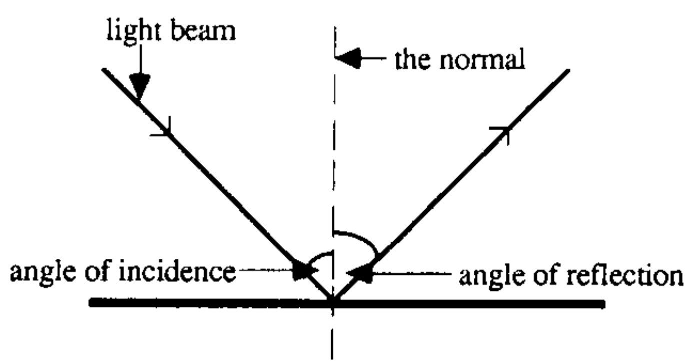

Figure 16.1
The angle of incidence equals the angle of reflection

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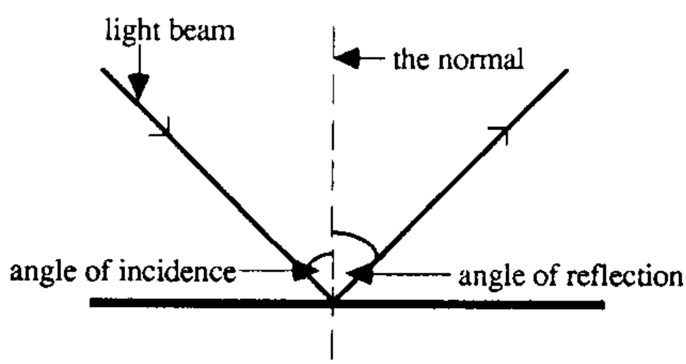


Figure 16.1
The angle of incidence equals the angle of reflection

16.1.2 Refraction

As a light beam passes from water to air it is refracted in accordance with Snell's Law which can be summarised by the equation:

$$N_{water} \sin \theta_{water} = N_{air} \sin \theta_{air}$$

Where N_{water} = Refractive Index of water
N_{air} = Refractive Index of air
θ_{water} = Angle to the Normal subtended by the light ray in water
θ_{air} = Angle to the Normal subtended by the light ray in air

in the case of light passing from water through a glass or plastic port into the air gap in a camera housing it is possible to look at the simple case where the port consists of a plane glass with parallel surfaces. The Refractive Index of glass and perspex is very similar to water and in this case the equation evolves to:

$$\sin \theta_{air} = N \sin \theta_{water}$$

Where:-

$$N = \frac{N_{water}}{N_{air}} = \frac{4}{3}$$

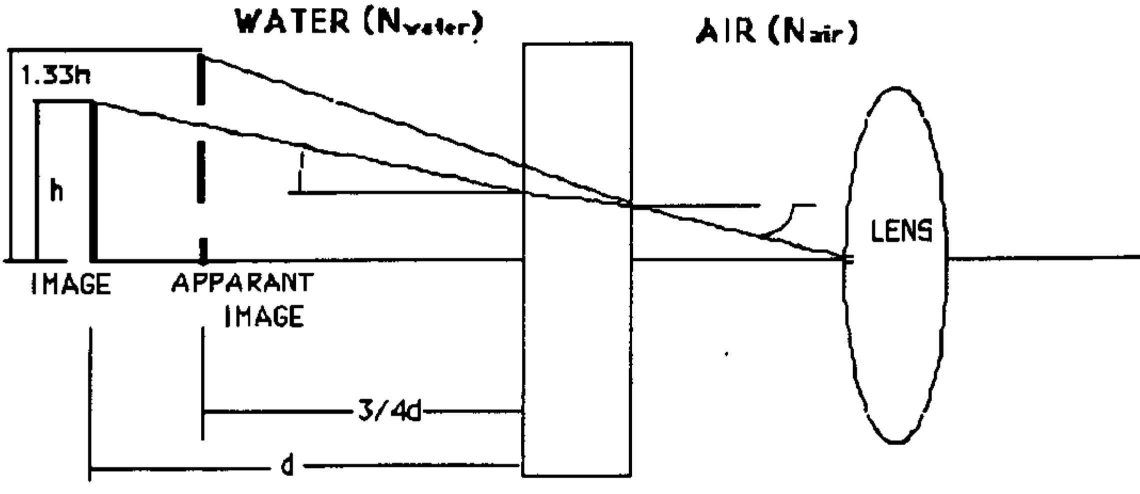


Figure 16.2
Refraction from Water to Air across a Plane Port

As can be seen from Figure 16.2 the light rays emanating from the image after passing through the port appear to originate from the apparent image. This has the effect that, without correcting the lens, distortion, focus errors and field of view errors are caused.

16.1.3 Distortion

Rays from points forming a rectangle in water will suffer "pincushion" distortion, unless the lens is corrected for this underwater effect .

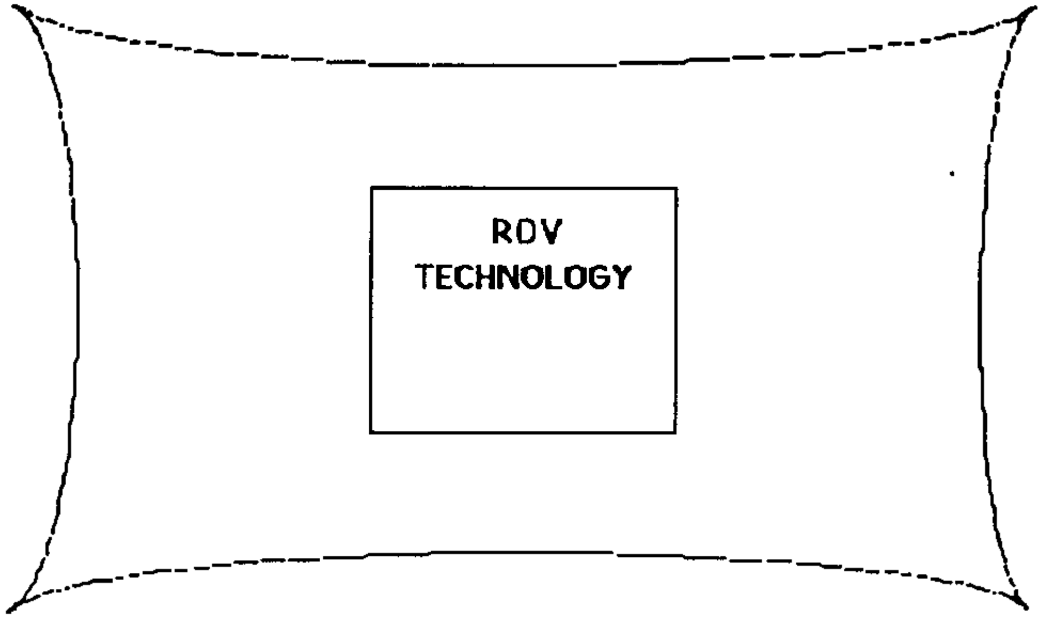


Figure 16.3
Pincushion Distortion

This diagram (which is exaggerated for emphasis) illustrates the effect of pincushion distortion which is more noticeable at the edges of the frame and less discernible towards the centre.

16.1.4 Focus Error

This effect is illustrated in Figure 16.2. The apparent image appears to be 1/3 larger and 1/4 nearer.

16.1.5 Field of View Errors

Objects in water appear to be larger than in air by a ratio of approximately 4:3 (refer to Fig 16.2). This means the lens appears to have a longer focal length in water and the object fills more of the frame. Also, because of refraction, any light beam entering the port at an angle other than the normal will leave at a wider angle. A camera has a fixed field of view and therefore in these circumstances its field of view in water will be less than in air.

16.1.6 Loss of Intensity

Light passing through water is attenuated in accordance with the relationship:

$$I/I_o = e^{-kx}$$

Where I_o is the initial intensity
I is the intensity after scattering and absorption
k is the attenuation co-efficient
x is the distance

The attenuation co-efficient, k, is the sum of the absorption co-efficient α and the scattering co-efficient β both of which depend on the wavelength λ of the light and the type and amount of suspended material.

16.1.7 Scattering

Figure 16.4 shows the effects of scattering where suspended particles in the water reflect some of the light at random angles dependent on the angle the reflecting surface of the particle presents to the beam. The more suspension the greater the amount of scattering and the greater the reduction in light penetration.

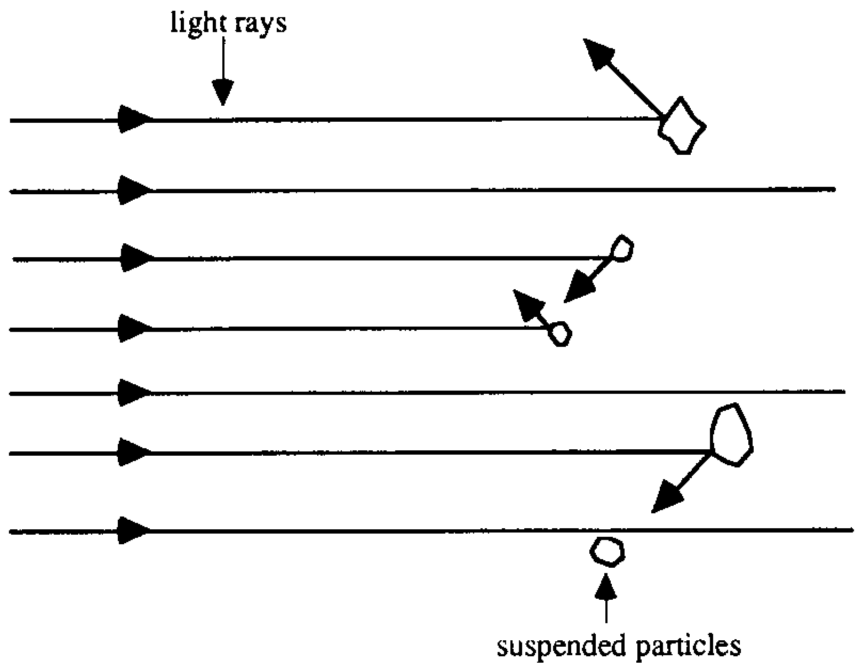


Figure 16.4
Scattering

Scattering is also responsible for back scatter which is a problem on photographs analogous to the effect of using headlights in fog. Light is reflected back and reduces the field of view.

16.1.8 Absorption

Fig 16.5 shows in diagrammatic form the effect of absorption which is to reduce the strength of the light beam. The reduction in strength is dependent on the turbidity of the water and on distance travelled.
The greater the amount of dissolved matter in the water and the greater the distance travelled the greater will be the loss.

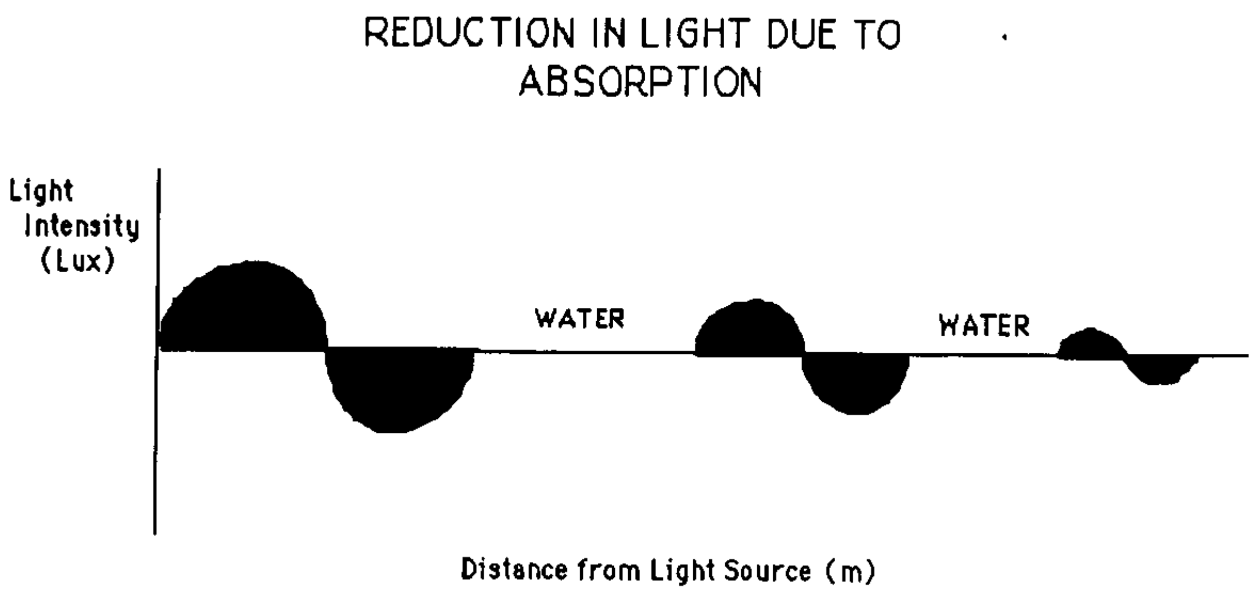


Figure 16.5
Absorption

Both absorption and scattering cause problems when the stand-off distance in sizeable. Scattering is more troublesome as it adds background illumination as well as removing useful light. This background illumination is called "back scatter" as shown in Figure 16.6.

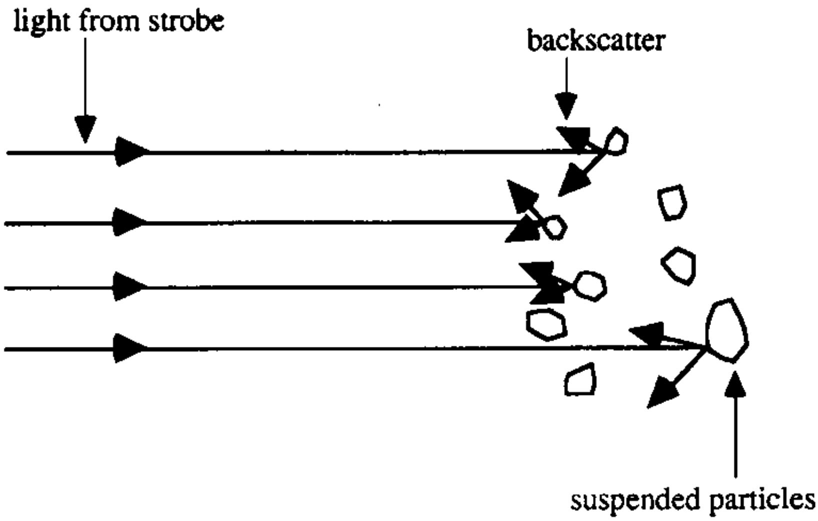


Figure 16.6
Back Scatter

In some circumstances it may be possible to compensate for the loss of light by absorption by using stronger lights, but if back scatter is a problem this option may not be possible due to the overall degradation of the light caused by the increase in back scatter. The effects of back scatter can be minimised by placing the light source at an angle as shown in Figure 16.7.

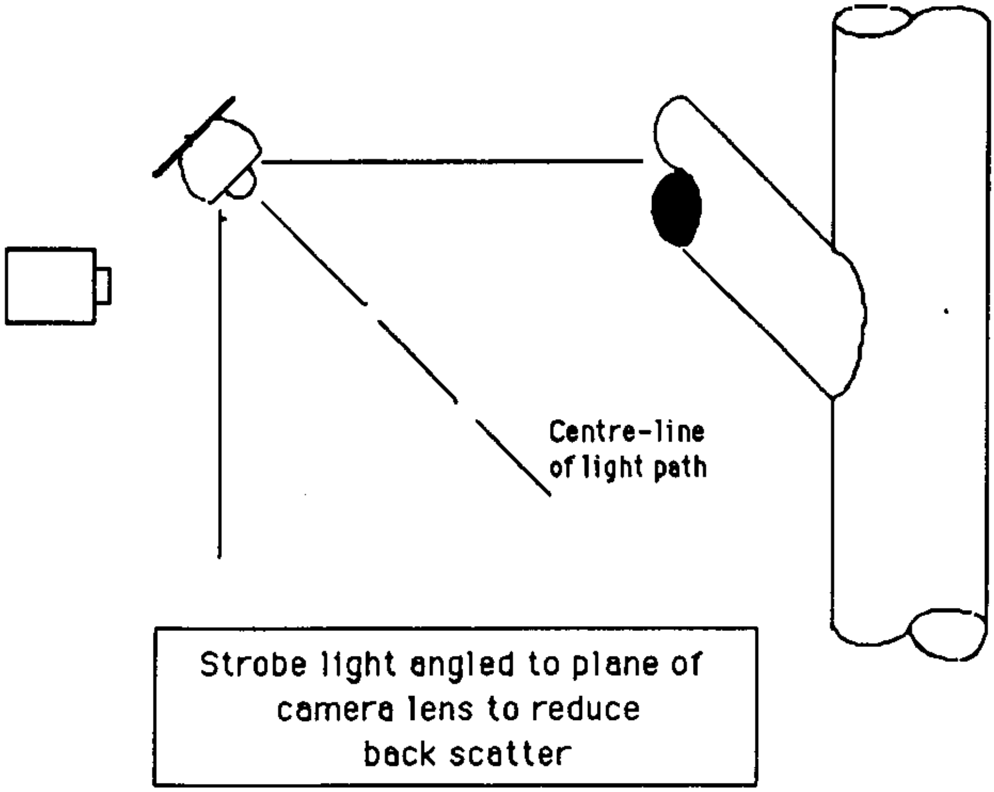


Figure 16.7
Minimising back scatter

Even using this technique it is quite possible, especially in coastal waters, that usable photographs can only be taken at a range of a meter or two at most.

16.1.9 Loss of colour

White light is made up of the colours of the spectrum and as it penetrates the water these colours, which have different wavelengths, are absorbed at different rates. The shorter wavelengths are absorbed quickly with red light, for example, being absorbed approximately 6 times faster than blue light. This effect causes underwater long-range photographs to have little colour other than blue-green. Figure 16.8 illustrates this graphically.

COLOUR ABSORPTION IN WATER

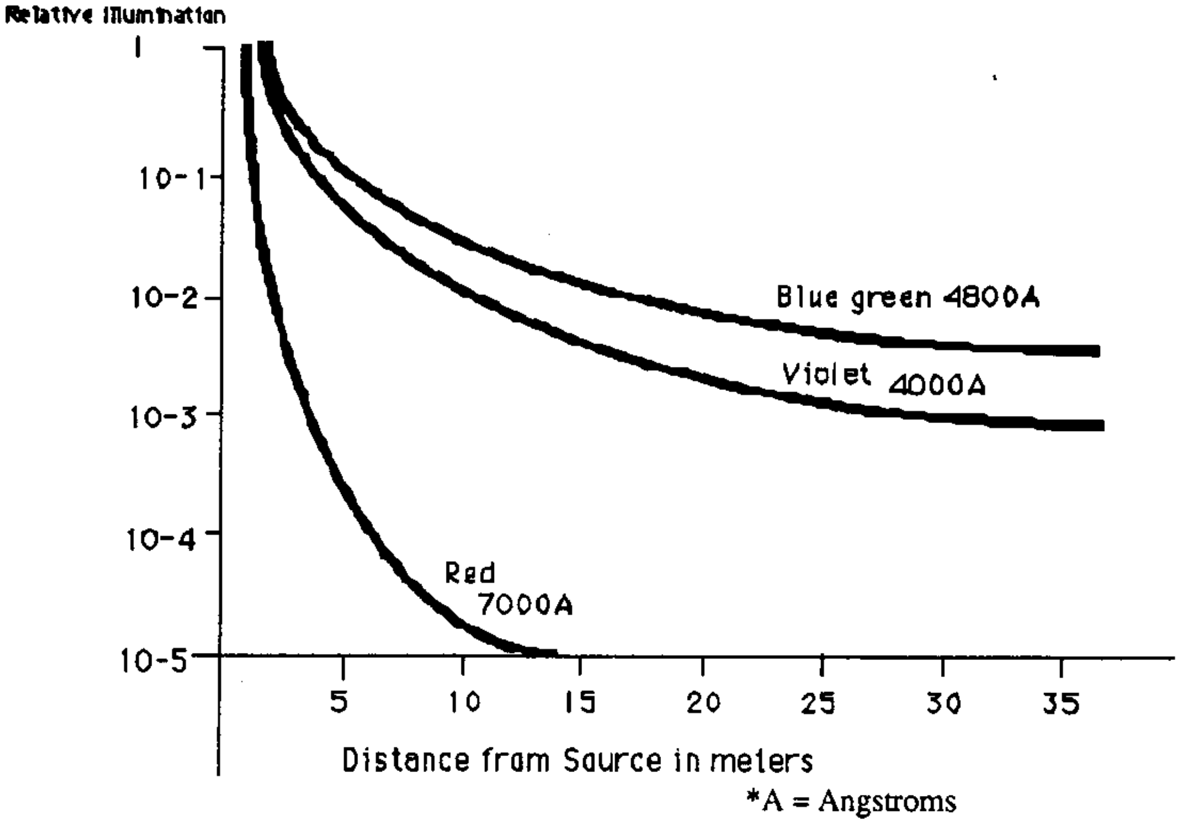


Figure 16.8
Colour Absorption

The method for overcoming this problem is to use a strobe that is powerful enough to illuminate the viewing area sufficiently. The basic advice therefore, with any strobe, is to get close to the subject.

16.1.10 Contrast

When we observe an image its form and texture are made apparent to the eye by the different intensities of reflected light coming from its surface. If the difference in intensities is strongly marked then the contrast is good and the image is said to be 'crisp'. If the differences are poor then so is the contrast and the image is said to be 'muddy'. Underwater there is always less light available than in air and with increasing depth light intensity decreases. Thus the situation in water is that there is always poor contrast and without introducing artificial light this problem gets worse with depth. The solution to this problem is to use a powerful enough strobe to compensate for the loss of natural light and ensure you are as close as possible to the subject.

16.2 Electronic Strobe Lights

All the problems associated with loss of light can be overcome or at least improved by using an appropriate underwater strobe light. In air photography the output from strobe lights is indicated by the Guide Number. This number is calculated generally for use with 100 ASA film (film speed and the ASA system are discussed later). When a strobe is to be used to provide the light the camera shutter speed control is set at the flash synchronisation speed which is often 1/60th second.

16.2.1 Guide Number

The guide number is used to determine exposure and is the product of the distance to the subject and the iris setting

Guide Number = f X D where f = f stop
D = Flash to Subject Distance

it is determined by the flash rating and film speed.

16.2.2 Estimating Proper Exposure

The chart reproduced as figure 16.12 shows f stop versus object distance for various film speeds using a 150 watt-sec strobe. This is a good starting point for estimating correct exposure. The chart is worked out assuming no ambient light. In high ambient light the iris should be stopped down further than the settings shown to compensate. The amount of iris adjustment will depend on the levels of ambient light in any particular application but a rule of thumb would be either one half or one f stop.

F STOP vs OBJECT DISTANCE BASED ON 150 WATT/SEC STROBE

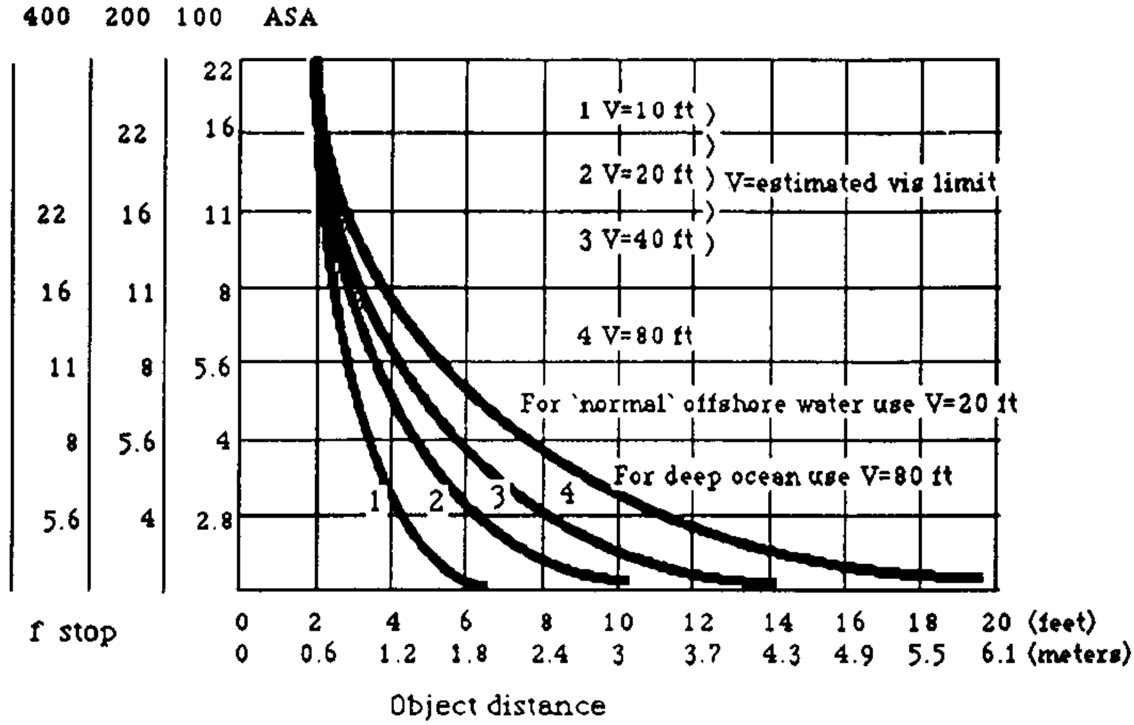


Figure 16.9
F Stop Verses Distance

16.3 Camera Controls

The amount of light entering a camera is controlled by the size of the aperture and the speed with which the shutter opens. Both these controls are adjustable on the types of camera used for photography offshore. An understanding of how these controls work will be useful no matter what camera is being used because there is a standard method applied by all camera manufacturers.

16.3.1 Aperture Control

The size of the aperture is controlled by the iris diaphragm which is adjustable. A large aperture and a long focal length can transmit the same brightness of light as a small aperture and short focal length. The scale used in photography to relate focal length and aperture size is called the f number system. This system is applied as a standard method by manufacturers so that an aperture of, say, f4 will always transmit the same brightness of light whatever the focal length. The series of f numbers as a whole is arranged so that each reduction of one f stop halves the amount of light admitted into the camera. For example f4 allows twice the amount of light as f 5.6 to enter but only half the amount as f2.8.

f no.	22	16	11	8	5.6	4	2.8	2	1.4
units of light	2	1	2	4	8	16	32	64	128

Figure 16.10
F stops

The size of the aperture affects the image definition of a lens. At maximum aperture the sharpness of the image in the centre of the picture is nearly always greater than in the corners. Stopping down the lens improves central definition slightly and corner definition much more. At small f stops such as f22 there is usually slight fall-off in sharpness caused by diffraction, the scattering of light rays collected in the front of the lens as they pass the edge of the iris diaphragm, but this is not important in underwater photography.

16.3.1.1 Depth of Field

Depth of field describes the extent of the picture in focus at a given f number. The length of the zone on either side of the subject depends on the size of the aperture and the focal length of the lens. In theory, only the subject in which you focus is completely sharp but an area of acceptable sharpness lies in front of and behind it. As the size of the aperture decreases, the depth of field lengthens, bringing more of the picture on either side of the subject into focus. The subject focused on is not in the centre of this sharp zone which extends two-thirds beyond and one-third in front of the subject.

16.3.2 Shutter Speed

The shutter speed is set by adjusting the shutter speed control, which is calibrated in seconds and parts of seconds. Here, the relationship between stops is obvious and follows the same method as f stops, the difference between one shutter speed and the next is a ratio of 1:2. A typical series is shown in the table below.

1	1/2	1/4	1/8	1/15	1/30	1/60	1/125	1/250	1/500	1/1000

Typical Shutter Speeds

Here 1/60 passes 2 as much light as 1/30 but twice as much light as 1/125

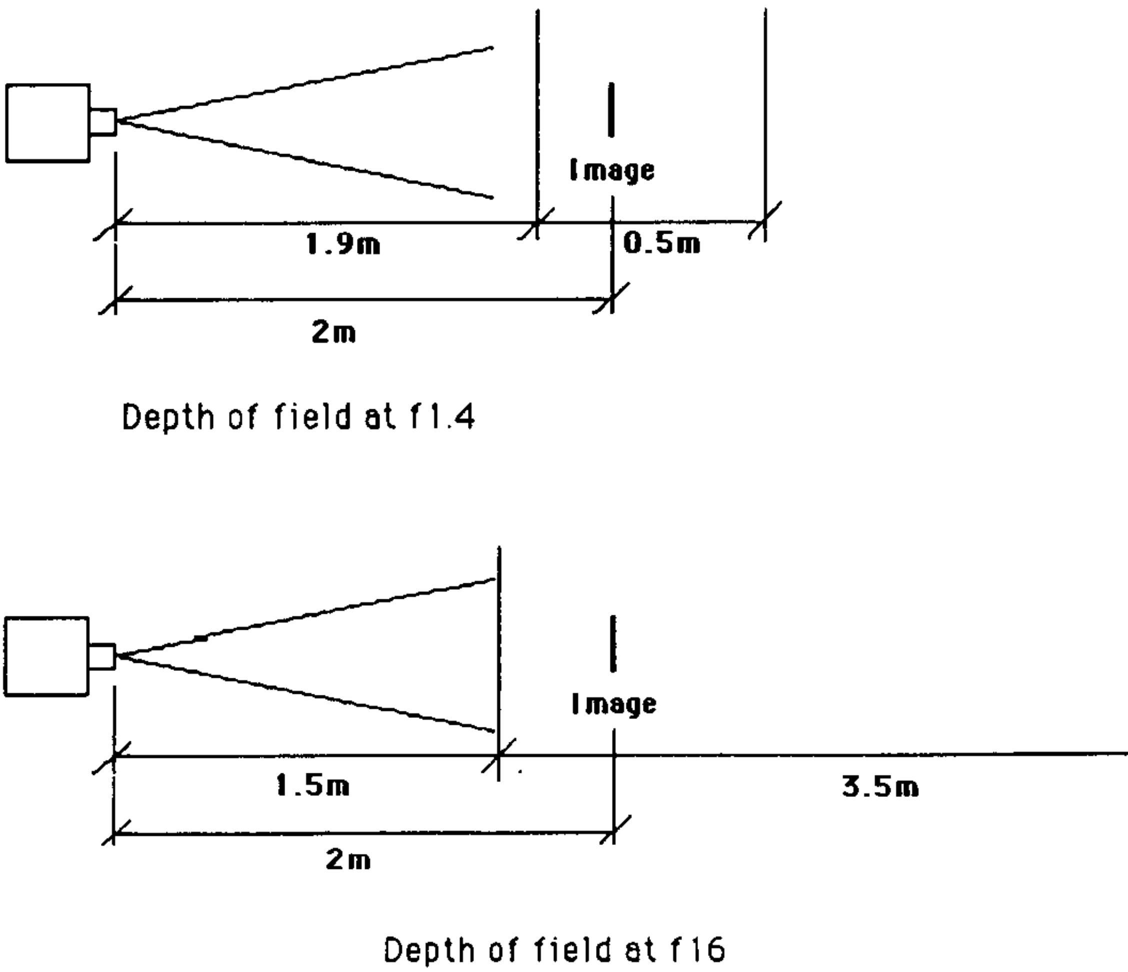


Figure 16.11
Depth of Field
Using a Typical
50 mm Lens

16.4 Film

Films vary from one manufacturer to another and there is a wide variation in choice from one photographer to another because each will present a different hue and one may be more pleasing than another to different individuals. Underwater the choice tends to be more limited however because of the low light conditions.

16.4.1 Film Speed

The speed of reaction to light for any film is rated on one of two international scales which have been rationalised by the International Standards Organisation (ISO). The American scale is referred to as the ASA (American Standards Association) method and the European scale is referred to as the DIN (Deutsch Industries Norm) method. The table below shows the relationship between the two methods and the ISO rationalisation.

System	*Film Speeds*					
ASA	25	50	100	200	400	800
DIN	15	18	21	24	27	30
ISO	25/15	50/18	100/21	200/24	400/27	800/30

As can be seen from the Table the ISO has grouped the ASA and DIN methods together. Both methods apply the same rules and an examination of the ASA system will show how both work. As the number increases the film's reaction to light is faster. The film speeds illustrated are grouped into slow films with ASA of 25 and 50, medium films, ASA 100 and 200 and fast films ASA400 and above. As the value increases by 1 step the light reaction increases precisely twofold; for example 100 ASA is twice as fast as 50 ASA. This equates to one full stop on the camera aperture or shutter speed controls. The speed at which a film reacts to light is determined by the size of the silver halides on the emulsion. The smaller the grain the slower the reaction to light. By careful selection of grain size, the film manufacturer determines the ASA rating of the film but as the film speed increases the grain size also increases and thus the finished print becomes more and more 'grainy' as the ASA rating increases. Thus in selecting a film speed it is necessary to balance the reaction to light against finished print quality. A sensible choice for most offshore work is Ektachrome 200 which is a reasonably fine grain film with a moderate reaction to light.

16.4.2 Types of Film

There are basically two kinds of film:-

a) Negative film which requires a print to be made before you can properly interpret the subject.
b) Positive or Colour Reversal film which allows the subject to be viewed directly on the film.

16.4.2.1 Colour Sensitivity

Films also vary in their sensitivity to different parts of the light spectrum. For example Ektachrome is more sensitive to blue light, Kodachrome to red and Fugicolour to green. Some films are specifically balanced for artificial light and are marked "Tungsten". It is recommended that only daylight film be used for underwater photography as these films are balanced for use with strobe lights which are exhaustively used in underwater photography.

16.4.2.2 Film Format

There are basically two film formats to choose from in underwater photography, either 35 mm or 70 mm. 35 mm is by far the most popular film format having the following advantages:-

a) Cameras are smaller and lighter and less expensive than 70 mm.
b) 35 mm film is more universally available and less expensive than 70 mm.
c) 35 mm is easier to process.
d) 35 mm film is less bulky to store.

70 mm film produces a much larger negative than 35 mm, as indicated in Figure 16.12 and for high quality or photogrammety this is a major advantage.

35mm vs 70mm

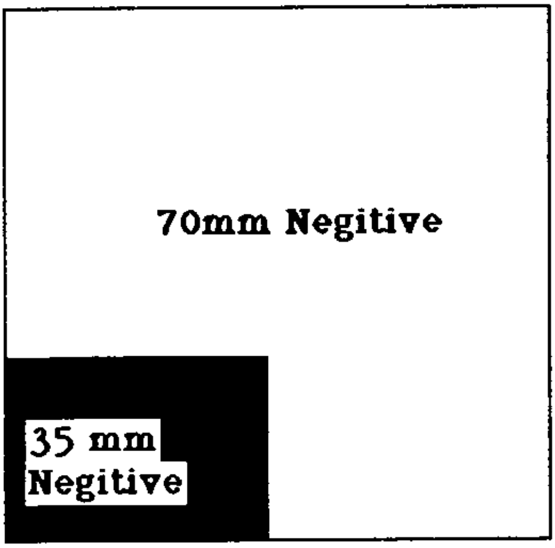


Figure 16.12

It is unquestionable that 70 mm will give better quality prints than 35 mm the question is whether 35 mm is acceptable or not.

16.4.3 Film Selection

There is a wide selection to choose from and the basic recommendation is to experiment with different films at first and then select the one that suits the requirements best and stay with it. Over time if one film is used constantly, better pictures will result because of the consistency of approach.

16.5 Framing the Subject

Manufacturers of underwater cameras normally list the angle-of-view (in water) of the camera lens system, and from this information the area-of-coverage at various distances can be calculated using simple trigonometry. Figure 16.14 illustrates this for a 35 mm camera.

VIEWING AREA OF A TYPICAL 35mm CAMERA

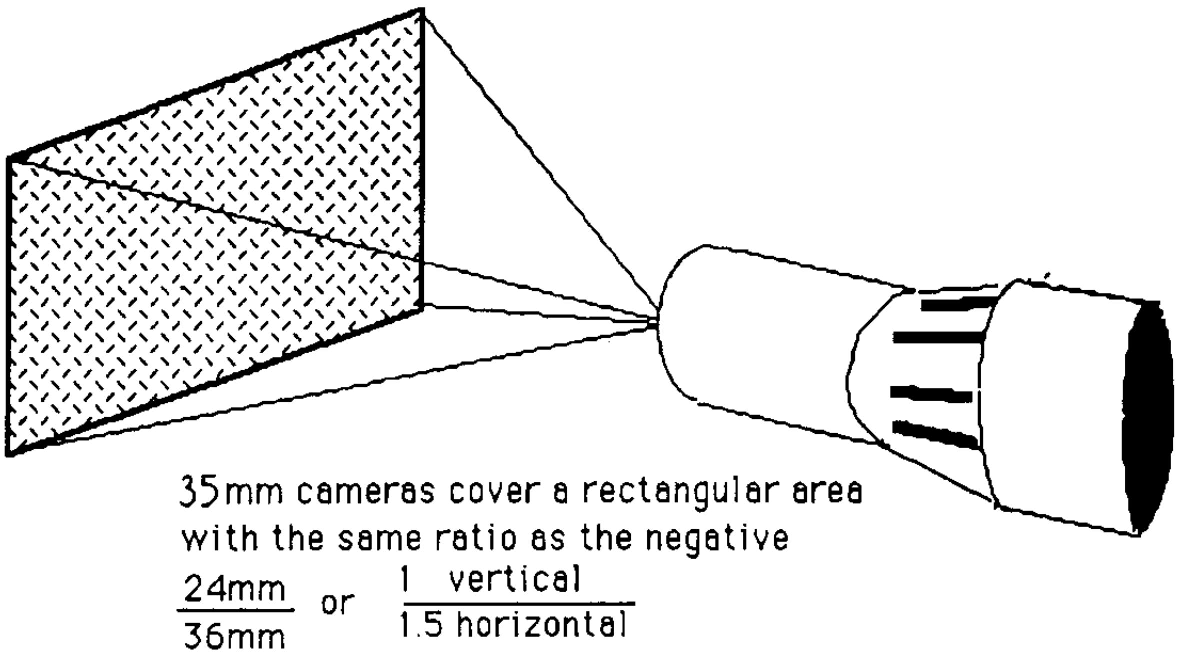


Figure 16.14
Area of View

This straight forward head-on situation gives the basis for calculation but in a real situation it may be more complicated. For example if the camera is looking obliquely down the area of coverage is a trapezoid. This is illustrated in figure 16.15 below.

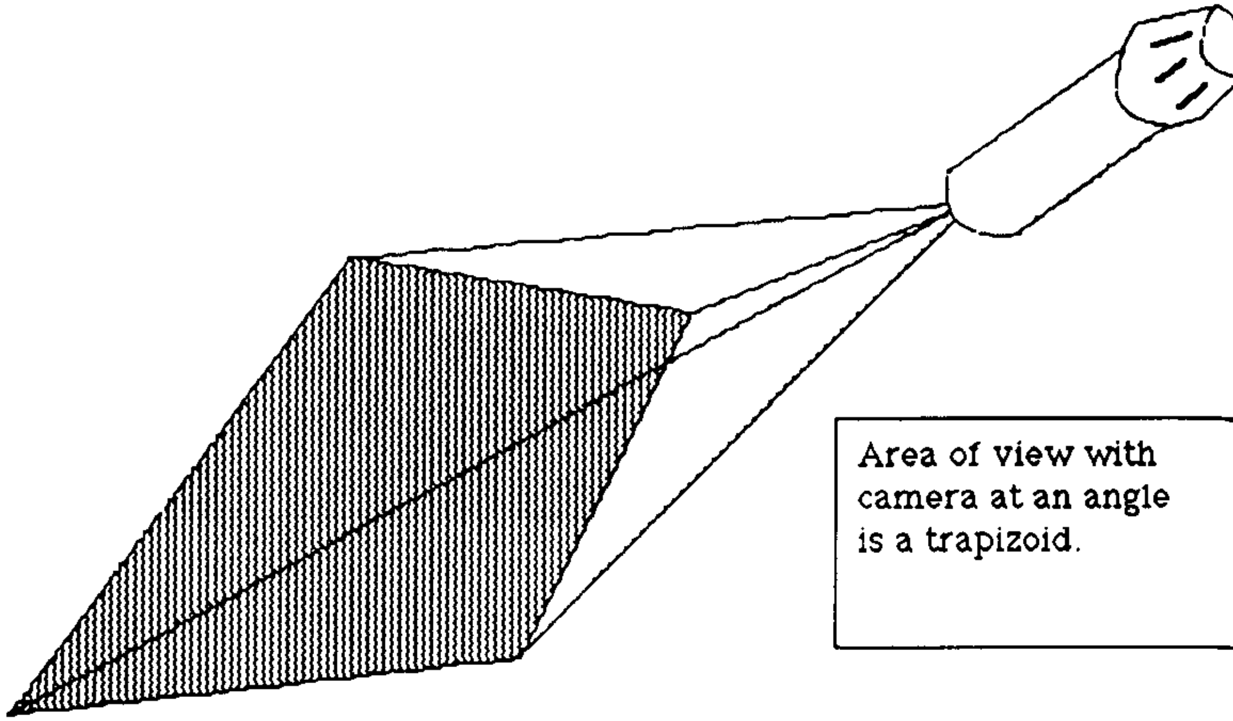


Figure 16.15
Area of View
When Camera is Tilted

This problem of framing a subject can be a difficult one to overcome but applying the principal shown here and with some practise a satisfactory solution should be found. Some camera systems are more helpful than others and there are two systems which use the same lens system for both the Video and the Still camera thus what you see on video is what you get on the still photograph.

16.6 Camera Systems

There are several camera systems available for use on ROVs but one manufacturer, Photosea Systems Inc. are currently the most popular. They manufacture several different types of remotely operated camera systems designed to take close up, stand-off or stereoscopic photographs. To compliment their range of cameras they manufacture compatible strobes and can offer total packages suitable for all ROV requirements.

16.6.1 Photosea 1000

These cameras can be fitted to ROV's and are also available for deep sea and diver held modes. Depth capabilities range from 600 m to 6000 m. Standard features include:

- a 28 mm water-corrected lens system.
- b Completely self-contained, weighs less than 1.1 kg. in water.
- c Rechargeable internal power packs.
- d Electronic film advance.
- e Data chamber with time, alpha/numeric code and frame number.
- f Daylight load film magazine accepts standard 36 exposure or 250 exposure cassettes.

16.6.2 Photosea 2000

This camera is a single, completely self-contained stereo camera, incorporating a dual lens system and a single film magazine. All problems associated with taking stereo photographs with a complex two-camera/two strobe system have been eliminated. With the Photosea 2000 series cameras stereo-scopic viewing can be achieved with a system as simple as conventional single frame cameras. Stereo pairs are automatically registered and is a major advantage over two-cameras stereo systems where developing and handling two separate rolls of films and trying to match stereo pairs can be a tedious and time consuming task.

16.6.3 Photosea 70 Series Cameras

These 70 mm cameras were designed for the offshore professional desiring the best in high resolution deep ocean photography. These cameras utilise large format 70 mm film with more than 32 times the negative area of 35 mm film. Combined with the high resolution water-corrected lens designed and built by Photosea.

16.6.4 NDT 3000 Macro Stereo Camera

This camera has been specifically designed to provide high resolution stereo photographs at close distances to assist in the detection of cracks, pitting and corrosion during non-destructive testing and structural inspection. The most unique feature of the NDT 3000 is the ability to take stereo photographs at a subject distance of 15 cm.

16.6.5 Combination Photo/TV Camera

Two companies manufacture 'combination photo/TV cameras. These units include a television camera inside the housing, which is used as a 'viewfinder' for the photo camera.

16.6.5.1 Sub-Sea Stereo view 2000

This combination camera includes a colour television camera and a Photosea 2000 'metric' stereo camera in the same housing. In addition to the ability to take 'mono' or stereo photographs, the stereo pairs produced by the camera can be used to take actual photogrammetic measurements. The system also includes a data chamber. This equipment is available from

Sub-Sea Systems Inc.
753 West Washington Ave.
Escondido
California 92025
USA

16.6.5.2 Osprey TVP Combination Camera

This system includes either a black and white SIT camera or a colour television camera and a 'mono' single-lens reflex photo camera in the same housing. The system also includes a data chamber with capability of remotely annotating the film. T he system is available from:-

Osprey Electronics, Ltd.
E27 Wellheads Industrials Centre
Dyce
Aberdeen AB2 0GD
Scotland

16.7. Strobe Lights

Almost all underwater still photography is accomplished using high energy strobe lights which are necessary to offset the high attenuation characteristics of light in water. In addition, a powerful strobe will provide the balanced illumination needed for high quality colour photographs since red light is virtually non-existent in ambient light at depths beyond 4-5 m.

16.7.1 How They Work

The strobe flashtube is essentially and arc-chamber made of glass, or quartz (for high output lamps) with an electrode sealed into each end. The size of the arc-chamber, which is normally filled with inert Xenon gas, is determined by its operating parameters and the applications for which it is designed. Flashtubes are available as straight tubes, or coiled into a helix for greater concentration of light. A third electrode, usual attached to the external wall of the arc-chamber, is needed to trigger the flash. An invisible coating of conductive material on the tube, or a fine wire wrapped around the wall of the lamp is usually used. Flashtubes are used in a capacitor discharge circuit, see figure 16.16.

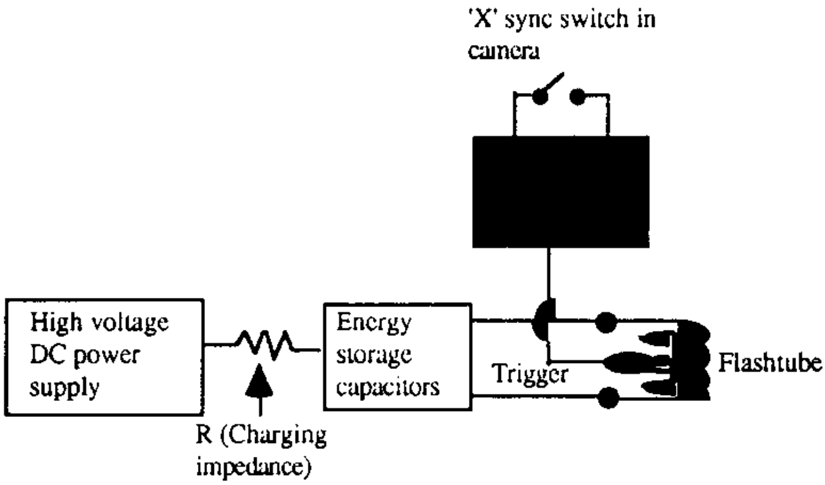


Figure 16.16
Basic Strobe Circuit

The main components of the circuit are:-

a. DC power supply.
b. Charging impedance - This limits the charge rate of the energy storage capacitor and allows the flashtube to de-ionise and extinguish after the flash.
c. Capacitors - store the energy for the flashtube.
d. High voltage trigger pulse circuit - This is usually a simple step-up transformer, pulsed from the discharge of a small capacitor controlled by the camera shutter 'sync' contact. The high voltage pulse activates the flash by ionisation of the gas in the arc-chamber.
e. The flashtube - changes electrical energy into light.

16.7.2 Strobe Power Ratings

As mentioned earlier the light output of most 'topside' strobe lights are rated with a guide number, but because of the wide variance in water clarity and its severe light attenuation characteristics, this guide number is useless in water. As a result, most underwater strobe lights are rated in terms of watts per seconds (joules). This rating describes the input power to the flashtube itself.

16.7.3 Maximum Power Input

All flashtubes also have a specification called 'maximum power input'. Although this specification is normally only of interest to strobe designers, users of strobe lights should be aware of what it means, because it can have an impact on overall system design for a specific photographic requirement where the flash frequency is important. Maximum power input is the relationship between the energy per flash, and maximum flash frequency. For example, a '218' series flashtube (used in Photosea 1500 strobes), has a maximum watt per second rating of 200. At 150 w^{-s} it has a maximum power input rating of 5 watts.

Therefore:

$$\frac{150\ w^{-s}}{5\ w} = 30 \text{ seconds maximum flash repetition rate}$$

If this particular tube operating on a power level of 150 w^{-s}, were flashed at a rate faster than 1 flash per 30 seconds, it would overheat and prematurely fail. Thus the w^{-s} rating is actually the input power to the flashtube.

16.7.4 Reflector Efficiency

The amount of actual light output, and the pattern of light is affected significantly by the reflector design. The old style reflectors were circular cross sections and therefore focused the light causing 'hot spots' which were very common in many underwater photographs. See Figure 16.17.

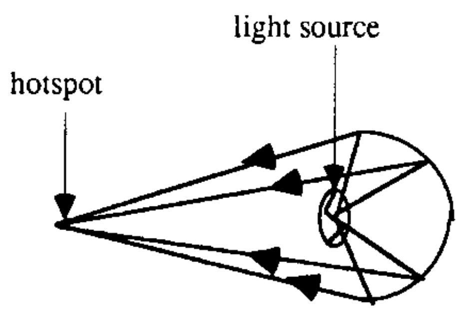


Figure 16.17
Circular Cross-section Reflectors
Focus the Light Causing Hotspots

New reflector designs that are parabolic shape with coatings that diffuse the light give good even illumination across the field-of-view of the camera eliminating these 'hot spots'. See Figure 16.18

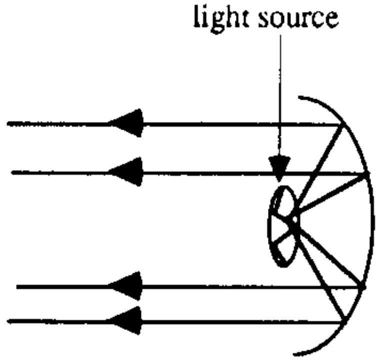


Figure 16.18
Parabolic Shape
Provides Even Illumination

16.7.5 Strobe Light Colour Output

Because of its spectral output, no other underwater light source can match the electronic flash for quality underwater colour photographs. All flashtubes have a continuous spectral distribution through-out the visible energy range. This visible radiation is approaching 'daylight' which produces excellent colour in all parts of the spectrum. 'Daylight' rated film should always be used when using an electronic flash. See Figure 16.19

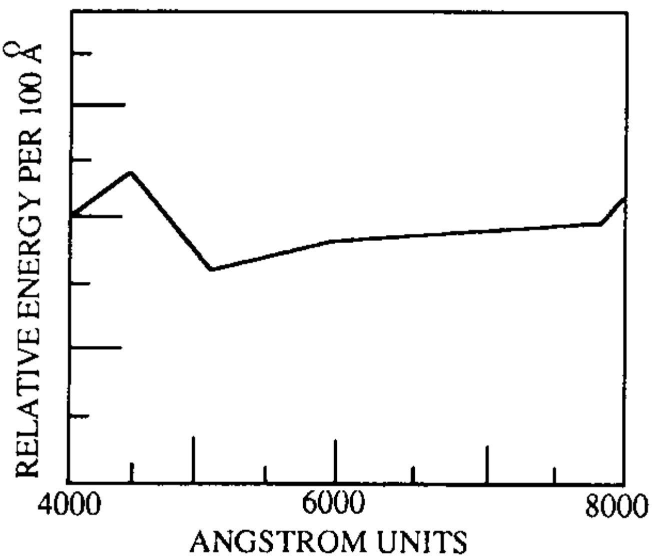


Figure 16.19
Spectral Distribution of a
Typical 1000 v Flashtube

16.7.6 Strobe Units

Photosea supply the 1500S and 1500SX (external power)which both provide energy output to 150 w $^{-s}$ and the 3000 series up to 300 w $^{-s}$. All these units are lightweight and have housing options to 6000 m depths and all have internal diffusing reflectors.

16.8. Operational Control of the Camera System

Camera systems are commonly actuated by a contact closure which could be a remote switch initiated by an operator, or a 'bottom contact' switch which triggers the system automatically when it reaches the bottom, or by an internal electronic timer that triggers the system at pre-set timed intervals. In each case some interfacing is required. In situations where long cable lengths are used, or where there is the potential for high electronic 'noise', from manipulator or thruster motors for example, it is always best to 'actuate' the photo system with a relay located close to the camera, such as in a nearby electronic bottle. The reason for this is that most new camera designs include solid state timers which are susceptible to noise and can be 'false' triggered. If this problem is occurring, it will be obvious; the camera system will 'actuate' itself. This problem is easily cured by using a voltage which actuates a relay which in turn actuates the camera system. Some system designers have also used opto-isolators for the same purpose. See Figure 16.20.

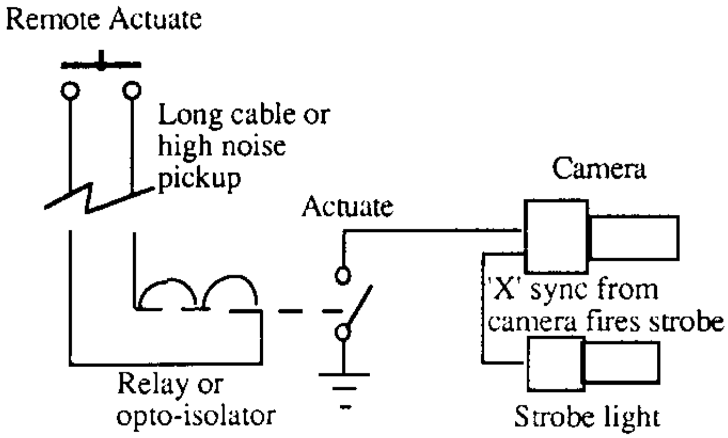


Figure 16.20
System Actuation

16.8.1 External Power to Strobe

Strobe lights can be operated from internal batteries or external power. When operating a high powered strobe light from external power, care should be taken when interfacing because of the high peak currents involved. The following comments apply to Photosea 1500 strobes but the principles apply to all electronic flash units which draw high peak currents when recharging.

a) Strobes draw short peak currents of up to 10 amperes during recharge (quiescent current after cut-off is 12 mA). Therefore the power source should be capable of supplying these peak currents, and it is also advisable to fuse your strobe power line with an 8-10 amp slo-blo fuse or breaker.

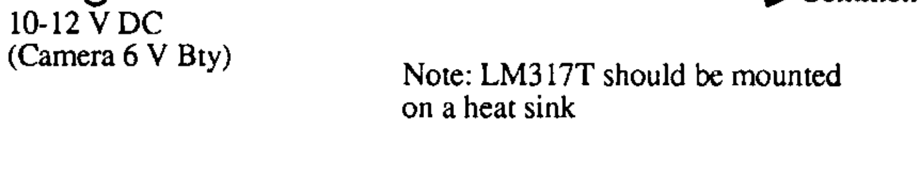
b) If possible, a remote ON-OFF switch should be installed in the power line so the strobe is not operating during prolonged periods of time when not in use.

c) Input cable connections are critical when operating a high power strobe from a remote power source.

No. 12 or 14 gauge wire is recommended to keep line resistance to a minimum. For example Photosea strobes require at least 21 volts to fully charge and shutoff. With just 1 ohm line resistance and peak currents exceeding 8 amp at 24 volts there could be an 8 volt loss in the cabling to the strobe and it would never fully charge and shut off. The strobe will simply keep turning itself ON and Off and oscillate erratically as the voltage sags below the 18 volt shutoff point and then rises after the current drain is removed. Typical current drain of a Photosea 1500S strobe during its recharge cycle is a short, 250-500 ms, peak of up to 10 amp at the beginning of the recharge cycle, average current of approximately 4 amp during the 3 second charging period, and 12 mA standby current after shutoff. It is recommended that the external power source be a battery or a voltage source that will not 'sag' due to these short peak current loads. A voltage source should never be connected directly to a strobe light that includes internal batteries as the batteries may become permanently damaged.

16.8.2 Trickle-charging NICAD Batteries

NICAD batteries can be 'trickle-charged' continuously during operations to keep their capacity up. All NICADs must be charged from a constant current source. Typically trickle charge current is in the 25-50 mA range for a 1-2 ampere / hour battery pack. An important point to remember is that the voltage capability of the constant current source must be at least 4-5 times higher than the fully charged voltage of the battery pack or the battery will try to charge the charging circuit. For example, a 24 V NICAD battery pack, 20 cells at 1.2 V per cell, will charge up to 28 V, 1.4 V per cell at full charge. Therefore, if the charging circuitry requires 2-3 volts drop, the constant current source should have a voltage capability of at least 30-32 volts. Figure 16.21 shows a simple and reliable constant current source.



R_1 Value	Trickle charge current I
48Ω 4 w	25 mA
24Ω 4 w	50 mA

Figure 16.21
Simple Charging Circuit

16.8.3 System Installation

Actual installation of a photo system will vary depending on specific applications, but there are several guidelines that should be followed whatever the installation.

16.8.3.1 Camera/Strobe Positioning

Back scatter in turbid water can be the biggest enemy in taking quality underwater photographs. Suspended particles in the water will reflect light back into the camera lens resulting in a reduction of contrast. In turbid water this problem cannot be eliminated but separating the camera and strobe with at least a 0.5 m distance will help significantly. The least desirable strobe mounting position is directly adjacent to the camera. The strobe, or strobes, should be mounted so that they intersect with the camera axis at the approximate range of the required picture. Fig 16.22 illustrates this.

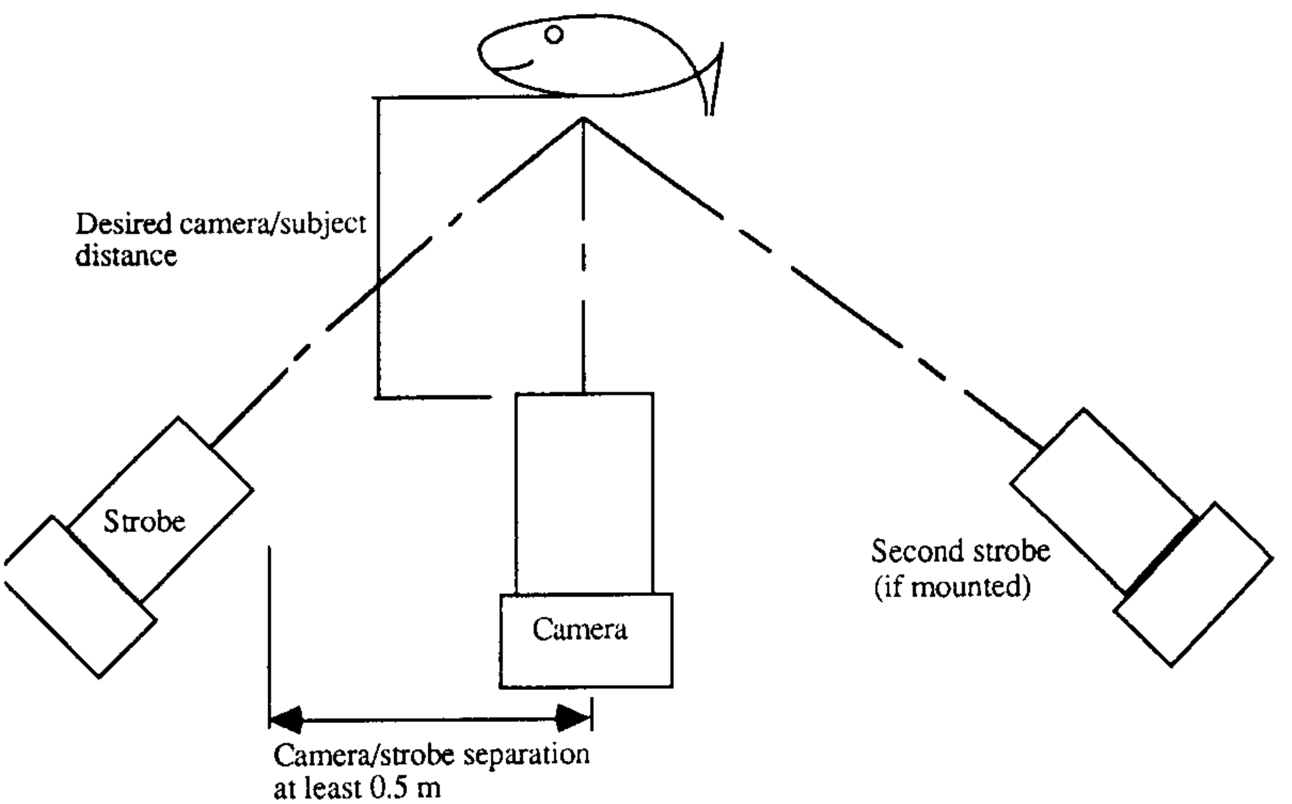


Figure 16.22
Mounting Strobes

16.8.3.2 Mounting

The normal method of mounting a camera and strobe is to use a saddle type mount with a clamping device. If stainless steel hose clamps are used, the units should be secured with at least two clamps, and the clamps should be covered with shrink tubing or similar insulating material. Remember that the camera and strobe should be accessible and easy to install and remove for charging and film changing. It is also necessary to have easy access to the ON-OFF switches. It cannot be over-emphasised as to the importance of proper routing and connection of cables. A very high percentage of problems offshore are caused because of poor cable connections.

16.8.3 Pre/post Dive Check List

Some important pre dive points are :-

- a Film installed properly and camera mechanism tested
- b Lens Focus/iris setting correct
- c Data chamber turned ON and properly set
- d Strobe and camera batteries charged
- e Power switches OFF until dive
- f System all connected and Test made
- g O rings properly greased and installed

Post dive:

- a All units flushed down with fresh water
- b Film unloaded in the dark and then labelled
- c All power switches switched OFF
- d Batteries charged
- e Housings properly stowed.

17.0 Introduction

In a handbook of this nature it is not possible to cover a vast topic such as seamanship in any detail. Seamanship itself includes topics as diverse as the use of lifting equipment on one hand to the art of navigation on the other. It includes safe working practices, rigging, boat handling, weather prediction and all the many and various techniques and skills which go to make up the art and skills of seamanship. The objective of this chapter is to cover in enough detail for operational use, those subjects which will have relevance for ROV Pilot/technicians offshore.

17.1 Lifting Equipment

One operation that the pilot/technician will certainly undertake regularly is the deployment and recovery of the ROV. This entails the use of lifting devices and as it is such a regular task this aspect of seamanship will be covered first. The subject will be broken down into three categories. Safety, which will be dealt with first, rigging and finally blocks and tackles which will give an insight into the mechanical advantages of lifting equipment.

17.1.1 Safety Aspects

As stated in Chapter 2 safety in the work place is the subject of numerous Acts of Parliament and Statutory Instruments. The basic requirement is that everyone must shoulder their own part of the responsibility for ensuring a safe work place. On any work site you are likely to go to it is no unlikely that you will find local safety requirements which have to be followed. In the majority of cases these will be along the lines laid out here. One should be aware, however, that there is a possibility of some local variations.

17.1.1.1 Personal Safety.

On a personal level one should always:

a) Observe and comply with all safety notices and instructions.

b) Always wear the correct safety equipment.
e.g. Safety boots, gloves, helmets, goggles, ear protectors, safety harnesses, life preservers etc.

c) Be sure of the correct operation of any, and all, tools and, or equipment likely to be required during any lifting operations. Read operating instructions before using any device for the first time or if in any doubt.

d) Always use the right tool for the job. Never make do with the wrong one.

e) Always stand well clear of overhead loads.

f) Understand fully what is required for any particular task undertaken as part of the overall operation.

g) Avoid leaning over the side of the ship and be aware of the location of life saving equipment.

h) Tie all equipment down and stow it correctly during periods of heavy weather.

17.1.1.2 Lifting Equipment Safety.

All appliances and gear used for lifting, lowering and handling loads must be inspected and tested at regular intervals. In the North Sea all such equipment is tested every 6 months by a competent person. The actual testing is normally carried out by specialist companies and certificates are issued once the equipment under test has been approved.

It is necessary to test to 1.5 times the SWL for static load testing this is outlined in Chapter 2 paragraph 2.1.1.

17.1.1.3 Safe Working Loads

All lifting equipment must be marked with the safe working load (SWL). If any item of lifting equipment is not marked it must not be used. If the item is in apparently good condition it should be put to one side and sent to a specialist company for testing and certification after which it may be put back into use.

17.1.1.4 Out Of Date Equipment

It is common practice for lifting strops, shackles and other such lifting equipment to be colour coded with paint in the colour of the month. This simplifies the job of checking that it is in date as all that is required is to ensure that only the correctly coloured strops etc. are used. Any equipment which is out of date must not be used but can be back loaded and re-certified by an appropriate authority.

17.1.1.5 Safe Practices

If equipment becomes damaged during use the operation must be suspended and the offending item replaced.

Inexperienced personnel and anyone under 18 years of age should not be in charge of powered lifting equipment unless under instruction, in which case close supervision by a competent person is required at all times.

Controls of lifting and handling equipment should be permanently and legibly marked with function and operating direction shown by arrows or other simple means.

Make-shift extensions should not be fitted to controls nor any unauthorised alterations made to them.

Foot-operated controls should have slip-resistant surfaces.

No lifting appliance should be used with any locking pawl, safety attachment or device rendered in-operative.

If, exceptionally, limit switches need to be isolated in order to lower a crane to its stowage position, the utmost care should be taken to ensure the operation is completed safely.

Any power appliance should always have a man at the controls while it is in operation, it should never be left to run with a control secured in the ON position.

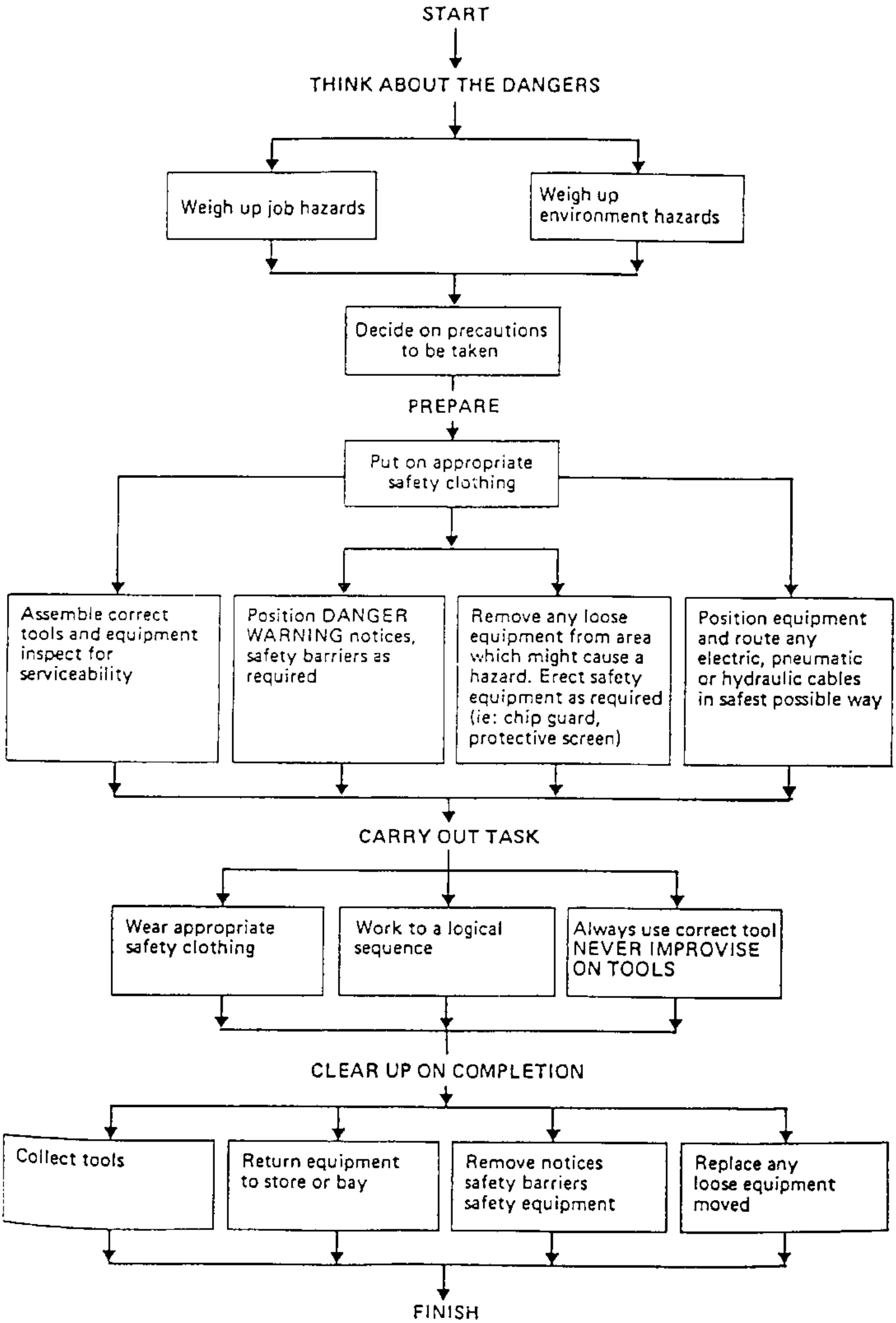
If any power lifting equipment is to be left unattended with the power on, loads must be taken off and controls put in 'neutral' or 'off' positions.

Where practical, controls should be locked or otherwise inactivated to prevent accidental restarting.

When work is completed power must be shut off.

Personal safety points may be summarised in a chart form which can be seen as Fig 17.1.

Figure 17.1
Personal Safety



17.1.1.6 Crane Signals

It is most common these days to use some form of voice communication directly to the crane driver but there may still be occasions when it is necessary to use hand signals to indicate your requirements. The current standard Code of Hand Signals is reproduced as Figure 17.2.

Code of Hand Signals

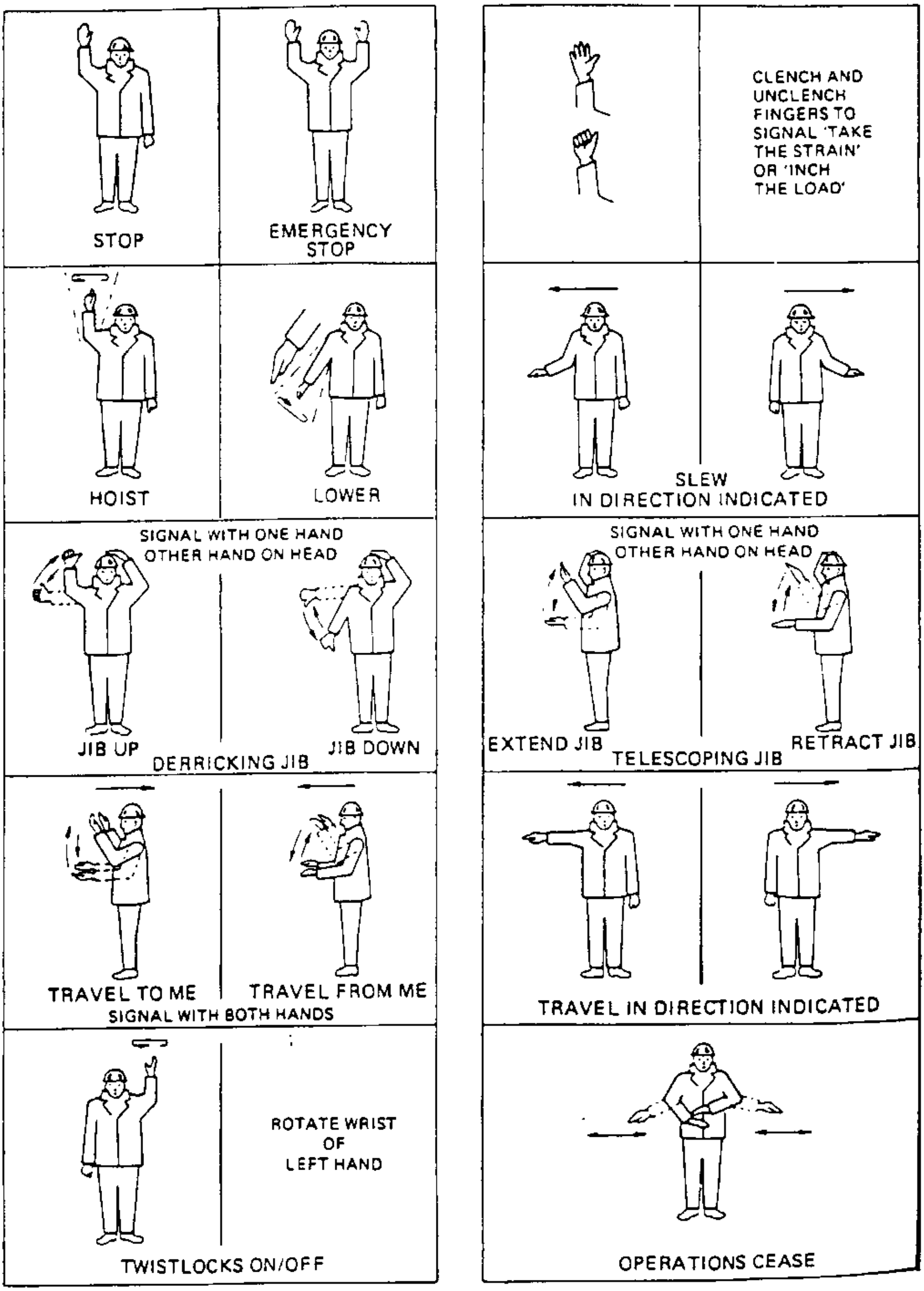


Figure 17.2

17.2 Fibre and Wire Ropes.

There are a variety of both man-made and natural fibre ropes and several different types of wire rope in use offshore on vessels and platforms. The intention here is to introduce the common types of both wire and fibre ropes, indicating the way they are constructed, their breaking strains and some uses.

17.2.1 Fibre Rope Construction.

All twisted or laid up ropes are manufactured in the same way. The selected fibres are combed into long ribbons which are then twisted into yarns. These yarns are then twisted into strands which in turn are laid up into the finished three or four strand rope. In order to achieve a good quality rope it is necessary to select and blend the fibres carefully to ensure uniformity. The spinning into yarns must be carefully controlled to achieve a uniform cross-sectional size, and with all the fibres twisted in at the correct tension and at the correct angle. Finally the laying up of the finished rope must also be at the correct tension and angle which is determined according to the intended application of the finished rope. Three strand ropes are referred to as plain lay and four strand as shroud lay, with the four strands commonly laid round a central heart. Both these types of rope are normally laid up right handed.

17.2.1.1 Variations

Both plaited and braided ropes are available but they are not so common as laid up ropes offshore. Their construction is the same as outlined above except that the final stage of laying up the rope is achieved differently. These ropes normally are put to special uses such as for mooring warps or anchor ropes and therefore the ROV pilot is less likely to come into contact with them.

17.2.2 Types and Properties of Ropes

Broadly speaking ropes may be divided into two categories; synthetic and natural fibre ropes. Outlined below are the main properties of these ropes.

17.2.2.1 Natural Fibre Ropes.

a. **Manila** - This is made from "abaca" fibre and may vary in colour from dark brown to ivory white. The rope is smooth, glossy, strong, flexible, very durable, easy to handle and has a very high resistance to sea water rotting.

b. **Sisal** - This is made from "aloe" leaves and is a creamy-white colour. The rope is very brittle, glossy, swells up when wet and it has a hairy surface. Top grade sisal is equal to medium grade manila but it is an unpleasant rope to handle due to its rough finish and is not used for preference in marine work if manila is available.

c. **Coir** - This is made from coconut fibre and is a reddish colour. The rope is very elastic, floats, is rough to handle and is extremely resistant to sea water rotting. It is about one sixth the strength and half the weight of manila.

d. **Hemp** - This is made from the fibre of the Hemp plant and is a dark brown in colour. It is mainly found in small sizes or as seizing twin in marine applications. It can be stronger than manila but its use is restricted.

17.2.2.2 Synthetic Fibre Ropes

a. **Polyamide (Nylon)** - This is the strongest synthetic fibre after Kevlar which is only available for special uses. The rope is very elastic, soft, pliable, easy to handle, will not rot in sea water and is pest resistant. It will absorb water however and will swell up if left for periods in the water. The rope dries quickly but should not be exposed to sunlight for long periods. Nylon is the du Pont trade name for polyamide.

b. **Polyester (Terylene)** - This rope is only a little less strong than nylon, for example 6 mm Nylon would have a breaking strain of 750 kg. while 6 mm Polyester would be 550 kg., and it has low stretch, with some grades being available pre-stretched. This rope has the same characteristics as Nylon except that it will not absorb water. Terylene is the ICI trade name for polyester.

c. **Polypropylene** - This rope has almost the same strength as polyester. In common with Nylon it will stretch, in fact 40% before parting, and it will absorb water but only 0.1% of its weight. This rope floats and it will melt at 165^0 C. It is very common offshore.

d. **Polythene (Courlene)** - This rope is much less strong than polyester, for example its breaking strain for 6 mm would be 375 kg. This rope has low stretch, it floats, it will not absorb water, it is resistant to sunlight, it is usually orange in colour and has a waxy, slippery feel to it. It is cheap and is widely available. Courlene is the manufacturer's trade name.

17.2.3 Use and Care of Ropes

The Common causes of failure are: excessive stress; this damages the fibres, abrasion; or cutting ;on a sharp object; exposure to chemicals and bad storage with inadequate ventilation, particularly of wet ropes. Rotting often commences on the inside of a rope and is difficult to detect unless the lay is opened. Loose fibres or dust on the inside indicates dry rot. If the interior is darker than the outside, this is a sign of dampness while a grey powdery substance indicates mildew and poor ventilation. Ropes should be stored away when dry, on gratings or hung on wooden or galvanised hooks. The storeroom should be well ventilated and dry, away from moist air. Artificially dried ropes will become brittle, as most fibre ropes are spun with a small amount of lubricant introduced at the time of manufacture to reduce internal friction and increase rope life. If left on deck, ropes should be protected from sunlight, rain and frost (as the ice particles cut through the frozen rope). Ropes should also be kept away from all chemicals, such as cleaning materials, paint thinners, etc. After use in salt water, ropes should ideally be hosed down with fresh water. Knots and kinks should be avoided as much as possible. When coiling rope, as most ropes are laid up right-handed , they should be coiled right handed i.e. clockwise. When heaving on a rope, ensure that it does not chafe when passing through fair leads or over the rough edge of a dock wall ashore. Sharp edges must also be avoided. Mooring lines (warps) may have short lengths of plastic hose tied onto them to reduce chafe. When a rope passes around a sheave, the sheave diameter should be nine to twelve times the rope diameter.
When using winches with ropes, ensure that a laid rope is put onto the winch in the same direction that it should be coiled down. The lead onto the winch must be such that the turns on the drum do not ride over the following turns. See Figure 17.3

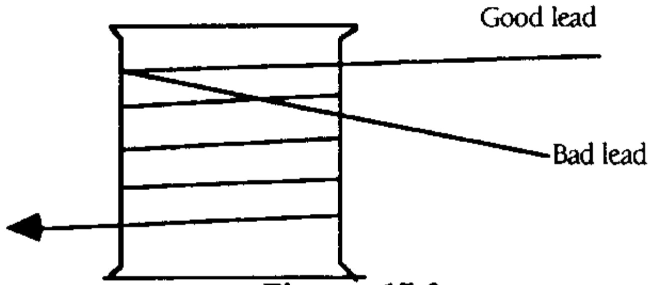


Figure 17.3
Leading a Rope
Onto a Winch

17.2.4 Wire Ropes

Wire ropes are used extensively for all type of standing and running rigging, crane wires, winch wires and strops. In any offshore application where ROV's are being deployed wire ropes in one form or another will be used.

17.2.4.1 Selection

When selecting a wire rope four main factors should be considered:

a. What job is it to be used for?
   - i) If the wire is required for standing rigging it will be less flexible for example, than if it is to be used for running rigging.

b. What safe working load is required?
   - i) This will effect either the diameter or the material properties of the rope. If it is required that the diameter of the rope be a particular size, for example, it may be necessary to select a high tensile type of wire rope.

c. Will the job require specialist properties form the wire?
   - i) A Tirfor wire needs to be wire core instead of hemp core for example.

d. Will it have adequate resistance to the corrosive factors present in the environment?
   - i) Standing rigging is often galvanised to provide some corrosion protection because of the aggressive environment it has to withstand.

17.2.4.2 Construction

All specialist handling qualities a rope possesses are introduced into the rope in the manufacturing stage. Therefore, it is important that we know how a rope is formed as the material properties are selected to match the method of lay. There are three basic forms:
Ordinary Lay;
Lang's Lay;
Preformed.

a. **Ordinary Lay** - A rope of ordinary lay has its strands laid up together right handed, in the opposite direction of their constituent wires, which are laid up left handed to form a strand. See Figure 17.4

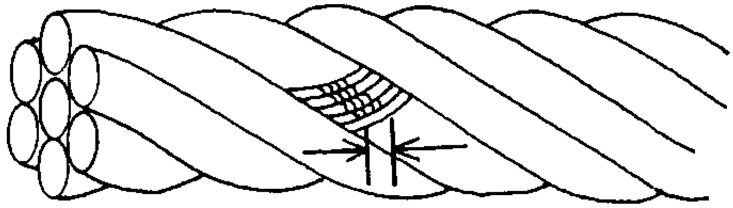


Figure 17.4

b.. **Lang's Lay** - A rope of Lang's lay has its strands laid up together in the same direction as their constituent wires are twisted. This means that care is required when handling Lang's Lay as it tends to unlay itself. See Figure 17.5

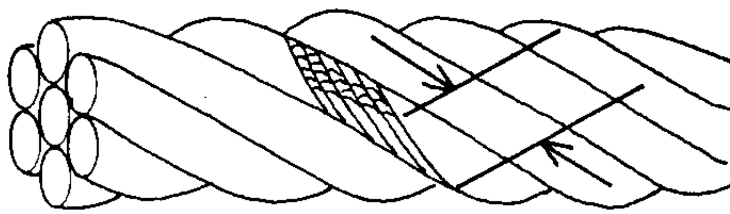


Figure 17.5

c. **Preformed rope** - This is a modern development in the manufacture of wire rope. The manufacturers form individual strands into spirals before the strands are laid into the rope. This is known as preforming and results in each strand laying in its correct position in a completed rope without a tendency to spring out should the rope break of be cut. Preformed ropes are safer to handle.

17.2.4.3 Specialist Qualities

Three factors which determine a rope's specialist qualities are:

a. The type of core that is used in the wire rope;
b. The size and number of individual wires used to form a strand;
c. The number of strands used to form the wire rope.

a. **Cores** - The type of core used in a wire rope plays a part in the wire's flexibility, rigidity and resistance to crushing.

i) Flexible Steel Wire Rope(FSWR) and Extra Special Flexible Steel Wire Rope (ESFSWR) generally have a core of manmade fibre, occasionally natural, which is impregnated with a lubricant to reduce corrosion. ESFSWR is generally stronger than FSWR, as it is made of better quality steel.

ii) Steel Wire Rope (SWR) frequently has a steel core and contains fewer wires in each strand than flexible ropes. It is generally used when strength is a greater need than flexibility.

b. Wires. Steel wires are often described as being of , for example, "6 x 37" construction. This description means that the wire consists of 6 strands, each comprising 37 wires. There is a wide variety to choose from, as an illustration:

i) 6 x 24 Galvanised. Figure 17.6 illustrates a Round Strand Rope, right hand lay, which is 6 x 24 laid over a fibre core. This type of rope would commonly be used for topping rope and cargo runners. The majority of wire ropes have six strands which form the rope. There are, however, multi-stranded ropes, used for their non-rotational properties and as many as 16 strands may be used to form a rope.

6 x 24 Galvanized

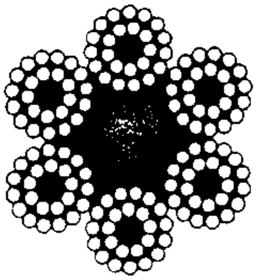


Figure 17.6

ii) 12 x 6 over 3 x 24. Figure 17.7 shows diagrammaticly a Multi-strand, right hand Lang's lay rope which is 12 x 6 laid over a 3 x 24 core. This type of rope would commonly be used for, cargo purchases on derrick cranes, and deck cranes where non-rotating properties are desirable.

12 x 6 over 3 x 24

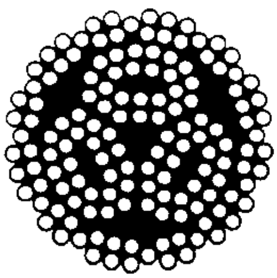


Figure 17.7

17.2.2.4 Handling

Wire ropes should always be treated with the utmost respect. The following points should be noted:

a. Never handle wire ropes when wearing rings on the fingers.

b. Never keep a wire rope turned up around a bollard for a long period, especially if you have a pull of 50% or more of the breaking strain of the rope. This will deform the rope.

c. A wire rope which is under a load near to the limit of its breaking strain will emit a high pitched whining note, it may vibrate and it may show signs of oil being squeezed out between the wires. A rope in this state in under extreme

17.3 Safe Rigging Practise

Rope manufacturers will provide information on the safe working loads for their products and tables are available which can be consulted. For general use, however, laid out below as Figure 17.9, are the recommended safe loads which can be used with fibre rope, FSWR, stud and open link chain. These formulas can be used in normal working conditions.

METRIC FORMULAE FOR BREAKING STRESSES OF NATURAL AND SYNTHETIC FIBRE ROPE, STEEL WIRE ROPE AND CHAIN

		MATERIAL	FACTOR (Breaking Strain)
FIBRE ROPE 3 strand hawser laid			
	Grade 1 manilla	(7mm to 144mm)	$2D^2/300$
	High grade manilla	(7mm to 144mm)	
	Polythene	(4mm to 72mm)	$3D^2/300$
	Polypropylene	(7mm to 80mm)	
	Polyester (Terylene)	4mm to 96mm)	$4D^2/300$
	Polyamide (Nylon)	(4mm to 96mm)	$5D^2/300$
FLEXIBLE STEEL WIRE ROPE			
	6 x 12	(4mm to 48mm)	$15d^2/500$
	6 x 24	(8mm to 56mm)	$20D^2/500$
	6 x 37	(8mm to 56mm)	$21D^2/500$
STUD LINK CHAIN			
	GRADE 1	(12.5mm to 120mm)	$20D^2/600$
	GRADE 2	(12.5mm to 120mm)	$30D^2/600$
	GRADE 3	(12.5mm to 120mm)	$43D^2/600$
OPEN LINK CHAIN			
	GRADE 1	(12.5mm to 50mm)	$20D^2/600$
	GRADE 2	(12.5mm to 50mm)	$30D^2/600$

$$SWL = \frac{\text{Breaking Strain}}{6}$$

The diameter D is expressed in millimetres, the breaking stress in tonnes.

Figure 17.9

17.3.1 Shackles

Shackle sizes and types vary ranging from about 25 mm in length to over 1 m. They do have one thing in common for offshore use; all are tested and stamped with their safe working load (SWL). It is also common practise in the North Sea , as has been stated previously, for all lifting equipment, including shackles, to be colour coded to indicate that it is in date for test..

17.3.1.1 Safe Use of Shackles

In any situation where a shackle is employed as part of the rigging only tested shackles should be used. This will eliminate any risk of failure of the rigging and thus ensure safety of personnel. Whenever shackles are being used they must be moused to prevent them becoming accidentally un-fastened. Figure 17.10 Shows diagrammaticly how this is done.

stress and the loading should be eased at once but in a controlled way, **not** suddenly.

c. Always inspect before use. Look for distortion of strands, as this is a result of kinking, crushing or serious crippling. Broken wires are a result of fatigue and wear. A rope with a good external appearance but with a dry powdery heart should be discarded.

d. The diameter of any sheave over which the rope will pass must be correct. The smaller the sheave, the greater the friction and the smaller the bend radius. The smaller the bend radius the greater the stress concentration factor. See Chapter 4 paragraph 4.3. The greater friction is caused because the strands and wires furthest from the centre of curvature move apart whilst those nearest move closer together. This results in friction between the wires and strands and the smaller the sheave the greater this friction will be. Generally the diameter of the sheave should be at least 6 times the circumference of the rope.

e. Coiling. Long lengths of wire rope should be stowed on reels. Wire rope is less able to absorb turns than fibre rope, so when coiling down it is sometimes necessary to use left handed loops called "Frenchmen". Frenchmen serve to counteract any twists caused by coiling down right handed. See Figure 17.8

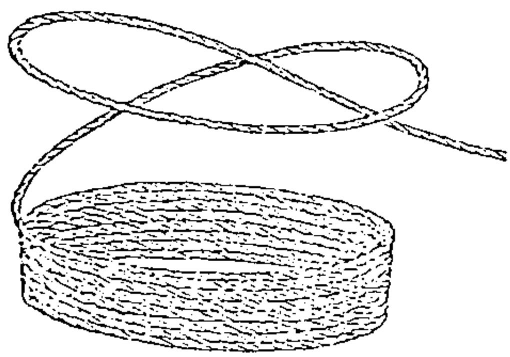


Figure 17.8

f. Opening a coil. A coil of wire must not be opened up in the same manner as a coil of rope or a multitude of "kinks" will be the result. Instead, it should be unrolled in the opposite way to which it was made up. Small coils can be rolled along the deck in the same manner as a hose is unrolled, but larger ones require a turntable. No special turntable is kept for the purpose, so one has always to be improvised. This is best done with two substantial pieces of wood lashed together to form a cross. Two bridles are attached by making an end fast on each leg of the cross, about midway between the centre and the ends, and the bights must be long enough to reach through the centre of the coil when it is laid on the wooden cross. The bridle is then suspended from a suitable position, or a small crane if one can be dedicated for this purpose. The wire can then be uncoiled and it will revolve freely if the crane hook or method of suspension is fitted with a swivel. Otherwise the coil must be landed occasionally to take out any turns put into the suspension device.

g. Cutting. Before cutting whipping or strong tape must be put onto the wire either side of the cut, otherwise, once cut, the strands may fly apart and spoil the rope for some considerable distance. A few sharp blows with the edge of the hammer in the space between the whippings (about 25 mm) will flatten the surface, so that the sharp cold chisel will cut more evenly. Cutting must be done on a good, solid foundation, so that a clean cut is achieved.

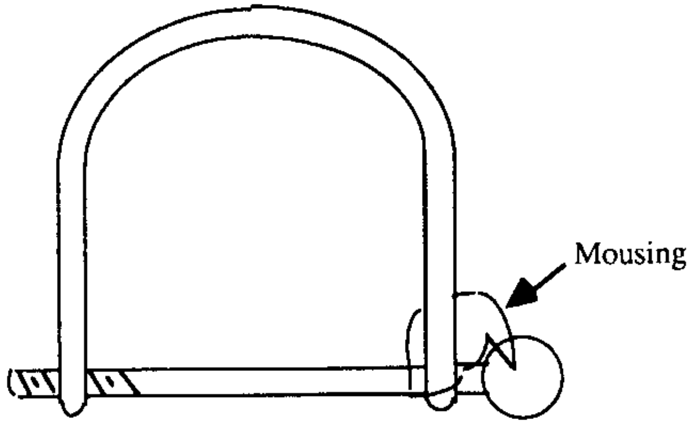


Figure 17. 10
Moused Shackle

17.3.2 Lifting Strops

Similarly whenever lifting strops are employed they must never be doubled over and the recommended method requires the lifting hook to be placed centrally with the strop forming an angle of 120^0 where it hangs over the hook. Figure 17.11 illustrates this.

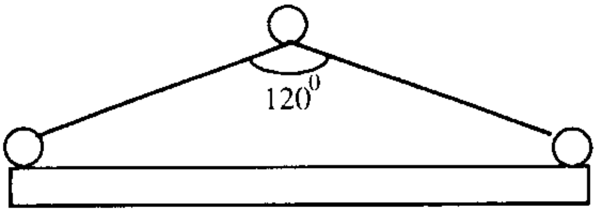


Figure 17.11
Safe Use of a Lifting Strop

17.4 Knots, Bends and Hitches and Their Uses

In the normal course of work around an ROV spread it is probable that you will frequently need to secure objects in place and the most likely way of doing this is by using rope or some form of cordage. If the term "knot" is then accepted as the general work for a fastening made with cordage, some more precise definitions follow:

a. The standing part. Is the main part of the rope above a loop or bight. It is the part opposed to the *end.*
b. The end. Is the end or unsecured part of the rope.
c. A bight. Is a half or open circle in a rope and also refers to the middle part of a length of rope.
d. A loop. Is a closed circle in a rope.
e. A knot. In the precise meaning of the term , is any knot other than a bend or a hitch. The best known knots are "stopping" knots, such as Figure of Eight knot, which is used to prevent the rope running out through a cleat or fairlead.
f A bend .Is the knot used for tying one rope to another.
g. A hitch. Is used for fastening a rope to another object, such as a sp tent peg. See the following diagrams. Figure 17.12 to 17.25.

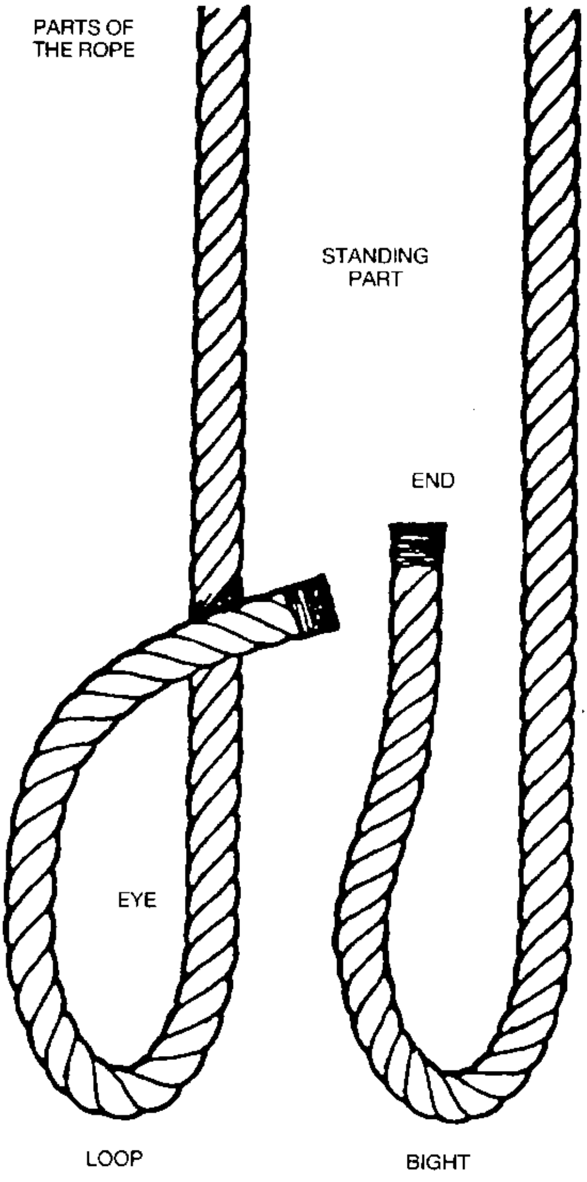
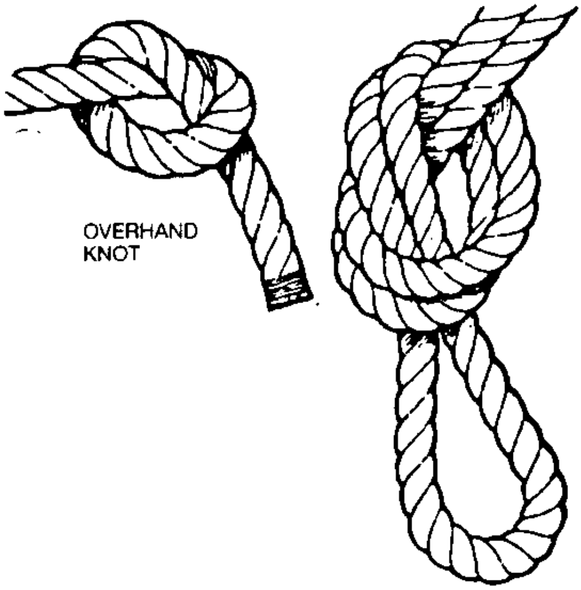
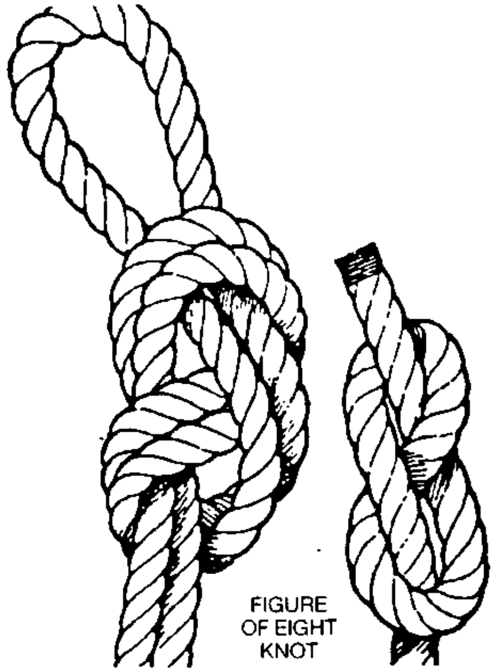


Figure 17.12



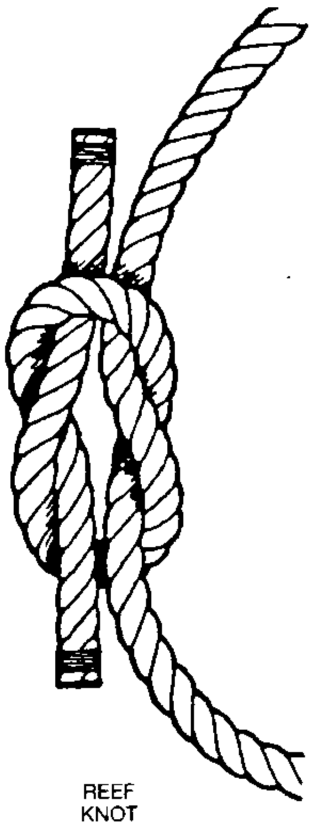
Stopping tail end of rope running through a sheave of a block

Figure 17.13



Used on tail ends of sheets, to stop ends running through clews or sheaves of blocks.

Figure 17.14



General purpose knot for joining two of equal sized ropes together.

Figure 17.15

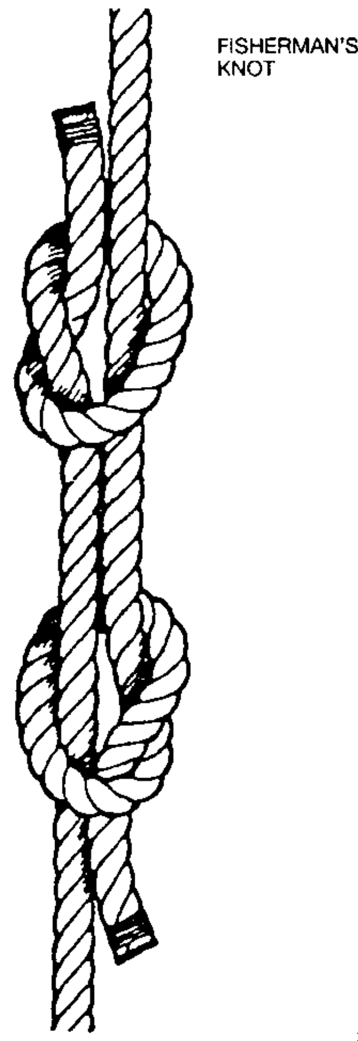
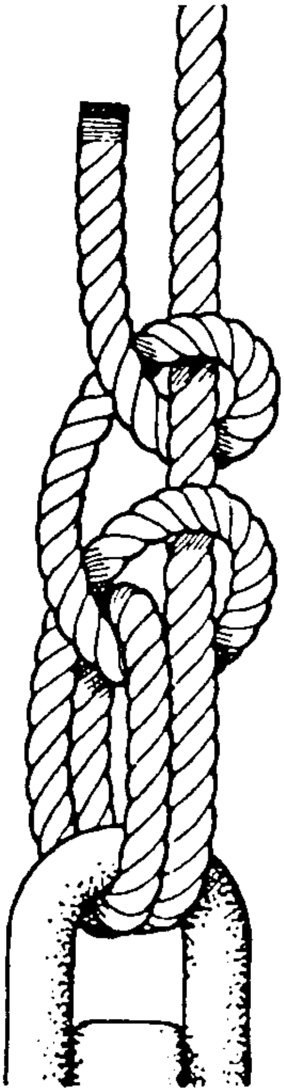


Figure 17.16



To secure boats painter to buoy ring

Figure 17.17

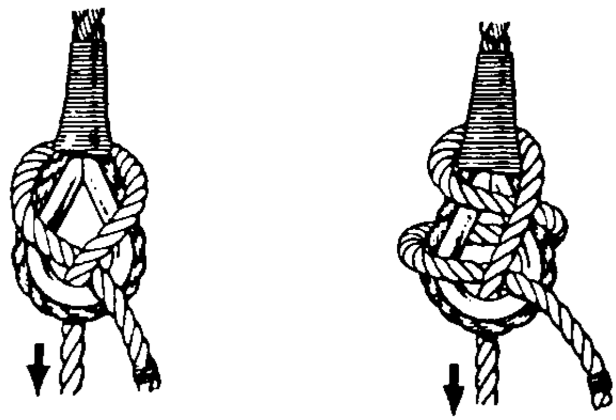
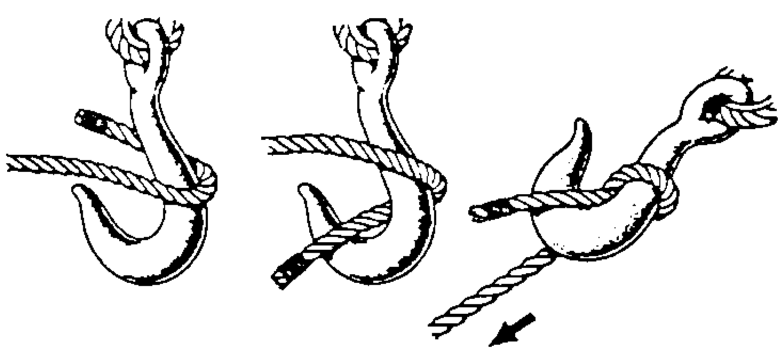


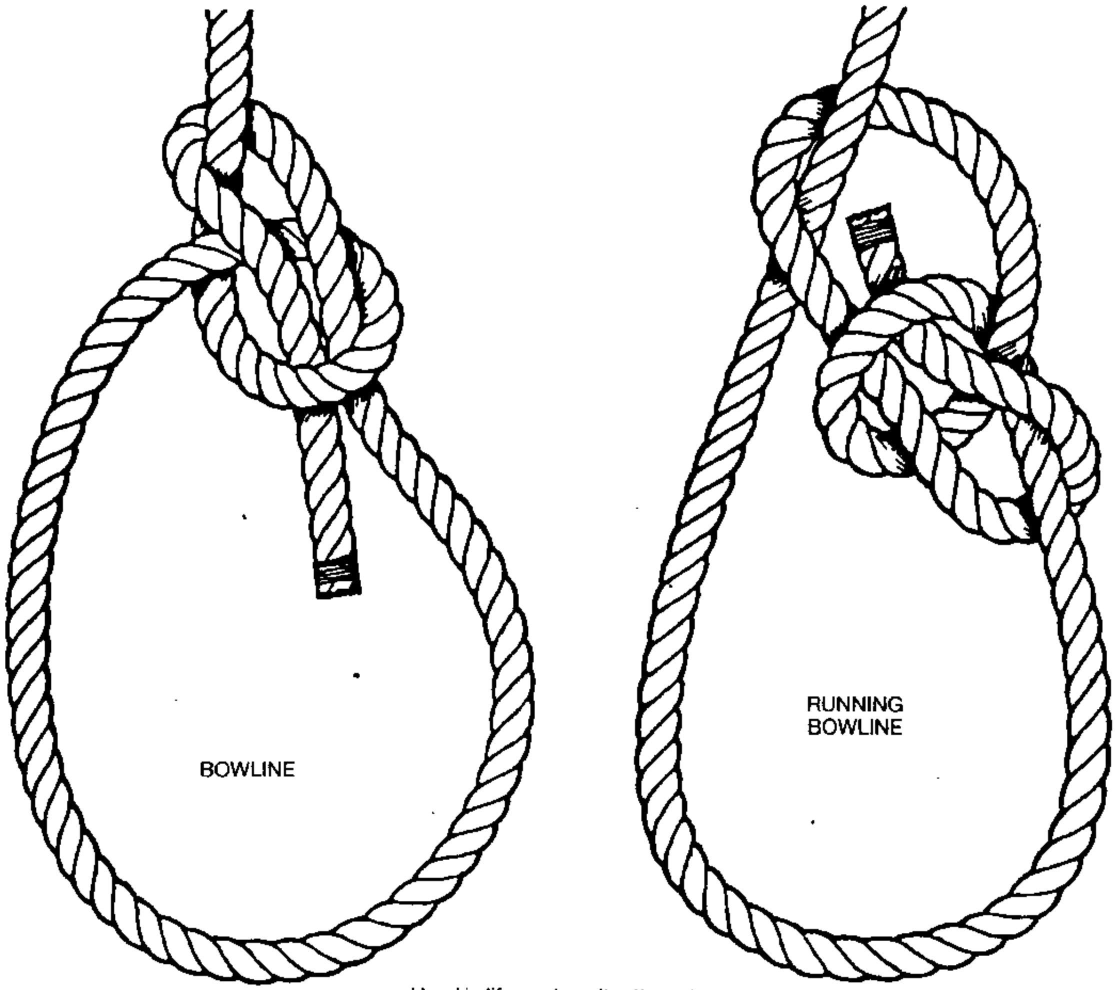
Figure 17.18



Blackwall hitch

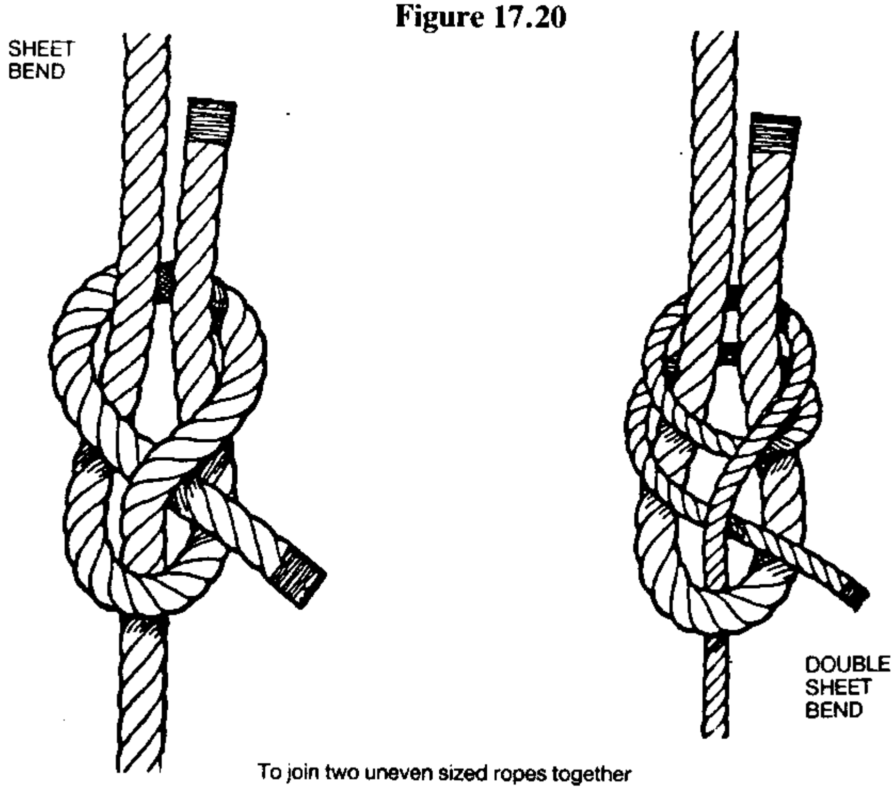
To secure lifting pennant to lifting hook

Figure 17.19



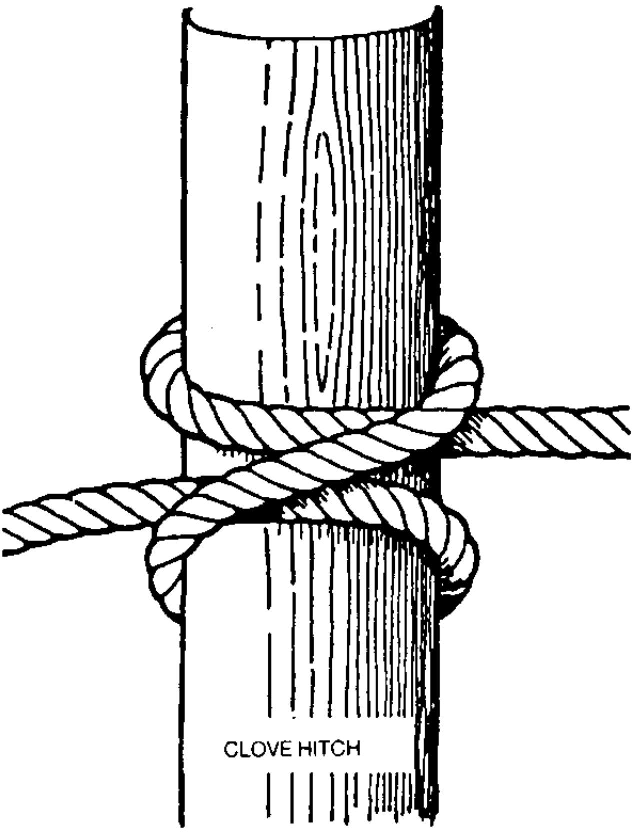
Used in life-saving situations, i.e. securing a lifeline to a diver, or man working from heights

Figure 17.20



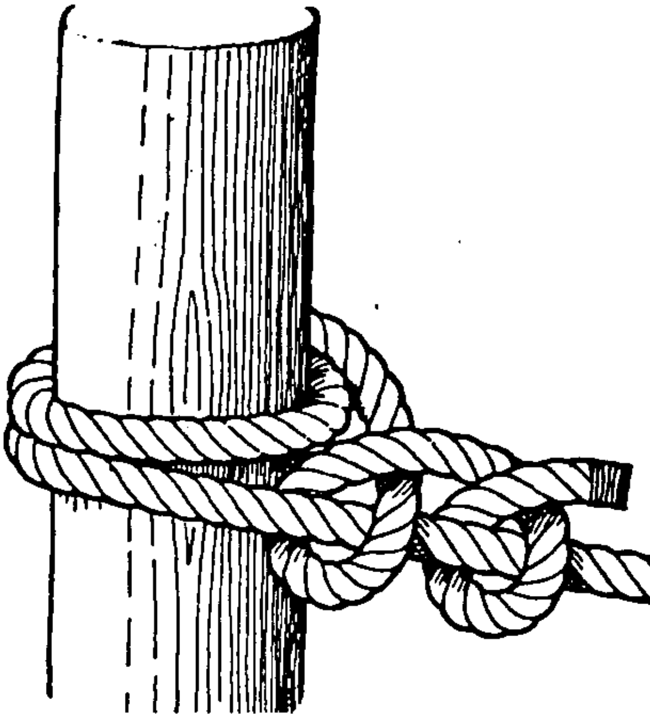
To join two uneven sized ropes together

Figure 17.21



General purpose hitch. Can be used for securing boats painter to mooring ring for short durations.

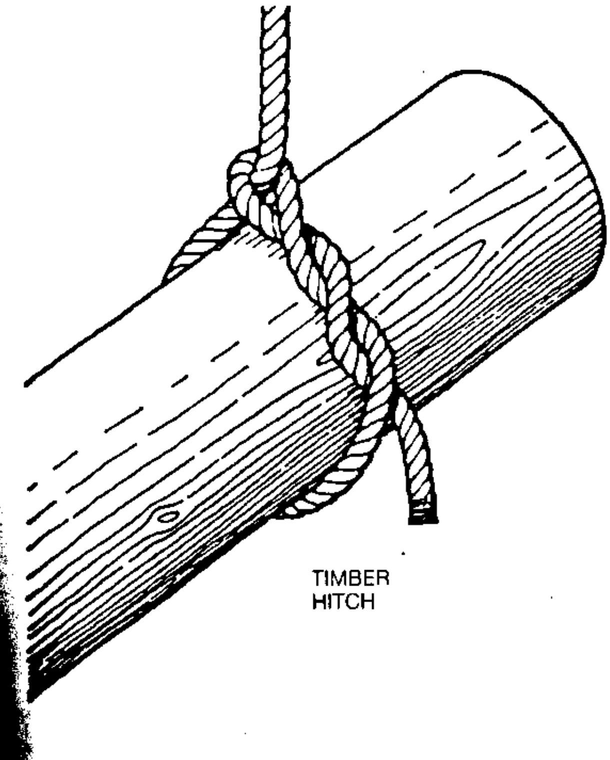
Figure 17.22



ROUND TURN AND TWO HALF HITCHES

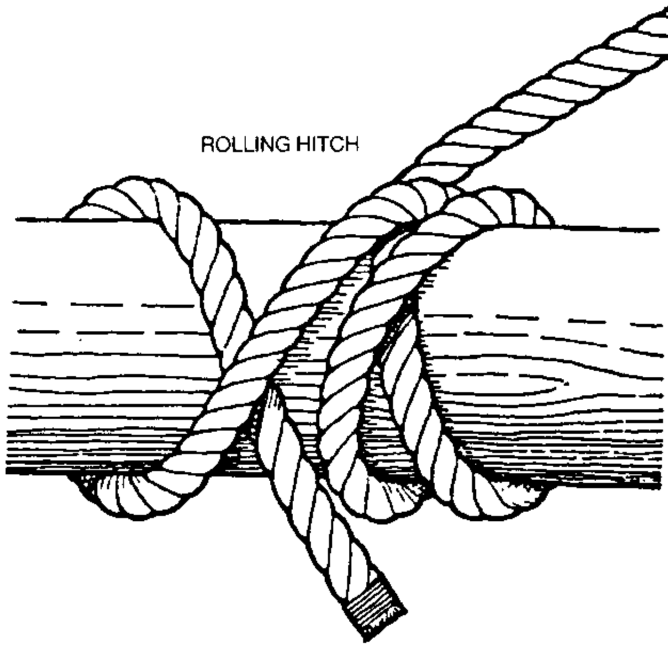
General purpose hitch for securing lifelines to anchor points on barge or harbour wall. Boats painters to bollard or mooring points on jetties.

Figure 17.23



To lift pilings, timber or any round cylindrical objects.

Figure 17.24



Lifting slippery, shiny cylinders, scaffold poles, etc.

Figure 17.25

17.5 Blocks

This item of rigging is in common use in many different types of lifting equipment such as cranes, launching systems, winches etc. Because it is in such widespread use the various parts which go to making up a common block are shown in Figure 17.26

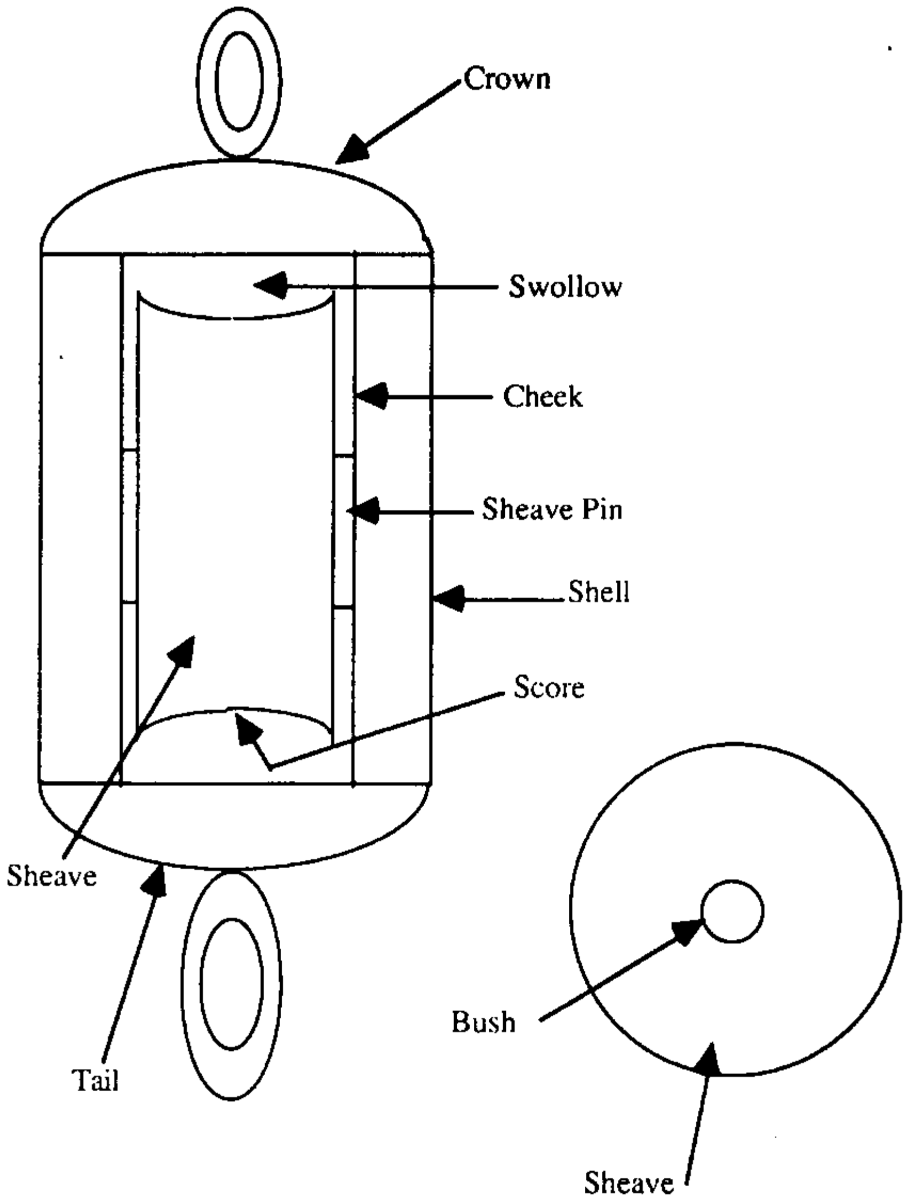


Figure 17.26
Parts of a Block

17.5.1 Types of Block

Blocks are put to many uses and there are specialised types available, obviously for special purposes. Two types which may well be included in ROV deployment systems are snatch blocks and lead blocks.
Snatch blocks have one cheek hinged and held in place by a locking pin. They can therefore be inserted into a working line and this is their purpose.

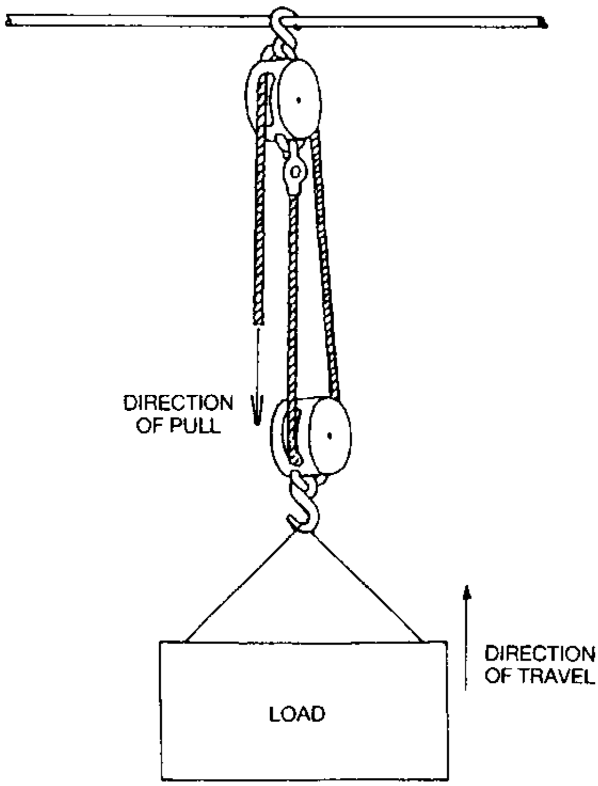
Once in place they can then be employed to change the direction of pull on the load and thus become Lead blocks. Common blocks are frequently used for this purpose when the rigging is first being set up and they can be threaded onto the falls or working line.

17.6 Tackles

A brief introduction to tackles will illustrate the method employed by all cranes and similar lifting devices. A tackle is a simple device which gives increased power by a combination of blocks and ropes. The number of sheaves in the block, the manner in which the rope of fall is rove through them, and whether or not the standing part is made fast to the top or bottom block are all distinguishing features of the various types of tackle. The theoretical power gained is proportionate with the number of sheaves in the tackle and typically varies from two to nine times according to the type of tackle used.

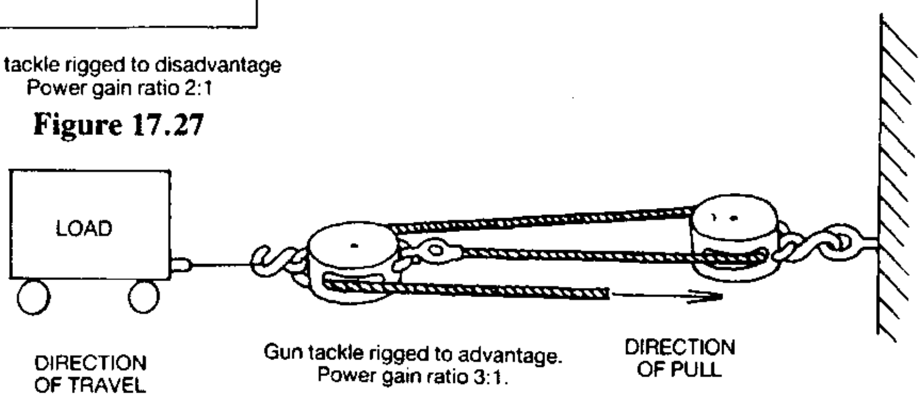
17.6.1 Gun Tackle

The name for this simple tackle is derived from the fact that these tackles were used to run out the guns on sailing men o' war. It simply illustrates the principle involved in using purchases to increase lifting power which is why it is illustrated here. The theoretical power gain is two or three depending on whether it is rigged to advantage or disadvantage. See Figures 17.27 and 17.28.



Gun tackle rigged to disadvantage
Power gain ratio 2:1

Figure 17.27



Gun tackle rigged to advantage.
Power gain ratio 3:1.

Figure 17.28

Figure 17.29

Figure 17.30

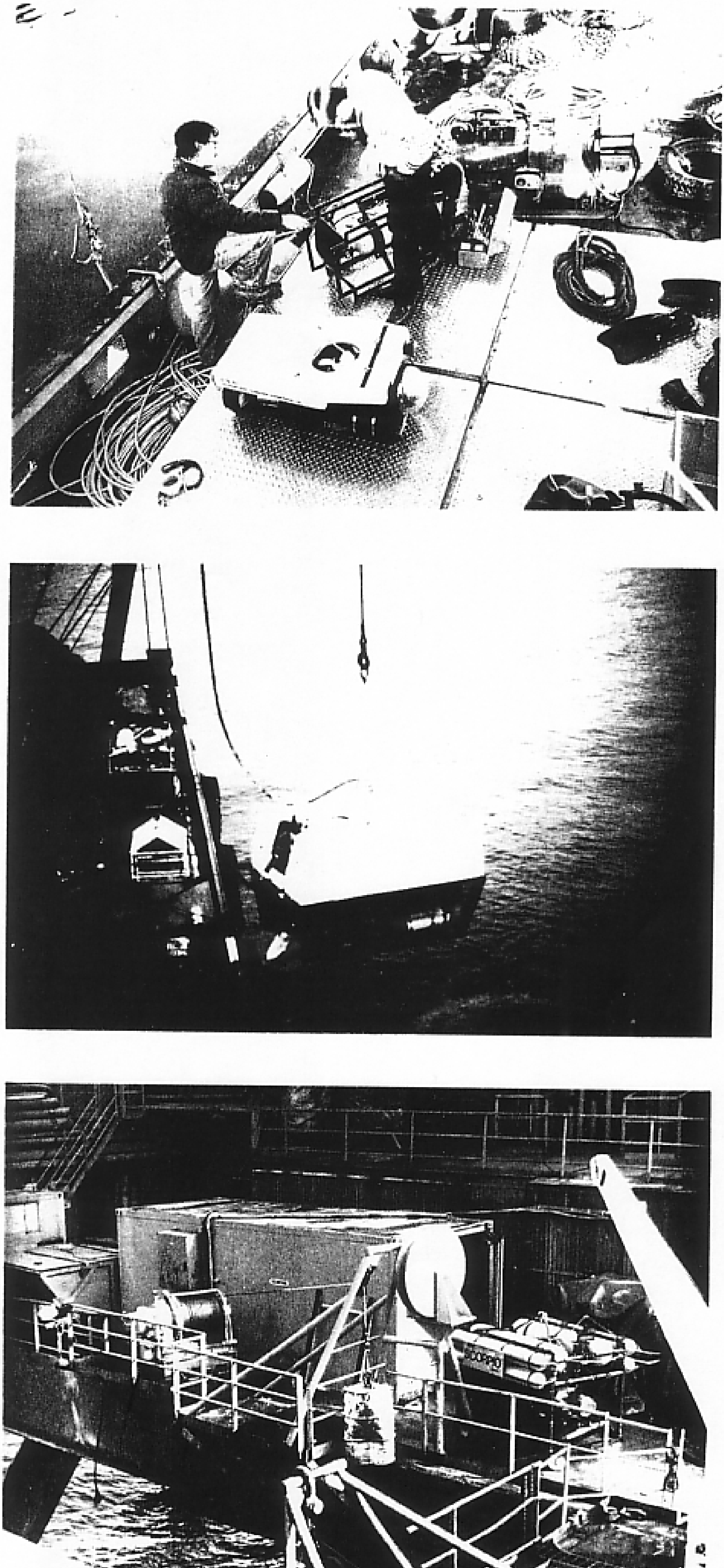


Figure 17.31

17.7 ROV Deployment Systems

ROV's can be operated from the following:

a Monohull vessels;
b. Semi-submersible vessels;
c. Fixed platforms.

ROVs are launched either over the side or through a moonpool and may be deployed with or without a cage or garage. There are several handling strategies but four examples will adequately illustrate the possibilities and these are outlined below. Whatever the method, however, it will require the use of either a crane or a winch to control the vehicle. See Figure 17.29 and 17.30. If a winch is used it will commonly employ an A frame to suspend the ROV clear of the deck and move it inboard and outboard. The crane has the advantage of being able to cover a larger area on the deck and is more flexible. The A frame is more rigid and there are fewer controls which makes operating easier. Both cranes and winches must be designed within the requirements of an approved classification society, such as: American Bureau of Shipping; Lloyds Register of Shipping or Det Norske Veritas. Winches are very widely used and are most often controlled directly by the ROV team as opposed to cranes which most often have a dedicated operator. Some specific points on winches therefore will not go amiss.

17.7.1 Winches

Of the numerous factors considered when designing or choosing a winch the most obvious is the line pull required. This is determined by the weight to be recovered and will not be more than the breaking strain of the cable, taking account of the appropriate safety factor. Another factor is the drum diameter which will be determined by the minimum bending radius of the wire. The number of wraps to be stored on the drum will also be considered. This will be determined by the length of the umbilical to be used and the cable diameter, this in turn will determine the drum flange diameter. It is best to use a winch with a level wind to ensure the umbilical is evenly spooled. If this is not possible a good fleet angle is required which is not always possible when deck space is at a premium. Another important factor is the braking method. Two methods are common. Manual braking is used during normal operations and an automatic brake will be applied in an emergency situation, such as a rapid drop in oil pressure.

17.7.2 Pick-up Hook Recovery

In this case the umbilical used is medium and lightweight and may be winch or hand tended. When this approach is used simple cranes are employed, often on an opportunity basis. This method of launch and recovery is generally employed when live boating. See Figure 17.31

17.7.3 Specialist Latching

A specialist "grabit" or "go-getter" is run down the umbilical and latches a pick-up device to the top of the vehicle. The vehicle is then recovered using a dedicated crane. This method is generally used without a cage and in a live boat situation.

17.7.4 Umbilical Launch and Recovery

This method is occasionally used with large vehicles which have sufficient power to manoeuvre with the armoured cable that is necessary to take the weight of the vehicle during the launch and recovery. Once more this method is mainly used when live boating and without a cage.

17.7.5 Cage and Winch Deployment

A cage containing the vehicle is lowered from a dedicated winch using an 'A' frame. The actual cage may be a garage arrangement where the vehicle is parked into it or it may be a "top hat" arrangement where the vehicle is latched under the cage. Whatever type of cage is employed it will contain the following major elements:-

The framework
Spooling drum
Slip rings
Power source

Additionally some cages are fitted with a depth gauge and a TV camera. This enables the ROVs position relative to the cage to be assessed. The umbilical from the surface winch to the cage is armoured and heavy duty to take the stresses and strains of the launch and recovery and the vehicle umbilical is lighter. This vehicle umbilical may be neutrally buoyant in sea water. This neutral buoyancy is unlikely to last however as any small cut in the cable outer will allow sea water to enter and the neutral buoyancy is dependEnt on the specific gravity of the water anyway. The cage method of launch and recovery provides several advantages compared to other methods. These include:-

Vehicle protection during launch and recovery
Isolation of umbilical drag from the vehicle
A method of carrying tools down to the worksite
A means of keeping the main umbilical clear of obstructions

The cage and ROV should be protected by fendering to absorb the strains imposed by the odd knock which is inevitable in normal operations. These knocks can be minimised by careful handling paying particular attention to minimising swinging motions. See Fig 17.32.

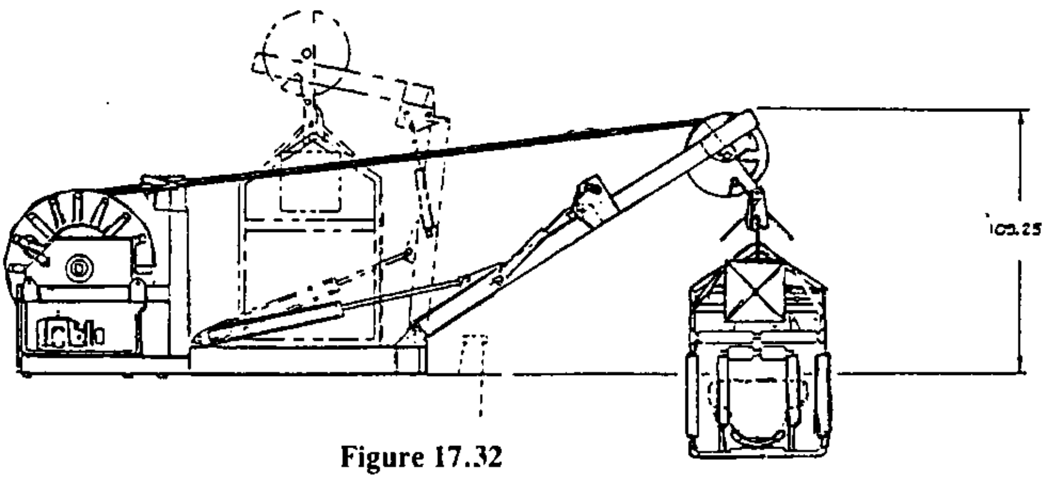


Figure 17.32

Figure 17.32 illustrates a typical tether management system.

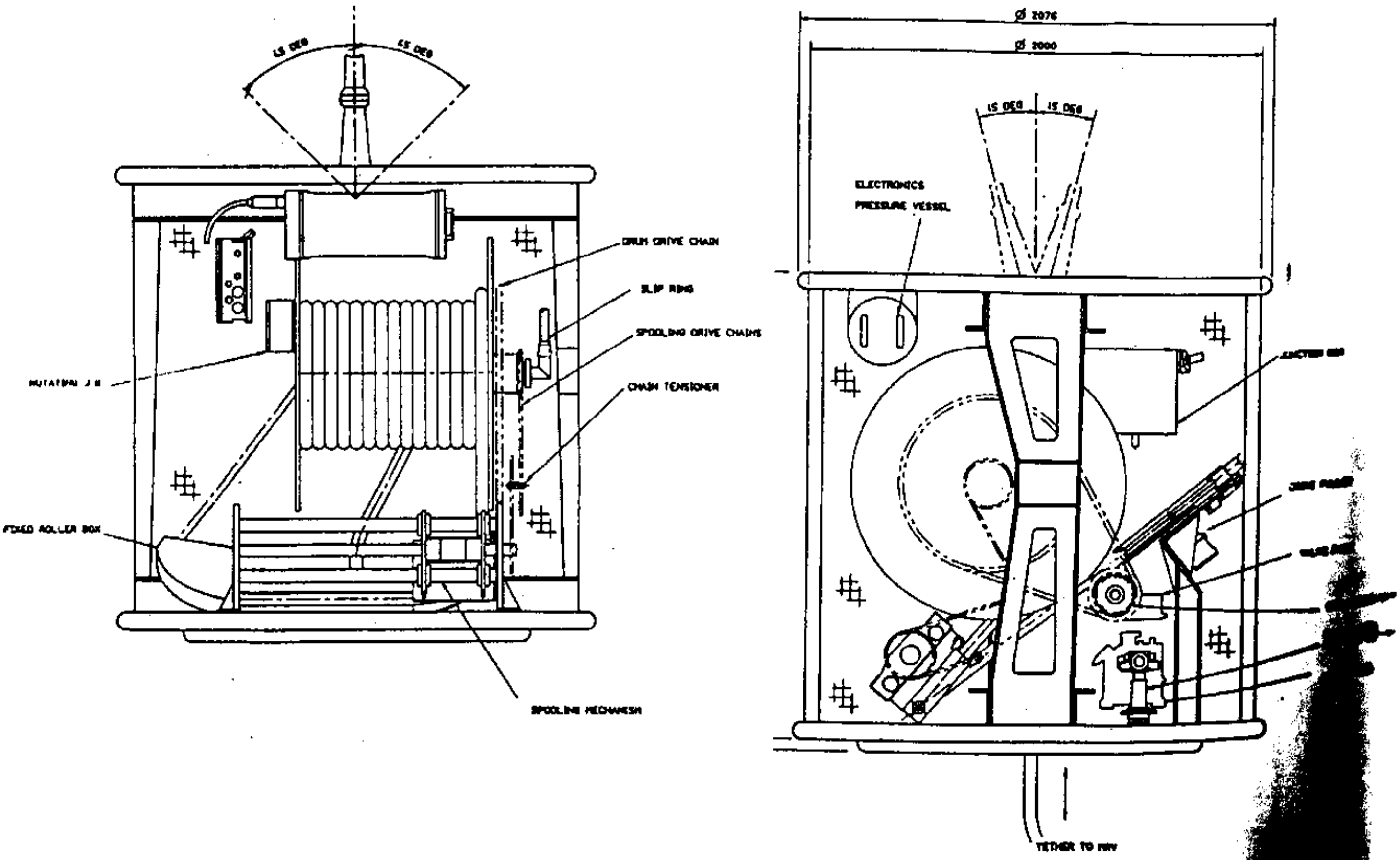


Figure 17.33

Another method of ROV deployment is the tether management system (TMS). In this case the ROV is latched to the bottom of the unit during launch and recovery. The TMS and ROV are lowered to the worksite on a armoured lifting umbilical. Once in position the latches are opened and the ROV can be flown to the worksite. When flying the ROV it is important to co-ordinate the paying out of the tether with the speed of the ROV. There is a danger that the tether may snatch if payed out too slowly leading to damage of the internal conductors. If too much tether is payed out it can lead too excess drag and eventually limit the manoeuvrability of the vehicle, for this reason the system will have an umbilical turns counter fitted.
A system of rollers ensures tension is maintained on the tether in order to prevent it becoming fouled on the drum. A guiding on mechanism also ensures the tether is correctly spooled on to the drum.
The whole system is hydraulically powered and synchronisation is achieved by spooling drive chains.
Typical maintenance tasks are as follows:

a) Checking hydraulic oil levels by observing the compensators

b) Adjusting or replacing the drive chains

c) Testing the latching mechanism

d) Checking the guiding on mechanism especially the diamond wheel for ware and if necessary replacing the pawl

e) Testing the lift umbilical according to the guidelines referedto in chapter 2

17.7.6 Motion Compensation

Occasionally motion compensation is required for the system. One technique used in live boating is to attach floats to the umbilical; this essentially decouples the vehicle from the surface forces. Active and passive winch compensation is also available but these methods are complex and involve the use of: high response drive systems; counter weights or accumulators. A different approach has been used which involves the aeration of the moonpool. This permits the safe launch and recovery of the vehicle up to force 5/6.

17.7.7 Launch Hazards

If motion compensation is not used the homing and docking of the ROV with the launcher can be both difficult and hazardous. Small ROVs, up to 500 kg, normally respond adequately to a little application of appropriate shock absorption and brute force. Where ROVs are being deployed without cages they are normally connected to the handling arrangement at the surface and hazardously close to the vessel. Abrupt, dynamic loading to the hoisting system often occurs when lifting the vehicle clear of the water in these cases. If motion compensation is not used this calls for careful timing and a good deal of experience on the part of the winch or crane operator.

17.7.8 Power Requirements

Normally this is 440 volts 3 phase and most often the power train on the winch is electro-hydraulic which allows for good speed control. The size of the power supply is dictated by the line speed and pull. This is established by distance per unit time multiplied by force (the units of power). The number of wraps of cable around the drum must be taken into consideration as this affects the torque required and starting currents, which are higher than working current, must also be considered.

17.7.9 Locating the Launch Site

A centrally located site on the vessel places the ROV near to the pitch and roll centre and maximises safety and efficiency during launch and recovery. A central location will also provide shelter from the elements which is of benefit during maintenance periods. If a false deck can be provided it will allow access under the deployment system and it will help to isolate the system from sea water. It will also give access for cables and hydraulic lines. Finally if a winch is being used in conjunction with a crane of opportunity it may be necessary to use lead blocks to ensure a correct lead is maintained.

17.7.10 Operating in Tide or Weather

Unless an ROV weighs several hundred kilos with power to match it is not expected to operate on the surface or in the splash zone in any adverse weather conditions. The first point about operating in these conditions then, is to get below the surface as quickly as possible. The second point is that the effects of current will be more noticeable on the umbilical than on the vehicle itself. As a guide "eyeball" ROV's will generally operate in 1.5 knots of tide or current but, because of the current effects, it is prudent to pay particular attention to the reduction of drag on the umbilical. This is where the garage method of launch and recovery is such an asset and why it has become so favoured.

17.8 Navigational

The nature of the work undertaken by ROVs is such that an understanding of some aspects of navigation are an asset. Being able to follow a compass course, for example ,is a skill that is required of any ROV pilot. Similarly the ability to be able to interpret information available on charts is a helpful technique to have when planning a dive in a new location.

17.8.1 Compasses

Traditionally compass cards were marked in points (one point is 114 $^{\circ}$) but now they are marked in degrees. It is often adequate when steering an ROV to go by the compass points and for this reason the compass rose is reproduced as Figure 17.33. If it is necessary to steer a more accurate course it is conventional practise to use 3 digits to indicate the bearing, as in 180° or 030°.

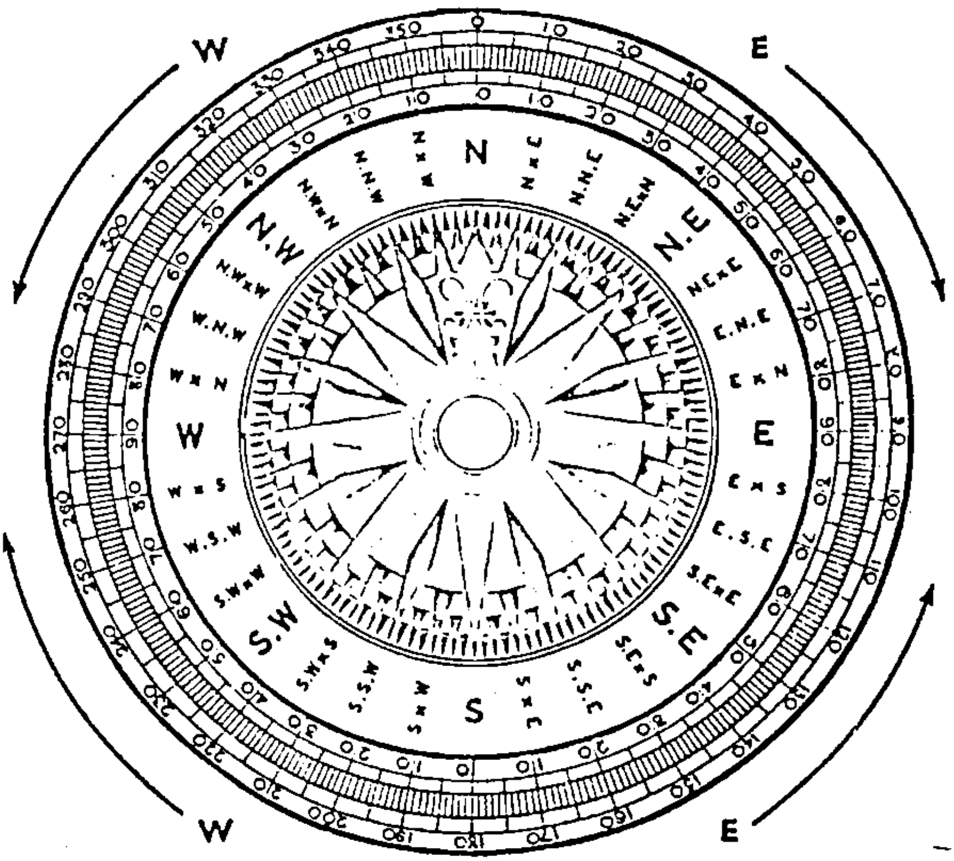


Figure 17.33

17.8.2 Magnetic Compass

The magnetic compass responds to the earth's magnetic field by way of a magnetic needle, which is freely suspected, aligning itself North South. On the bowl of the compass is a "Lubber Line" and connected to the magnetic needle is a compass card. The compass is suspended in gimbals so that movements of the ROV do not interfere with the swinging of the needle. As the ROV then changes direction, the compass bowl moves with the vehicle, while the card is held in a North/South direction by the needle. The relative movement between the lubber line and the card can then be read off directly in degrees which indicates the heading of the vehicle.

17.8.3 Gyro Compass

Most ROVs are fitted with gyro compasses which use the properties of gyroscopic inertia and precession. A child's conical top, when not spinning, will topple over. If it is made to rotate rapidly it will not deviate from the upright position. This is an example of gyroscopic inertia, i.e. the axle of a rotating body tends to remain pointing in a fixed direction. If a force could be applied to the rotating parts of a spinning body in such a way that it were not slowed down, it would be seen that the object would move in a direction contrary to that expected. This is the property of precession exhibited only by rotating objects. These two properties of rotating bodies are harnessed in the gyro compass to produce a mechanism which continuously points to North, provided its sensitive rotating parts are kept energised from a suitable electrical power supply. The gyro compass ideally seeks to align itself in the true north-south direction, but, in common with most mechanical apparatus it is subject to small errors. These must be allowed for when the compass is in use.

17.9 Charts

The chart is an important and reliable source of information, which is available to the ROV pilot as required via the ship's bridge. The most common charts available in the North Sea are Admiralty charts, but word wide there are a great many variations. All charts use similar methods to indicate various features and objects on what is a conventionalised picture on a flat surface of a portion of the curved surface of the earth.

17.9.1 Scale

The natural scale of a chart is the ratio of the area of the picture to the actual area represented therein. The larger the ratio, the smaller the scale and the less the extent of the detail that can be shown. Thus a chart having a natural scale of 1: 72,000 (1" to 1 nautical mile) shows more detail than one with a natural scale of 1: 393,000 (5 " to 1 nautical mile).

17.9.2 General Information

The general information in charts is given by means of standardised symbols and abbreviations, which are listed in a key chart. In the case of Admiralty charts this is known as chart 5011 and is available is book form. This key chart will be available in the ship's bridge.

17.9.3 Chart Title

The title is much more than a mere label and should be read carefully, since it contains much key information. The contains, in addition to a statement of the area charted, such key information as the natural scale, the way in which bearings, soundings, and heights of land, drying banks, or rocks are given and the datum levels from which soundings and heights are measured. The surveys on which the chart is based are also included, and often further information, such as the exact positions of prominent land features.

17.9.4 Corrections

Always see that a chart is up to date and so far as possible keep it so. Charts as sold by the agent are corrected up to date at the time of sale and the corrections incorporated are shown by a string of numbers outside the frame of the chart at the bottom. They represent the year and numbers of the Admiralty or similar organisation's notices to Mariners which are issued regularly. These notices, which are numbered in sequence, are careful, plain language statements of changes in harbour lights, positions or removal of wrecks etc.

17.9.5 True Compass Roses

Circular notation. Several compass roses are usually provided. Each rose always includes an outer circle or true compass rose, which is divided in degrees from 0^o at True North, clockwise through East, South and West to 360^o. The even numbered degrees being indicated by radial lines, with the odd numbered degrees indicated by dots between them. Every tenth degree is indicated by a longer radial line marked with the number of degrees. These true roses are so oriented that a line between 0^o and 180^o is the true North and South.

17.9.6 Magnetic Compass Rose

Quadrantal Notation. These are concentrically within the true compass roses and are oriented so that the North point corresponds to magnetic instead of true North, Degree markings are given in the same way as on the true rose.

17.9.7 Magnetic Variation

A magnetic rose is twisted in relation to a true rose, for the North point of the former is magnetic North, whereas, that of the latter is true North, the angle between North and true North is called the variation. It is not constant, but varies all over the surface of the earth. It also changes slowly with time. This can be ascertained from the information printed across the E-W line of the rose.

17.9.9 Tidal Diamonds

The direction and rate of the tidal streams is given at selected points on the chart, in the form of a magenta diamond if it is an Admiralty chart. The chart shows a number of letters, tidal diamonds, with printed details referring to the diamond's position given in a box on the chart.

17.10 Tidal Information

There are many occasions when ROV's operate in areas subjected to tides. the following information should be of use in these circumstance.

17.10.1 Causes of Tides

The tides are caused by the gravitational pull of the Moon and the Sun, the moon has the greater effect. The ration of the effects of each body is roughly 7:3 i.e. the Moon's pull accounts for 7 "units" and the Sun's for 3 "units". The planets also exert much smaller gravitational attractions. Both the earth's atmosphere and the water surrounding the earth are free to move in response to the motion of the sun and moon around the earth. The atmospheric motion is not significant, causing only a small change in pressure through the day, but the water; being more dense, "bulges" significantly towards the attracting body. The bulge occurs on both sides of the earth, as shown in Figure 17.34

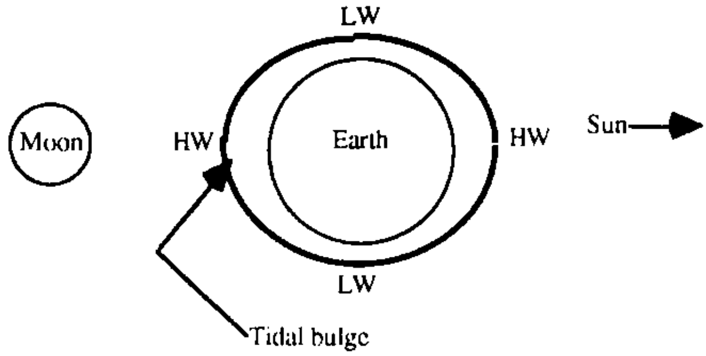


Figure 17.34
Tidal Bulges

Generally there are two high water and two low water times in each 24 hour period except in the Pacific. The earth rotates about its axis anticlockwise once every 24 hours. The moon orbits around the earth, in the same direction as the earth's rotation, once every 292 days (approximately). This means the lunar day is longer than an earth day by about 50 minutes due to the moon moving in the same direction as the earth's rotation. This in turn means the interval between two high waters or two low waters is on average 12 hours 25 minutes, giving a "semi-diurnal" tide i.e. twice a day. In European waters the tides are almost invariably semi-diurnal in character. In the pacific the tide is diurnal with only one high and one low each day. Local anomalies do occur, at Southampton for example there are four high and low waters each day caused by the tidal stream flowing around the Isle of Wight. The range of the tide is much affected by the shape of the sea or ocean, the gradient of the sea bed etc. If a sea or ocean has a natural period of oscillation near to the period of the tidal forces, then a greater range results. The North Atlantic has some of the greatest ranges in the world, particularly in the Bay of Fundy where a 17 metre range occurs at spring tides. In the Mediterranean there is very little tidal movement; generally less than 0.7 metres.

17.10.2 Springs and Neaps

The Sun and Moon may act together or at 90^0 to each other. They act together at New and Full Moon and at 90^0 to each other at first and last quarters. At New and Full moon the tides are higher at High Water and lower at Low Water than the average, giving spring tides. At first and last quarters the High Water is lower and the Low Water is higher than the average, giving a smaller range than average: termed neap tides. See Figure 17.35

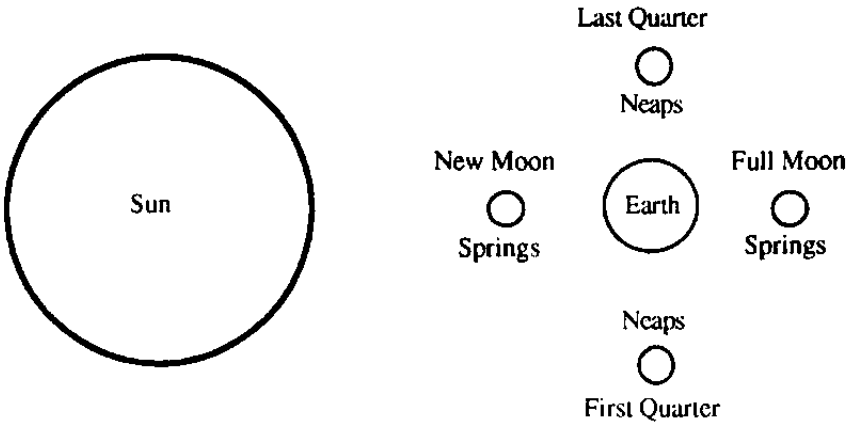


Figure 17.35
Spring and Neap
Tides

The Sun and Moon move North and South above and below the Equator. The Sun takes a year to make a full cycle from 232^0 N to 232^0 S and back again, while the Moon takes about 26 days to move from 282^0 N to 282^0 S and back again. When the Sun is at the Equator it gives the most direct pull to the semi-diurnal tides and thus the greatest tidal range. The same applies to the Moon. The Sun is at the Equator on March 21 st. and Sept. 21 st. and the New or Full Moon nearest to this date gives rise to the most extreme tidal range; particularly with the Moon also at the Equator. The spring tides near March 21 st., presumably give rise to the name for the tides having the greatest range.

17.10.3 Tidal Definitions

A number of terms have to be understood before calculations are carried out on heights and times of tides. These are best explained by the use of a diagram showing a tide pole in a coastal area. see Figure 17.36.

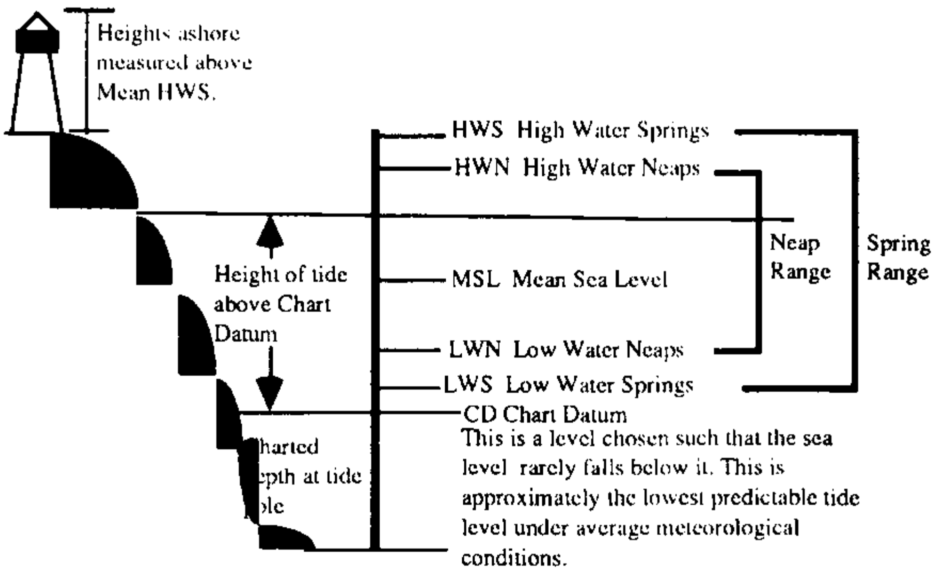


Figure 17.36
Tide Terminology

17.10.4 Times and Heights at Standard Ports

A number of ports throughout the word are known as Standard Ports. At these, observations have been made over a number of years and the effects of the positions of the Sun, Moon and the Planets have been determined for each Port, so that predictions can be made for many years ahead for the tidal heights which will occur at these ports and the times of HW and LW. This information is available in tabular form various sources such as the Admiralty, Reed's Almanac or the Macmillan Almanac. The way in which the tide rises and falls has also been carefully examined to allow curves of rise and fall to be produced for Spring and Neap tides. These are produced by a number of agencies the best known of which is the Admiralty. These books of tidal curves can be consulted when the tidal height is required.

17.11 Weather

In any operation undertaken at sea the weather must be considered. Weather forecasts are available world wide and the local forecast should be consulted before conducting operations.

CHAPTER 18 DRAG, BUOYANCY AND NAVIGATION

18.0 Introduction

There are two purposes for this chapter. The first is to introduce the effects of two forces that effect ROVs in the working environment; namely drag and buoyancy. The second is to discuss navigation on the ROV in practical terms.

18.1 The Drag Force

One important factor that should be appreciated when considering the effects of drag is that the drag force itself is still imperfectly understood and a great deal of empirical work is undertaken, in wind tunnels and test tanks, at the design stage for new developments because of this. This does not mean that ROVs are thus tested nor does it imply that nothing is known theoretically about the drag force. It is simply stated here to underline the complex nature of drag.

18.1.1 Fluid Flow

In considering drag the first consideration has to be the type of flow of the liquid causing the drag. This can be either LAMINAR or TURBULENT and many detailed experiments have been undertaken to study the effects of flow notably by Osboune Reynolds who published his results in 1883. His name is used to denote the non-dimensional *REYNOLDS NUMBER* that is decisive in determining the type of flow. The Reynolds number is determined thus:

$$Re = \frac{\rho u l}{\mu}$$

Re - Reynolds number
ρ - Density
l - Selected Dimension
μ - Velocity

The density of fresh water is taken to be 1000 kg m^{-3} and sea water about 1025 kg m^{-3}. The viscosity of fresh water is 10^{-3} Nsm^{-2} (1.0 mPa) (Pa - Pascal and 1.0 Pa = 1.0 Nsm^{-2})
An example should illustrate the use of this formula

Example :-

What is the Reynolds number for sea water flowing at 2 knots over a 1 m length of pipe?
(1 Kt approximately equals ½ m^{-1})
Thus 2 Kt = 2 X ½ = 1 m^{-1}

$$Re = \frac{\rho u l}{\mu}$$

$$= \frac{1025 \times 1 \times 1}{10^{-3}}$$

$$= 102{,}500$$

At low Re the flow is said to be laminar but at high Re it is turbulent. The actual Reynolds number separating these two states depends on l and the general flow and Fig 18.1 shows the transition from laminar to turbulent for a thin flat plate aligned with the flow to be at about Re = 500000.

18.1.2 Boundary Layers

The concept of boundary layers which was first introduced by Ludwig Prandtl has led to the development of Fluid Mechanics as a science. This concept has been the subject of much experiment especially in the aircraft industry and many advances in understanding have occurred. There is still much that is not understood and work continues in this field. To illustrate current knowledge consider a thin flat plate aligned with the flow. The drag coefficient associated with this flow would normally be denoted C_d but experiments have concentrated on the drag coefficient for a single surface as this simplifies the study. The drag coefficient for a single surface is often denoted C_f ($C_d = 2\ C_f$) and is called the friction coefficient. The simplest general boundary-layer case is summarised in Fig 18.1

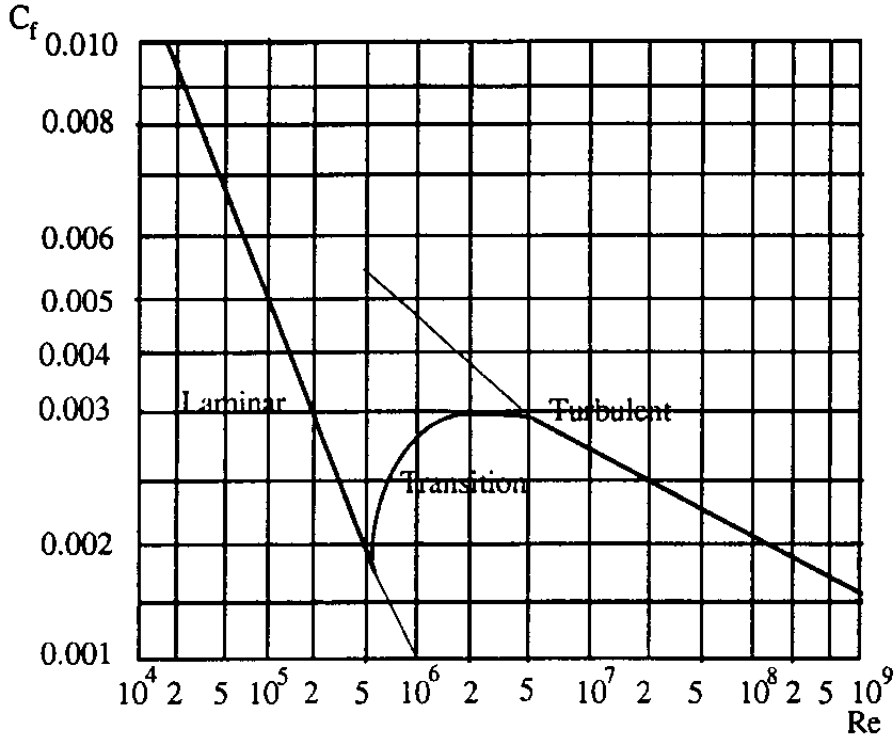


Figure 18.1

As indicated on the diagram the C_f at low Re (less than 500000) is laminar and C_f decreases as Re increases. Above Re = 500000 the boundary layer is likely to be turbulent. The more turbulent the flow the better it resists separation from the plate. Separation generally causes high drag and to minimise this and give an attached flow a streamlined shape as illustrated in Fig. 18.2 is employed.

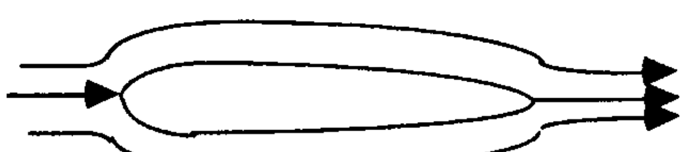


Figure 18.2

This shape is obviously far removed from the shape of a typical underwater vehicle which must be considered as a "bluff" shape.

18.1.3 Bluff Shape

Bluff shapes have detached flow at the rear and such a shape is shown in Fig. 18.3

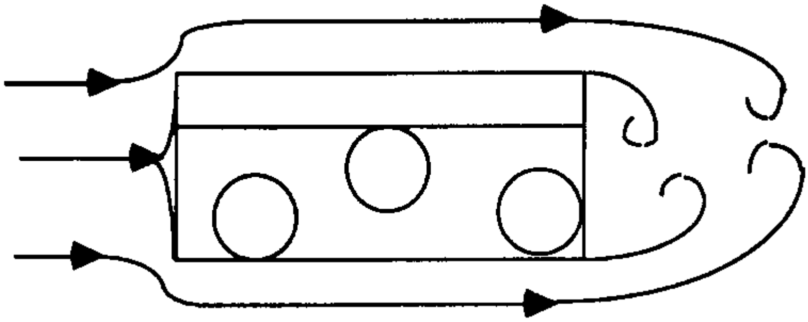
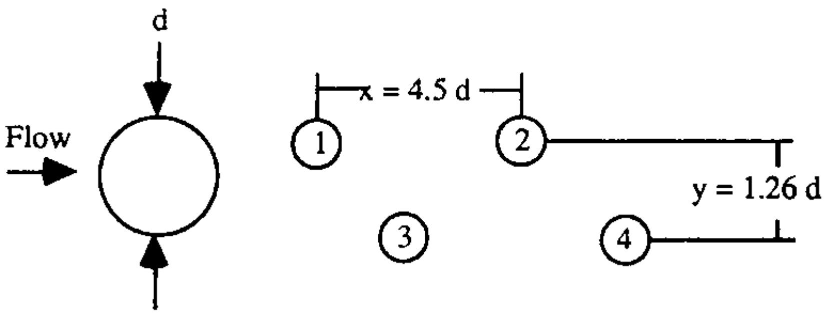


Figure 18.3

This section has a wake typically about the same width as the section containing flow that may be; very turbulent, varying in a regular manner, or some combination of these two. For a variety of sections, particularly circular cylinders the wake is often in the form of vortices in a regular pattern called the "Karman Vortex Street" as shown in fig 18.4



Vortex street at $Re \simeq 2000$
Figure 18.4

von Karman was able to demonstrate the arrangement in Fig. 18.4 was a stable one but this is by no means the usual case as most such arrangements are unstable. Whether the vortex street is stable or not, however, it causes violent lateral motions of the fluid behind the object and is associated with a high drag coefficient, which for bluff shapes is often denoted C_{df} (this being C_d based on frontal area).

a. A standard equation used throughout studies into fluid flow is Bernoullie's equation :-

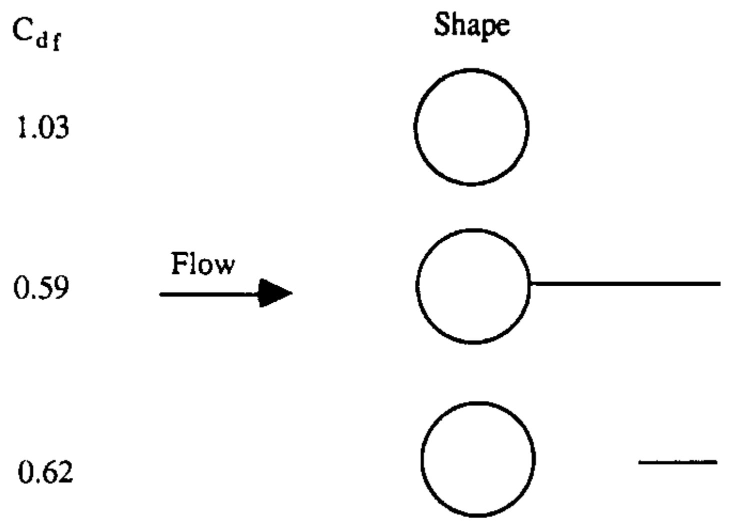
$$k_1 = p + \tfrac{1}{2} \rho u^2 x + \rho g z$$

k_1 = Constant
p = Static pressure
ρ = Density
g = Gravity
z = Height above datum
$\rho g z$ = Potential pressure term
u = Velocity
$\tfrac{1}{2}$ = Constant of integration

This equation and practical experiments show that fluid dynamic forces are proportional to the square of the speed. It is a common practise to express fluid force by a non-dimensional force coefficient C and :-

$$F = \frac{1}{2} \rho u^2 C A$$

Where A is a reference area. A common example of the force coefficient C is the "drag coefficient" denoted C_d.
A useful device to reduce drag is a " splitter plate" behind the object. The effects of this are illustrated in diagrammatic form in Fig 18.5.



Effects of Splitter Plate
Figure 18.5

18.2 Effects of Drag in Practise

To illustrate the practical aspects of the effects of drag consider a neutrally buoyant work class ROV operating in 150 m of water on a pipeline inspection. The ROV is deployed from the deck and locates onto the pipeline. The diagram in Fig. 18.7 shows a "snapshot" in time at a moment when the vessel is stationary vertically above the stationary ROV with the tether also rising vertically. This is not a realistic situation but it does give a start point for a simple analysis of the drag forces at this point in time. The drag coefficient can be found from the table in Fig. 18.6

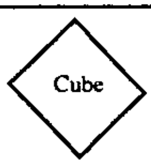
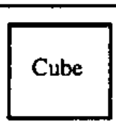
3D SHAPES	
SHAPE	C_{d_f}
	0.4
 Cube	0.8
 Cube	1.1

Figure 18.6

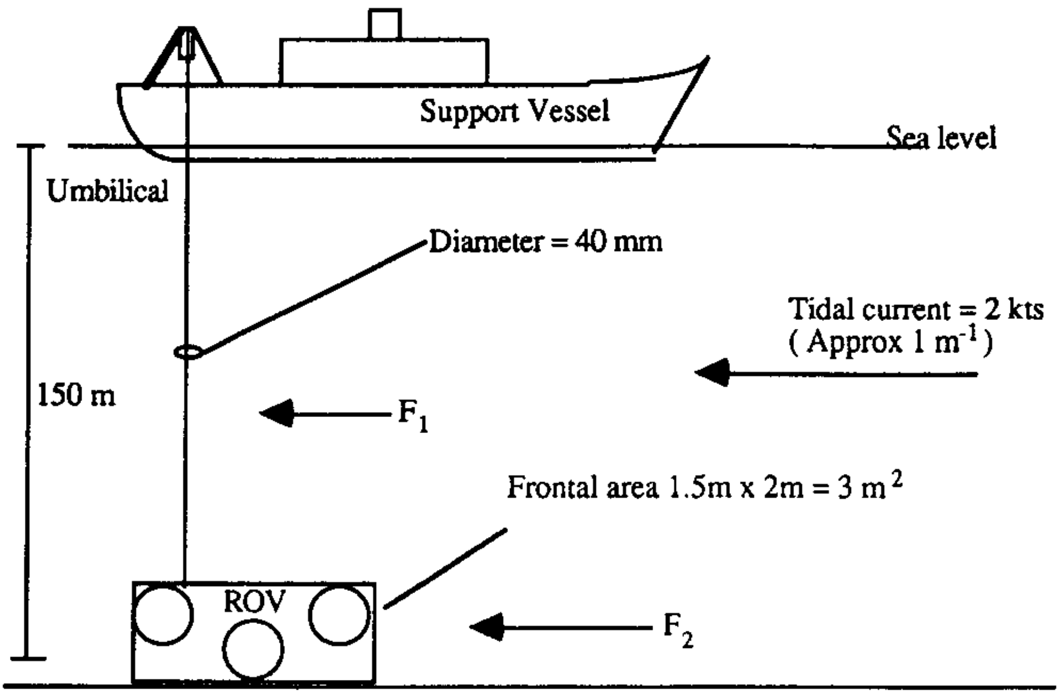


Figure 18.7

Consider first the force on the umbilical.

$F_1 = \frac{1}{2} \rho u^2 C_{df} A$

$= \frac{1}{2} \times 1025 \times 1^2 \times 0.4 \times 150 \times 0.04$

$= 1230$ N

Now consider the force on the vehicle.

$F_2 = \frac{1}{2} \rho u^2 C_{df} A$

$= \frac{1}{2} \times 1025 \times 1^2 \times 1.1 \times 3$
$= 1691.25$ N (1690 N)

These figures demonstrate that the force on the umbilical is considerable and for long lengths the drag on the umbilical is greater than the drag on the vehicle. The umbilical drag is effectively reacted 50% at the vessel end and 50% at the vehicle. This means that the total force reacted horizontally by the vehicle is:

$$615 + 1690 = 2305 \text{ N}$$

This in turn means that whatever power is available to the vehicle a percentage of that power is required to overcome this drag force thus reducing the power available for other functions such as manoeuvring. In the situation being considered here the ROV must achieve a rate of advance along the pipeline of approximately ½ m^{-1}. This will impose greater forces onto both the umbilical and the vehicle and require even more power from the vehicle just to go forward. The situation posed in this simple example is obviously far from the real case where the forces on the umbilical in particular will be imposed in a much more complicated manner as indicated in Fig 18.8.

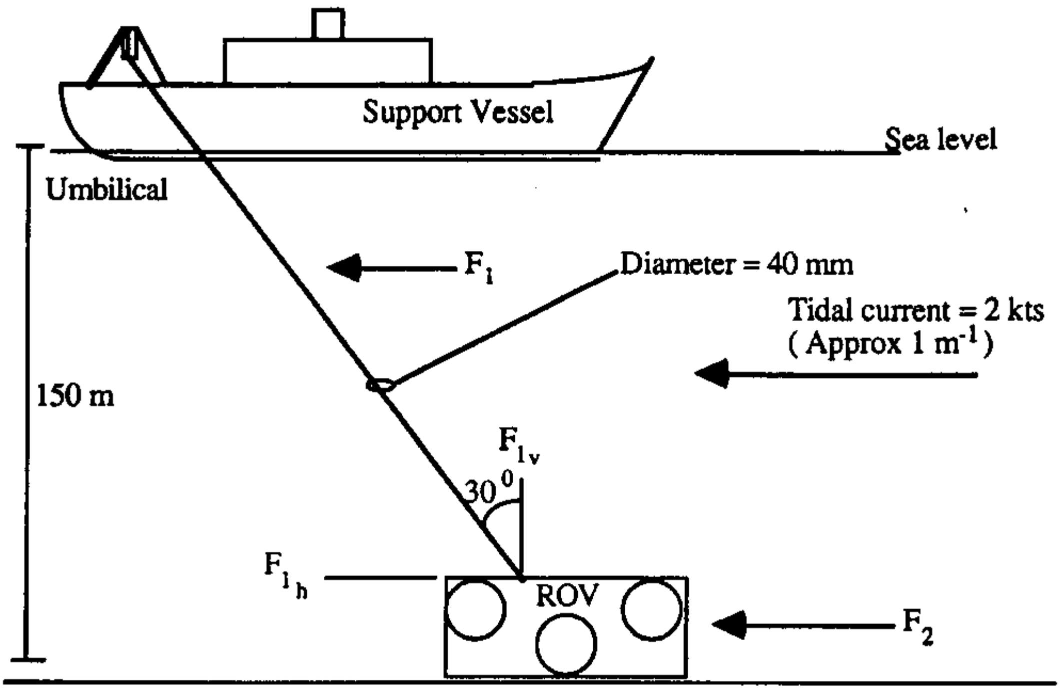


Figure 18.8

In this situation the force on the umbilical reacted by the ROV must be resolved into its two components thus:

$$F_{1v} = F_1 \text{ Cos } 30^0$$

and

$$F_{1h} = F_1 \text{ Sin } 30^0$$

In this case which is slightly more realistic some vehicle power is required for both horizontal and vertical reactions. The real situation is even more complex of course but the two points to bear in are; the drag force on the umbilical is considerable and will always affect the vehicle handling, and the total available vehicle power is never all available for forward motion because a proportion has to be used to counter the drag forces. In any situation this puts an onus on the pilot to navigate accurately and thus minimise the need for manoeuvring and conserve power. The drag force on the umbilical is also an important reason for employing a cage or tether management system whenever possible when deploying the ROV.

18.3 The Buoyancy Force

This force is encapsulated in Archimedes' principal, which states, "An object immersed in a liquid is subjected to an upthrust equal to the amount of liquid displaced". Quantitatively it is easily evolved by considering a vertical cylinder filled with air immersed in a liquid as shown in Fig 18.9

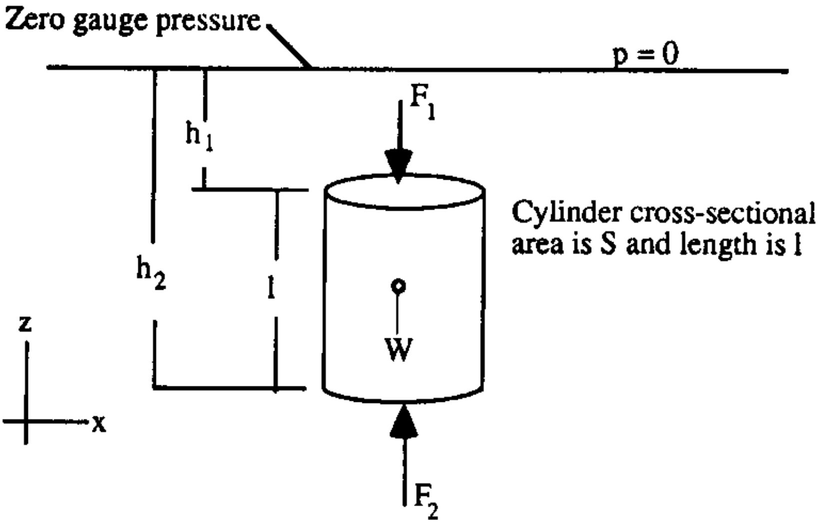


Figure 18.9

From the diagram:-

Buoyancy force $B = F_2 - F_1$

now

$F_2 = \rho\ g\ h_2\ S$ and $F_1 = \rho\ g\ h_1\ S$

$\therefore\ B = \rho\ g\ h_2\ S - \rho\ g\ h_1\ S$
$= \rho\ g\ S\ (h_2 - h_1)$

but $h_2 - h_1 = l$

hence $B = \rho\ g\ S\ l$

however $S\ l = V$

Thus $B = \rho\ g\ V$

It can also be seen from the diagram that the buoyancy force acts vertically upwards through the centre of gravity i.e. it opposes gravity.

18.3.1 Practical Applications

In practise the application of the buoyancy force to ROVs is in either fresh or salt water and it revolves around balancing the weight of objects. This allows a simplification to be made substituting weight for mass. It is then possible to assume that 1l of fresh water is equal to 1 kg weight. and if 1l of fresh water is displaced the buoyancy force will produce an upthrust equivalent to 1 kg of lift. In order to apply these simplifications the basic equation is:

Weight of Object - Displacement of Object = Lift Required

18.3.1.1 Examples

Suppose that a block of concrete 2m x 1.5m x 3m is to be lifted from the sea bed in 35m depth of water. An inflatable lifting bag is to be used. How much free air will be required?

Weight of Object - Displacement of Object = Lift Required

a. Displacement (D) = 2 x 1.5 x 3 = $9m^3$

now $1m^3$ = 1000l in fresh water and 1025l in salt water

hence D = 9 x 1025 = 9225 kg

b. Weight of concrete = 2200 kg m^{-3}

hence weight of block = 9 x 2200 = 19800 kg

$\therefore$ 19800 - 9225 = 10575 kg

Now if 10,575l of water is displaced the upthrust will equal this. Thus an airbag full of 10,575l of air will displace this amount of sea water. If this concrete block is to be lifted from the sea bed however the lift bag will have to be full of this amount of air at that depth. Boyles Law must therefore be applied to determine the required amount of air that has to be supplied from the surface. Boyles Law may be stated thus:-

$$p_1 V_1 = p_2 V_2$$

The pressure at the surface is p_1 and the pressure at the sea bed is p_2 and in these calculations it is easier to work in *Bars* (1 Bar is approximately 14.7 p.s.i.). Thus the amount of free air required will be:-

$$V_1 = \frac{p_2 V_2}{p_1}$$

At 35m water depth the Absolute pressure is 4.5 bar (approximately) and p_1 = 1 Bar

$\therefore$ V_1 = 4.5 x 10575 = 47587.5l

It would not be a usual ROV task to place such an air bag but it could be done. a more usual example may be to place transponders on the sea bed for a site survey. Suppose the transponders weigh 60 kg in air and are cylindrical in shape with a diameter of 0.5 m and a length of 1m. How many Grimsby buoys of 5l displacement are required to make the transponders neutrally buoyant?

Weight of Object - Displacement of Object = Lift Required

a. Displacement = $\pi r^2 l = \pi \times 0.5^2 \times 1.0 \triangleq 0.785l$

$\therefore$ 60 - 0.785 = 59.215l

In this case the displacement makes very little difference to the amount of lift re[illegible] but the calculation is included for completeness.

b. The number of Grimsby buoys required will be: -

$$\frac{60}{5} = 12$$

18.4 Navigation

Navigating an ROV can be very straight forward operation as, for example, when following a pipeline on a survey when the navigation will be in the hands of a specialist team. It may also be difficult as it can be when working off a platform and the sonar and compass go unserviceable.

18.4.1 Open Water Navigation

The task in open water is made straight forward by the provision of the vessel's navigation information displayed on a VDU is the ROV control room. The ROV will be provided with a sonar transponder which is interrogated by the ship's Hydroacoustic Positioning Reference System (HPRS).The response from the ROV is then displayed on the electronic chart and the pilot can see at a glance his position relative to the vessel. Navigational targets are displayed on the chart and the pilot can "read" his course directly from this. The ROV will normally have its own sonar and will be provided with a magnetic compass and probably a gyro compass as well. The compass is used to maintain course which is checked by the track on the VDU and as the range to the target closes the ROV sonar is used to pinpoint the target. The pilot can use this information to negotiate the vehicle in the most efficient way to the required position.

18.4.2 Navigation Without Electronic Aids

On occasion it may be necessary to navigate onto a target without the aids outlined in paragraph 18.4.1. In this case it will be necessary to resort to underwater pilotage using visual information gained from the ROV closed circuit television. The basic course can be maintained using the compass but to establish the course made good the "set and drift" of the ROV must be estimated. This can be achieved at sea bed level by facing the ROV into the current, centralising the camera and taking the bearing when the oncoming suspended sediment is observed to be coming directly at the camera. The reciprocal of this bearing is the current direction. Having established the set the drift can be estimated by adjusting the ROVs position so that the suspended particles are drifting directly across the front of the camera. The time taken for a selected particle to pass a known distance can be recorded. The known distance can be the length of a manipulator or some other visible part of the ROV. Using the simple equation that distance divided by time equals speed and the approximation that ½ m^1 approximately equals 1 knot the drift can be estimated. As experience is gained the current speed and direction can be estimated intuitively but initially while this experience is being gained the foregoing should be of some help. The set and drift of the current together with the vehicle speed can then be applied to a Velocity Vector Triangle and the course and time to the target can then be estimated. These methods can ensure that the ROV is navigated onto a target using only its compass.

18.3.3 Navigating Around a Structure

It is most important that the pilot makes himself familar with the structure by consulting the platform drawings. Some platforms have underwater identification marks which aid navigation and where these are in use the pilot must make himself aware of where they have been placed. A hazard to navigation around a structure is debris and sometimes fishing line and where this is likely to be a problem it must be anticipated before the dive. Once the ROV is on the structure itself the compass may not be of any assistance and the pilot must rely on navigating visually much more than is the case in open water.

The sonar can still be of great assistance provided the pilot is prepared to sit the vehicle in one position and allow the sonar picture to build. It is vitally important that the route taken around the structure by the ROV is memorised by the pilot. This will prevent the umbilical from becoming fouled. The pilot needs to cultivate the skill of spatial awareness in this type of operation much more than for other ROV operations because of this hazard to the umbilical.

CHAPTER 19 PRINCIPLES OF ROV PILOTING & SONAR

19.1.0 Piloting Competencies

19.1.1

This chapter is concerned with the principles of piloting ROVs which is often considered as something of a 'Black art'. The aims of this chapter are to explain as simply as possible the competencies (a competency is a combination of both knowledge and skills) that an ROV pilot should have if he is to succeed in what is a very difficult operational environment.

19.1.2

Piloting an ROV is often considered too difficult to teach, but rather as a set of competencies that only 'talented' people can learn, and only then by years of operating experience. It is clearly true that work experience is required for the Pilot to be fully capable, but we have found that the learning process can be considerably accelerated by initial Pilot training in these fundamental competencies.

19.1.3

Although each principle is easily understood in isolation, the fully capable ROV Pilot must incorporate them all at once and this can only be accomplished by practising them. It is also true, that the progress of the trainee Pilot is bound to be impeded if these principles are not properly understood during his initial training period as they form a valuable 'framework' to build upon through practice.

19.2.0 Teamwork

19.2.1

The ROV Pilot is one member of a small team of usually three people. For the Pilot to be able to operate successfully he must be able to understand the roles of, and communicate with the other team members. The Pilot depends on and must communicate with the supervisor to take care of overall safety and the operational planning, the observer to keep track of the vehicles position and keep records, and the winch man to adjust the umbilical length according to the vehicles circumstances.

The first fundamental principle is therefore that the Pilot can only be successful with the assistance of the other team members and that clear unambiguous communication must exist between each of these team members..

19.3.0 Navigation

19.3.1

Navigating an ROV can be anything from very straightforward to extremely difficult. In open water the task is made straightforward by the provision of a ships navigation display showing the ROVs position relative to obstacles and targets using information from the ships surface navigation system and the Hydroacoustic Position Referencing System. This system is however often unavailable and the Pilot may be required to navigate in open water. This is again straightforward if the target is large enough to be displayed clearly on sonar, it is much more difficult, however, if the Pilot is searching for a small target such as a well-head or a transponder, particularly if it is necessary to estimate the ROVs 'Set and Drift' to the target, allowing for the current direction and speed as outlined in Chapter 18.

i) Once the current is known, provided the through water speed of the vehicle is known allowing for umbilical length, then the Set, Drift and time to target can be estimated using normal methods of Triangles of Velocities.

19.3.2

When navigating around structures the Pilot needs to be familiar with the structure and any identification marks an Chapter 18 gives more information on this subject.

19.3.3

Navigation is assisted by planning the dive to ensure that work is carried out with the optimum visibility. Wherever possible the task should be undertaken with the vehicle facing into the current to prevent sediment disturbed by the vehicles own thrusters from obscuring the work site. In addition sediment must not be unnecessarily disturbed from the structure itself or the seabed. Although in many cases this is 'easier said than done' careful planning and care during dives can appreciably improve the situation.
The second fundamental principle is that the pilot must be able to navigate effectively in open water or around structures taking account of current, visibility and umbilical restrictions making use of navigational aids effectively, including where necessary 'Dead Reckoning'.

19.4.0 Spatial Awareness

19.4.1

In addition to being capable of Navigation, the ROV Pilot must develop a high degree of spatial awareness. That is, he must not only be able to go from A to B, but he must be able to visualise his relative position in three dimensions with reference to A and B. It is very common for ROV Pilots to be aware only of the video monitors and to determine the vehicles position on this alone during tasks.

The accomplished Pilot will however develop a sense of spatial awareness that transcends this and enables him to visualise the whole situation in three dimensions, rather like he was able to look at a model of the situation without the water being there. In this way he is able to reference everything to North and know the lie of the umbilical through or around structures and obstacles.
This essential ability comes more naturally to some than to others, but in all cases it can be improved by drawing the support vessel, ROV and Umbilical onto working drawings at regular intervals during dives.

The third principle is that the Pilot must have a highly developed sense of spatial awareness.

19.5.0 Vehicle Geometry and Systems

19.5.1

The position and power of vehicle thrusters, and the position of the umbilical attachment points are particularly relevant to the understanding of the vehicles performance. The geometry of the thrusters affects the performance of the vehicle the most fundamental way. It is clear that a vehicle in the standard configuration of two stern thrusters, one vertical thruster, and one lateral thruster will behave quite differently to a vehicle having three vertical thrusters, and one horizontal thruster in each corner of the frame at 45 . The latter configuration is more effective in countering the upward pull of the umbilical and enabling uniform manoeuvrability in the horizontal plane. The attachment position of the umbilical to the frame is also important because, as will be seen later, the umbilical pull is often very substantial and the point of application of this pull can severely effect manoeuvrability.

19.5.2

A knowledge of the vehicles technical systems is again essential. As an example of this; take a hydraulic vehicle that has a pump capable of providing an output of 3000 PSI hydraulic pressure at a maximum flow rate of 15 Gallons per Minute. If this vehicle has four thrusters each requiring 5 Gallons per Minute at full speed, then it is clear that the Pilot will not be able to demand full speed from each thruster at the same time. In this situation it may be inappropriate to attempt to manoeuvre the vehicle in turbulent conditions around structures with the Automatic Depth and Heading Circuits engaged, as the total oil demanded from the thrusters may be more than the 15 Gallons per Minute available resulting in a severe drop in oil pressure hence thruster power. The informed Pilot may well decide to disengage the Automatic circuits whilst manoeuvring in these condition to ensure maximum power at the thrusters where it is most required.

19.5.3

Clearly a knowledge of all the vehicles systems is essential for efficient and effective ROV operations and the Pilot must be well aware of the vehicles capabilities.

The fourth principle is that the Pilot must know the vehicles geometry, systems and performance capabilities.

19.6.0 Effects of Controls

19.6.1

The effects and secondary effects of the controls must be appreciated by the ROV Pilot and these are not always as straight forward as it first seems. For example if lateral thrust is applied to a vehicle it may be expected to simply traverse laterally maintaining its heading. However it is unlikely that the lateral thruster is positioned in the exact metacentre of the vehicle, and there is therefore likely to be the secondary effect of a heading change, or roll which will be required to be counteracted. Similarly, if a pilot is endeavouring to change the heading of a vehicle he may well find that the vehicle creeps forward as the stern thrusters may well be more effective when operating in the forward direction than when operating in the reverse direction, this may need to be counteracted by the application of reverse thrust in association with heading controls.

The fifth principle is, therefore, that the Pilot must know the effects and secondary effects of the control inputs. This is often best established initially in a test tank or on the surface, where the Pilot can see the vehicle and can monitor the effects directly, but can be quickly appreciated by the experienced Pilot in the work situation.

19.7.0 Vehicle Momentum

19.7.1

The significance of the vehicles momentum is very often not appreciated sufficiently by Pilots as ROVs behave very differently to cars in this respect. When turning a corner in a car the steering is simply applied until the desired new direction is achieved, then removed. The control input and resultant effect on the car is shown in Figure 1. The same control input to an ROV would not, however, have the same effect. Because the car is in contact with the road, the momentum effects are minimal. The ROV will, however, continue to turn after the control input has been removed, due to the high momentum and low drag forces (particularly in the case of heavy compact vehicles).

19.7.2

A similar control input to an ROV will therefore result in overshoot as shown in Figure 2. The required control input to affect a heading change of an ROV would be as shown in Figure 3. The ROV Pilot is therefore required to put in an opposite control action to every initiating action to achieve the desired vehicle movements. This is a very important skill for the ROV Pilot to attain and becomes apparent as the vehicle descends to seabed, when the Pilot is required to counteract the vehicle momentum by applying up-thrust on seeing the seabed, if he is to avoid touching down and spoiling the visibility. If the Pilot simply removes the down thrust, the momentum of the vehicle will ensure it continues downwards until either drag, the umbilical or the seabed prevents it, often obscuring the visibility by dislodging sediments.

The sixth principle is therefore that the ROV Pilot must be aware of the vehicles momentum and be prepared to counteract each initiating control movement with an opposite movement.

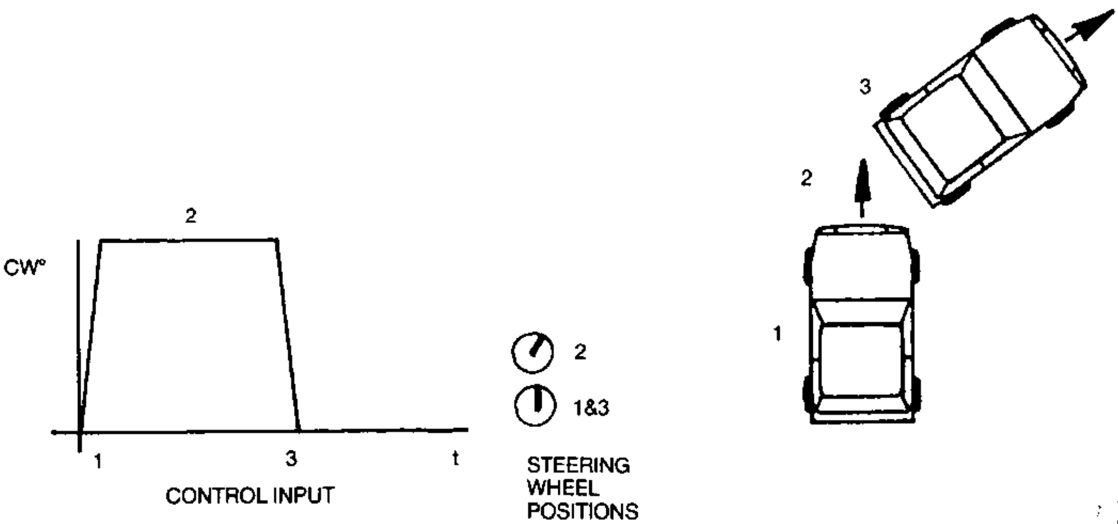


Figure 19.1

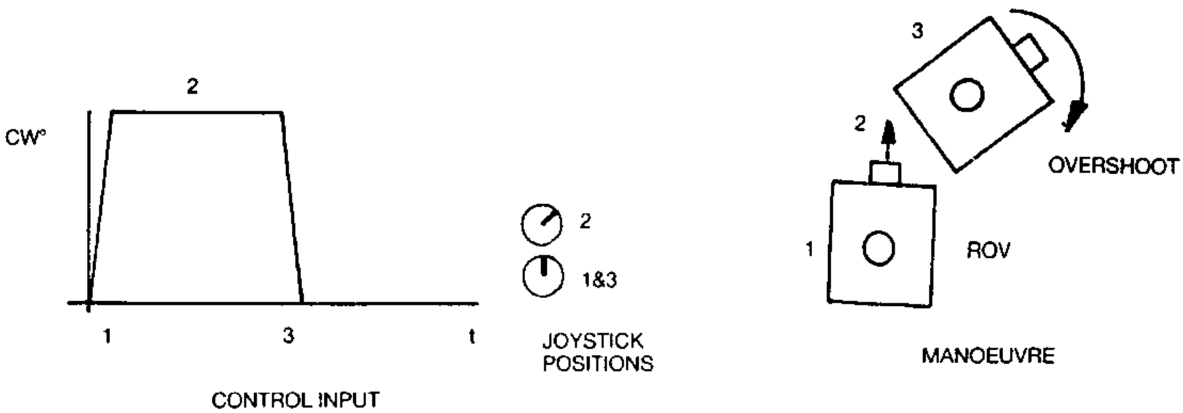


Figure 19.2

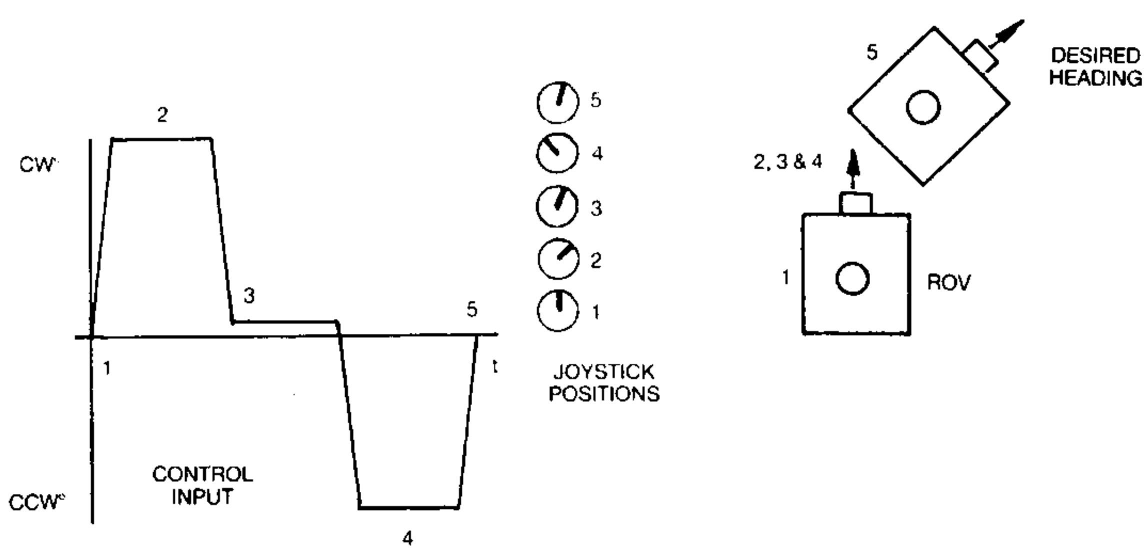


Figure 19.3

19.8.0 Drag Effects

19.8.1

Perhaps the most crucial factor effecting vehicle performance is the effect of drag on the vehicle and in particular the fact that the drag forces on the umbilical can be much greater than the drag on the vehicle itself. The example shown in Figure 19.4 shows clearly the relative size of these drag forces on a typical medium sized work vehicle travelling at 1/2 a knot at a depth of 300m. The example also shows the effect of the umbilical length, hence angle at the vehicle, on the direction of these forces.

19.8.2

In this example the drag on the vehicle itself is shown to be 20 kg whereas the horizontal component of the umbilical drag is 120 kg. This corresponds to a tension in the umbilical of 140 kg at 30 to the horizontal and 240 kg at 60. Significantly the upward component of this force is 70 kg in the first case (Figure 4.) and 207 kg in the second case (Figure 5). This means that in many cases the primary force at a vehicle may well be the upward pull of the umbilical and not a backwards force as may be expected. For further information on the method of calculating drag forces see Chapter 18.

The seventh principle is that the forces from the umbilical can be at least ten times the drag force on the vehicle itself, and the length of the umbilical is significant as a 'tight string' tends to pull the vehicle up off the job, rather than exert a purely horizontal force astern as may otherwise be expected.

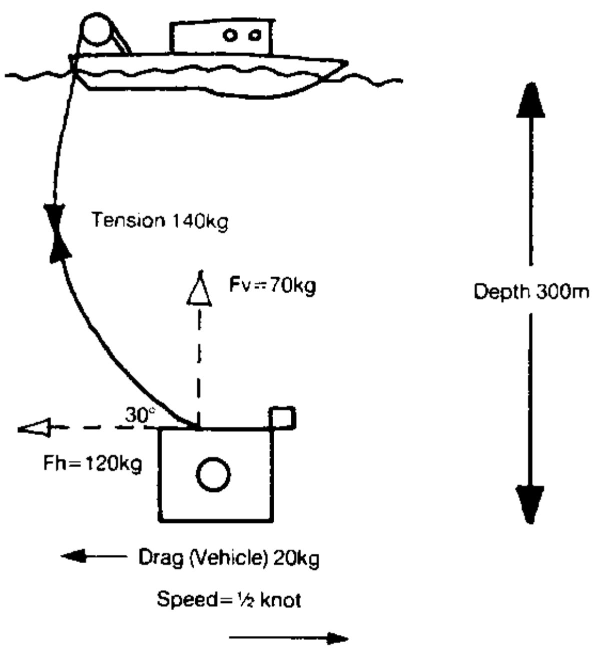


Figure 19.4

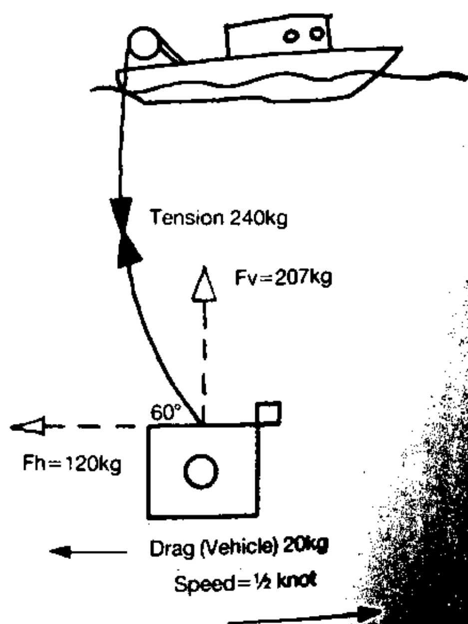


Figure 19.5

19.9.0 Hand/Eye Co-ordination

19.1.0

Hand/eye co-ordination is a skill that is partly hereditary and partly developed through practice. Co-ordination is generally over rated as a Piloting skill, as it is just one of the many required and not an end in itself . The difference in co-ordination abilities between one Pilot and another is often inconsequential as very few ROV tasks demand a very high degree of co-ordination. It is generally preferable that a Pilot has a good grasp of all the principles mentioned here, rather than simply having highly developed Hand - eye co-ordination.

The eighth principle is that the ROV Pilot must develop a high degree of Hand - eye co-ordination.

19.10.0 BE IN IT!

19.10.0

ROVs are difficult to fly because they are Remotely Operated, that is , there is no 'feel' associated with them. The capable Pilot will, however, imagine that he is actually onboard the vehicle, to the extent that he may actually lean when turning and 'duck' as the vehicle approaches obstacles. This is a good trait as being able to imagine ones self to be actually in the vehicle assists greatly with navigation and orientation.

The ninth principle is that the ROV Pilot should be able to imagine that he is actually 'in' the vehicle, particularly when navigating and attempting to orientate himself.

19.11.0 Familiarity and Experience

19.11.1

To be fully competent the ROV Pilot must have 'internalised' the principles and skills mentioned in the previous nine sections. This can only be achieved by thorough initial training, as provided at Wray Castle, followed by familiarity of the ROV system operated and experience of the job in hand. The pragmatic ROV Pilot will always take the time to familiarise himself with a new vehicle or task in a sheltered environment prior to undertaking the job for real.

The tenth principle is that the ROV Pilot will be familiar with the ROV he is operating and will have experience of the task in hand wherever possible prior to the offshore operation.

19.12.0 Difficulty Comparison

19.12.1

The following comparison is used at Wray Castle as a method of explaining the degree of difficulty experienced by ROV Pilots as compared with airline Pilots:-

Imagine you are to fly an airline from London to New York. Firstly replace the aircraft's high resolution radar systems with its sonar equivalent, a system that is many thousand times less accurate. Then limit the Pilots visibility to around three metres. Arrange for the wind to blow at around 300 Knots with directional changes every 6 hours. Finally arrange for a massive steel structure in the middle of the Atlantic ocean and attach the aircraft to a tether anchored to the ground at the other end. Effectively you will be reducing the information available to the Pilot and increasing the external forces acting on the aircraft.

This comparison serves to enable the trainee to understand the nature of the job and to comprehend the reasons for fully 'internalising' the 10 Piloting principles explained above.

19.13.0 Sonar Interpretation

19.13.1

In order for the ROV Pilot/Technician to be able to understand and interpret the sonars that are typically used during ROV operations it is necessary to review the theory. The depth of this review is sufficient to allow the scientifically educated reader to gain an appreciation of the complexity of sonar theory and the factors that affect the ability of a Sonar and its Operator to detect a target. This review is not intended to be exhaustive and the interested reader is recommended to read the appropriate scientific literature.

19.13.2

SONAR is an acronym for **So**und **Na**vigation and **R**anging. The term is used for systems that utilise underwater acoustic energy for observation and obstacle avoidance. Sonar is preferred to Radar because of the extremely high attenuation and scattering that Electro-Magnetic (EM) radiated energy suffers in a highly conductive medium such as sea water.

The Acoustic Triangle has the same purpose as the Electrical Triangle used for Ohms law and is to show the relationships between the fundamental quantities responsible for sound transfer:-

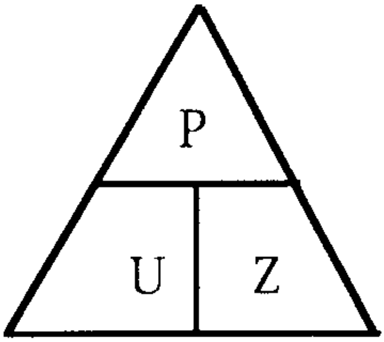


Figure 19.6

Where:- P = Acoustic Pressure (Equivalent to Voltage V) in micro Pascals.

U = Particle Velocity (Equivalent to Current I) in m/s.

Z = Acoustic Impedance (Equivalent to Resistance R) in Acoustic Ohms.

Then the acoustic equivalent of V = IR is P = UZ and the acoustic equivalent of Electrical Power is:- Instantaneous Acoustic Intensity = PU.

The sound velocity (C) at or near the surface in a water temperature of 15.5 C and a salinity of 34 parts per thousand is 1500m/s. This value can be taken to be reasonably constant throughout normal operating conditions, but allowances should be made for its variances when undertaking detailed survey work or similar.

19.14.0 The Sonar Equation:

The generally accepted equation for the signal to noise ratio (**Ns/N**) at the transducer of a sonar is:-

$$Ns/N = (SL - 2PL + TS) - (BN - DI)$$

Where:-

SL is the Source Level in dBs. This varies from 10dBs to over 100dBs dependent on the power capability of the sonar transmitter, type, size and the directionality of the transducer array.

PL is the propagation losses for which there are the following types:-

i) Spreading loss.
ii) Attenuation Loss.
iii) Scattering and Absolution.
iv) Heating by absorbtion.
vi) Seabed and surface reflection and absorption.
v) Reverberations.

TS is the Target Strength and is the echo level from an actual target in dBs above the echo level of a reference sphere. The value of Target Strength is dependent on:-

i) Size of target.
ii) Shape of target.
iii) Orientation of target.
iv) Internal construction of target.
v) Extent of Anechoic coatings.
vi) Frequency of transmission.

BN is the Background Noise and consists of the following types:-

i) Self noise is that noise produced by the receiver and its platform, it can be decreased by good design and maintenance.
ii) Ambient Noise is from; Thermal, Sea Surface, Biological, Traffic, Rain, Surf, and Turbulence sources.
iii) Reverberations are the portion of the scattered sound from any reflecting surface in the ocean which returns to the listening transducer.

DI is the Directivity Index of the receiving array which is dependent on the frequency and the length of the array. Directivity is for example better when the length of the array is twice the wavelength of the received signal than a quarter of the wavelength. Put another way, the transducer array needs to be longer at lower frequencies to obtain the same directivity.

The operators ability to detect targets is also a factor which should be taken account of by the **Recognition Differential RD** where the RD = Ns/N when there is a 50% chance of detection by the operator.

The above serves to show the complexity of the Physics involved in Sonar operations. In practice, although it is important to be aware of all these factors, the experienced operator will become familiar with his equipment, the optimum settings and the displayed information in order to identify targets.

19.15.0 The Transducer

The Transducer is the name given to devices which convert energy from one form to another, in the active (rather than the 'Passive' i.e. hydrophone) case this is the conversion of electrical energy into sound and vice versa.

There are two main types of transducers:-

Electric Field Types

Piezo-electric - Crystal Microphones, Transmitters etc.

Electrostrictive - The alteration of physical dimensions when under the action of an electric field.

Magnetic Field Types

Electrodynamic - moving coil.

Electromagnetic - moving iron.

Of these the Electric Field types are most common. With all Transducers the amplitude of the signal output depends upon the signal strength over the frequency bandwidth.

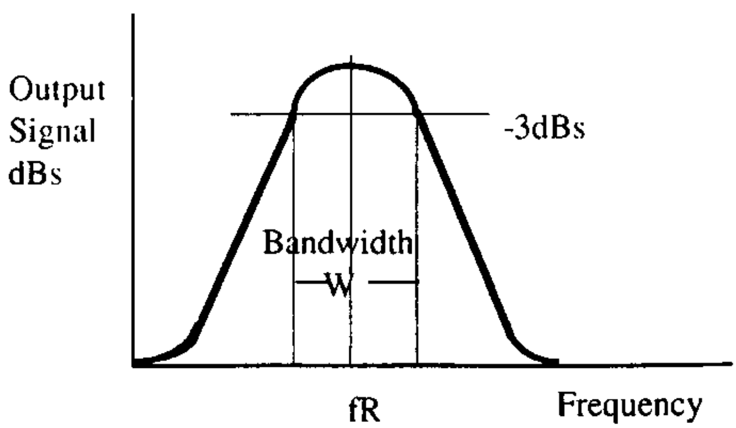


Figure 19.7

receiver to be blanked as the transmission pulse is transmitted to protect the receiver circuits. The head can either be mechanically or electrically scanned and the returns are usually displayed on a computer monitor where they can be logged on computer disks.

19.17.6

The advantages of these are that they are cheap, small and because the data communications protocol allow multiple devices such as altimeters and profilers to be connected to a single twisted pair, simple to install and versatile.

19.17.7

The disadvantages are that they transmit only one frequency making them a compromise between range and resolution, and also it is not possible to judge the range by an audible output.

19.18.0 Example of Ramped Frequency Sonar

19.18.1 An example of a ramped frequency Sonar is the Ametek Sea Probe model 250A as fitted to many Scorpio vehicles. The transmitted pulse is a frequency ramp from 107 to 122 KHz. The transmitting and receiving heads are fitted to the front of the vehicle and scanning takes place as the head is turned either in sector scan mode or continuously by an electrical motor. The audio output represents sonar returns that have been converted into audio difference frequencies by the receiver and fed into the speaker. The same receiver output is further processed in the analyser and display circuits and is presented in PPI format on the CRT. Figure 19.8 shows the display unit for this sonar.

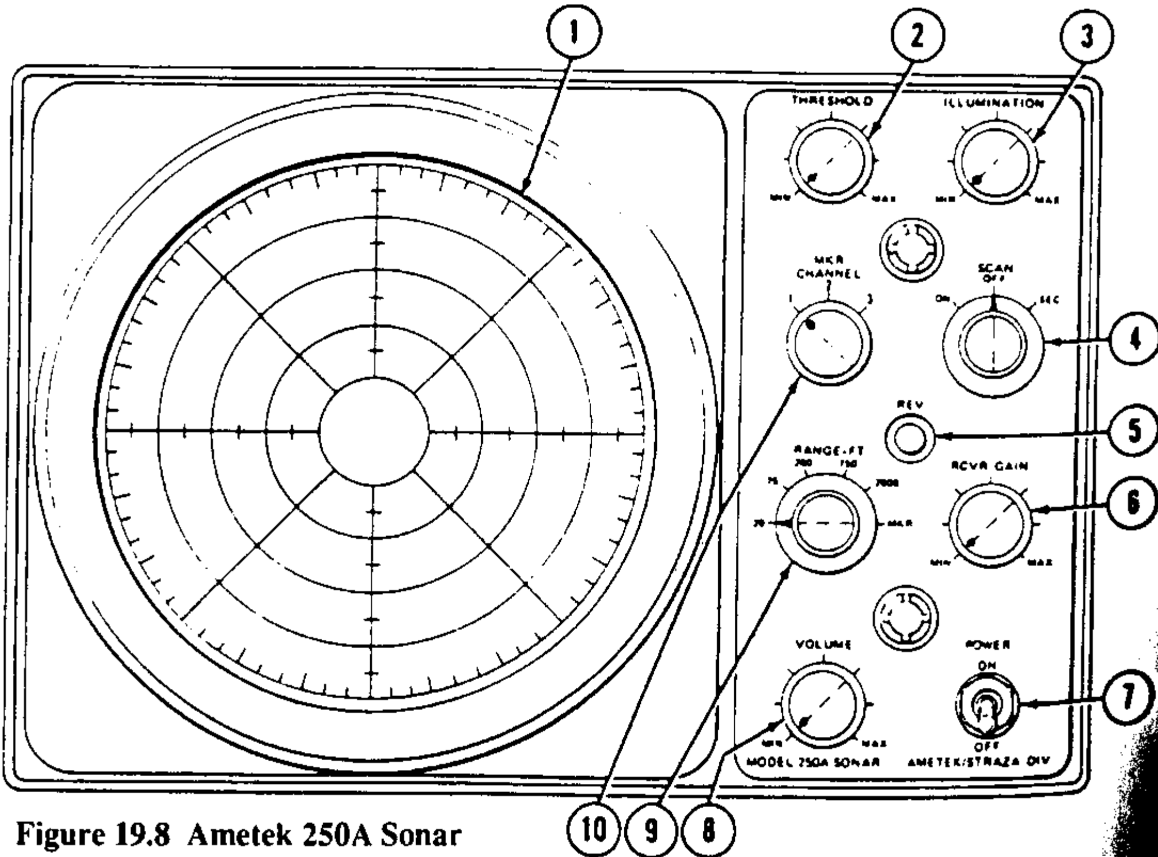


Figure 19.8 Ametek 250A Sonar

Q is the Quality Factor Q = fR/Bandwidth (W).

Q is important in the design of transducers and in an active Rx hydrophone the bandwidth W should be wide enough to accommodate the transmission frequency and the full range of Doppler shift while maintaining a high quality factor to attain satisfactory output signal levels. Transducers of the Electrostrictive type have capacitance and the only way to measure transducer deterioration is to measure the capacitance plus insulation and noise. Transducers are generally constructed from several smaller elements rather than one larger one for several reasons but primarily to enable directional coverage to be shifted from Mechanical Steering to Electrical Scanning, and to improve dependability although it also improves directivity and eases manufacture.

19.16.0 Trade-off:

19.16.1

In all cases the losses are higher the greater the frequency, this means that the Sonars with the highest frequencies have the shortests range. However the higher frequency sonars have greater Directivity enabling greater resolution to be obtained. This means that there is inevitably a 'trade-off' to be made between Resolution and Range when deciding a Sonars operating frequency.

19.17.0 Transmission pulses:

There are two basic types of transmission used in modern day Sonar:

19.17.1

The first transmits a frequency ramp and compares the frequency of the returning signal with that being transmitted (the difference frequency) to obtain the range.

19.17.2

The ramped frequencies are contained within a pulse and there is a blanking period between pulses.

19.17.3

The pulse repetition frequency (PRF) is increased as the range is decreased enabling the display (usually PPI) to use the same graticules on the CRT and simply to use a different scale.

19.17.4

A major advantage of this type is the fact that the difference signal can be amplified and listened to by the operator who can then judge the range of targets by the frequency; the lower the frequency the less is the difference frequency and therefore the closer the target. The disadvantage is that these are often more expensive than the simple pulse alternative.

19.17.5

The simple pulse type simply sends short pulses of sound at one frequency. The range is determined from the time taken for the pulse to return. It is usual for the

19.18.2

The operating controls of the Ametek 250A have the following functions:-

1. **CRT**: 7 inch CRT that represents target data in PPI format. Equipped with an illuminated graticule and filter. Graticule is graduated in 5 degree increments and marked every 45 degrees from 0 degrees relative with range rings for determination of target range.

2. **Threshold control**: Adjusts the level of intensity at which targets are displayed and sets the level for rejection of low amplitude video signals that are in the output of the analyzer. This control is effectively used to improve the signal to noise ratio of the displayed information by rejecting the low level signals and noise leaving only the stronger signals displayed.

3. **Illumination control**: Controls the brightness of the control panel and graticules on the display unit.

4. **Scan Switch**: Selects the transducer scan mode:

   ON position: Transducers scan continuously in a clockwise direction.

   OFF position: Transducer scan is halted.

   SEC position: Transducer scanning is a preset 90 degrees scan angle centred on 000 degrees automatically reversing at the scan limits.

5. **REV button**: When depressed, causes the scan to rotate in the counterclockwise direction. When released, scan is in the clockwise direction.

6. **RCVR GAIN**: Controls the gain of the Sonar and marker receiver circuit, thereby controlling the level of its output to the analyzer and audio circuits. Increasing the gain increases the level of the signals and the noise together thereby does not improve the signal to noise ratio.

7. **POWER Switch**: Controls the power to the Display Unit.

8. **VOLUME control**: Controls the loudness of the sound heard via the speaker or headset.

9. **RANGE FT**: Selects the operating range of the system or the **Marker** mode. Selectable ranges are; 0 - 20ft, 0 - 75ft, 0 - 200ft, 0 - 750ft and 0 - 2000ft.

10. **MKR Channel**: May be tuned to any frequency. Displays the direction but not the range to marker beacons.

The basic functions of these controls such as gain and threshold are similar for all Sonars and a full understanding of these functions are required by the operator.

19.19.0 Mechanically Scanned Simple Pulse Sonar

19.19.1

Examples of Mechanically Scanned Simple Pulse Sonars are the Tritech ST325, 525 and 725 Imaging and Obstacle Avoidance Sonars. A typical display for these is included as Figure 19.9 and the specifications are included as Figure19.10 It is important to note the 'trade-off' between range and resolution with these so that the correct Sonar can be selected for each job. For example the ST325 KHz has a range of 200 metres and a beamwidth of 4.5 degrees, the ST725 KHz has a shorter range of 100 metres but a greater resolution with a beamwidth of 2 degrees. In both cases the resolution can be improved by increasing the size of the transducers which narrows the beamwidth.

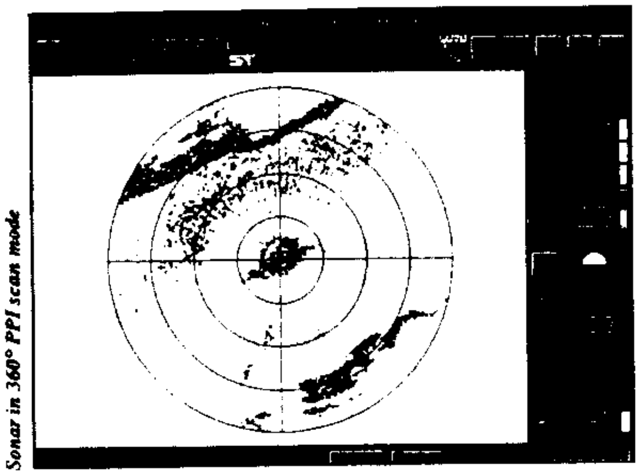


Figure 19.9 Sonar Display

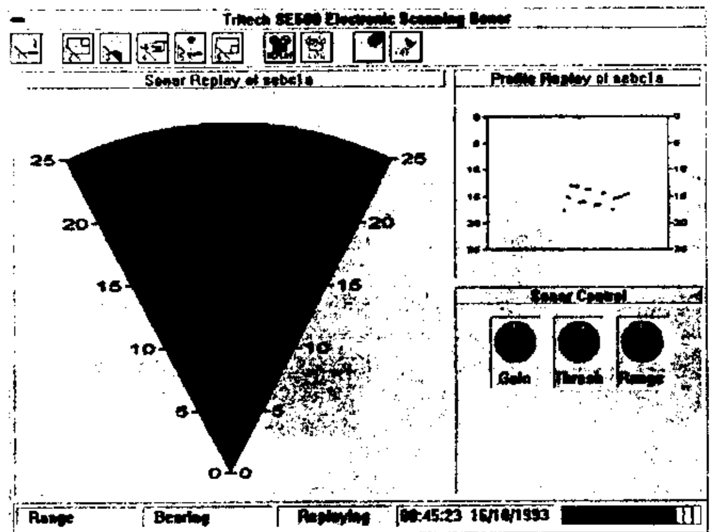
	ST325	ST525	ST725
Frequency	325kHz	525 kHz	725 kHz
Beamwidth, normal	4.5° x 24°	2.5° x 24°	2° x 24°
Beamwidth, Big Top	2.5° x 24°	1.2° x 24°	N/A
Maximum range	200 metres	150 metres	100 metres
Pulse width	60 - 1000μ sec.	60 - 1000μ sec.	60 - 1000μ sec.
Scan rate	8 - 40° sec.	8 - 40° sec.	8 - 40° sec.
Overall length	195 mm	195 mm	195 mm
Overall length, Big Top	199 mm	199 mm	N/A
Diameter	70 mm	70 mm	70 mm
Maximum diameter, Big Top	123 mm	123 mm	N/A
Weight in air	1 kg	1 kg	1 kg
Weight in water	0.5 kg	0.5 kg	0.5 kg
Depth rating	3000 metres	3000 metres	3000 metres
Communications	RS485, RS232	RS485, RS232	RS485, RS232
Long line drive	2,200 metres	2,200 metres	2,200 metres
Protection	Opto isolation Zener clamping	Opto isolation Zener clamping	Opto isolation Zener clamping
Power requirements	18 - 30 VDC @ 900mA max	18 - 30 VDC @ 900mA max	18 - 30 VDC @ 900mA max
Connector / penetrator	Tritech 6 pin	Tritech 6 pin	Tritech 6 pin

Figure 19.10 Tritech Sonar Specification

19.20.0 Electronically Scanning Sonar

19.20.1

An example of an Electronically Scanning Sonar is the Tritech SE500. An example of a display for this is shown in Figure 19.11. This has rapid Sonar image update rates but has the disadvantage of only allowing a 60 degree scan angle rather than the full 360 degrees. Figure 19.12 shows the Sonar head itself and the system specifications.



• *Sonar image of platform risers*

Figure 19.11 Tritech SE500 Electronically Scanned High Resolution Sonar Display

A compact, high speed imaging sonar for ROV, ROTV, MCM and other subsea operations that require very fast sonar image updates.

SE500 Sonar head

Sonar update rate, maximum	4 per second
Frequency	500 kHz
Sector Width	60°
Number of sonar beams	64
Vertical scan angle	13.4°
Optional vertical scan angles	3° - 13.4°
Horizontal beam width	2.7°
Maximum range	75 metres
Range resolution	100 mm (depending on range)
Beam forming method	Fast Fourier Transform
Data protocol	SDLC @ 375 kBaud
Data transmission	Screened, twisted pair
Length	265 mm
Diameter	100 mm
Power supply	24 VDC @ 2A
Depth rating	300 metres
Weight in air	2.5 kg
Weight in water	1.25 kg
Materials	Anodised aluminium, polyurethane

Figure 19.12 SE500 Head and Specifications

19.21.0 Multibeam Bathymetric Sonar

19.21.1

An example of a Multibeam Bathymetric Sonar system is the SeaBat 9001, shown in Figure 19.13. This Sonar system displays and updates the sonar image and a full digitised profile of the seabed in real time. The high data density allow total area coverage within a 'footprint' of 90 by 1.5 degrees making it suitable for such applications as sea floor mapping.

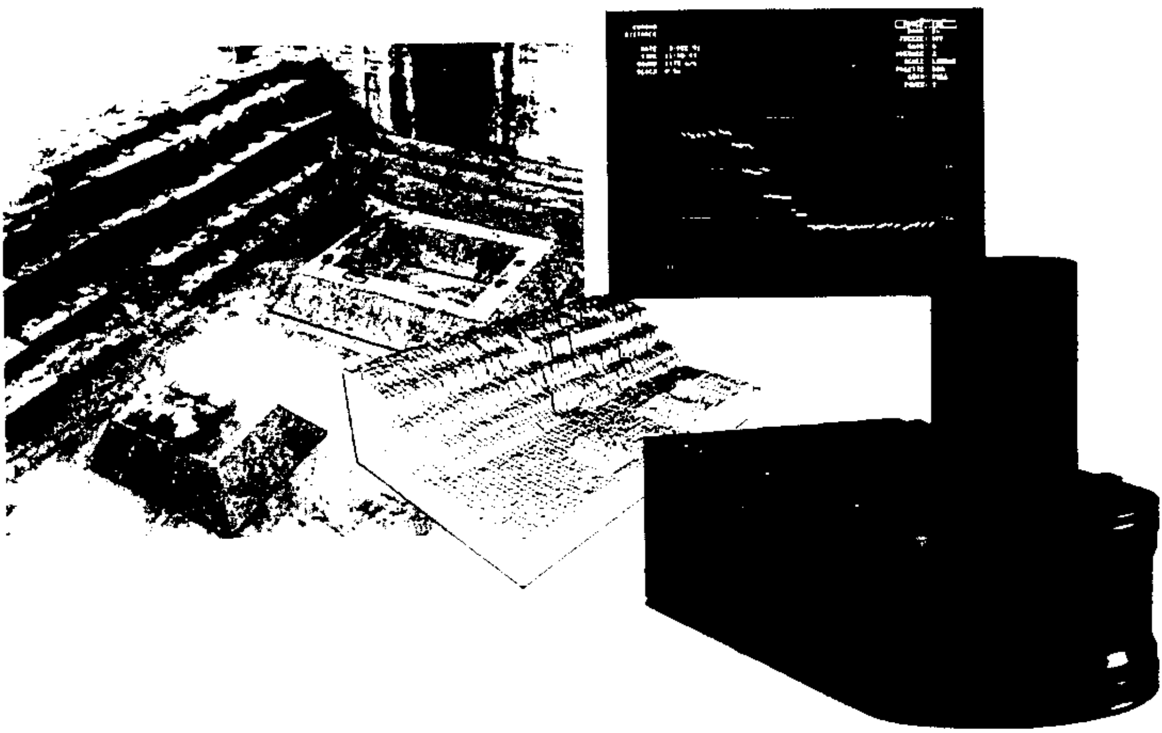


Figure 19.13 Reson, SeaBat 9001 Multibeam Bathymetric Sonar System

19.22.0 Scanning profiling Sonars

19.22.1

An example of a multihead (usually dual) Scanning Profiler display is shown in 19.14. The Sonar is used to scan vertically downwards to determine the profile of the sea bed and any feature such as a pipeline that may be across it.

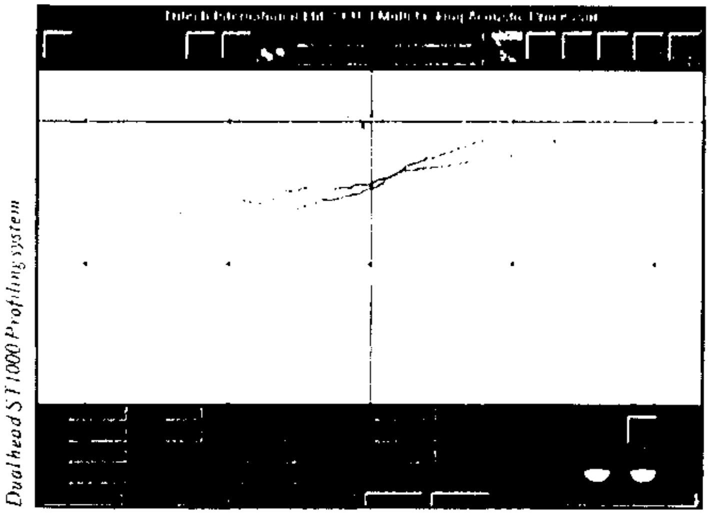


Figure 19.14 Tritech ST1000 Multi-Head Scanning profiler Display

19.23.0 Altimeters

19.23.1 Figure 19.15 shows an example of an acoustic altimeter. Altimeters are used on ROVs to determine the height of the vehicle from the sea bed.

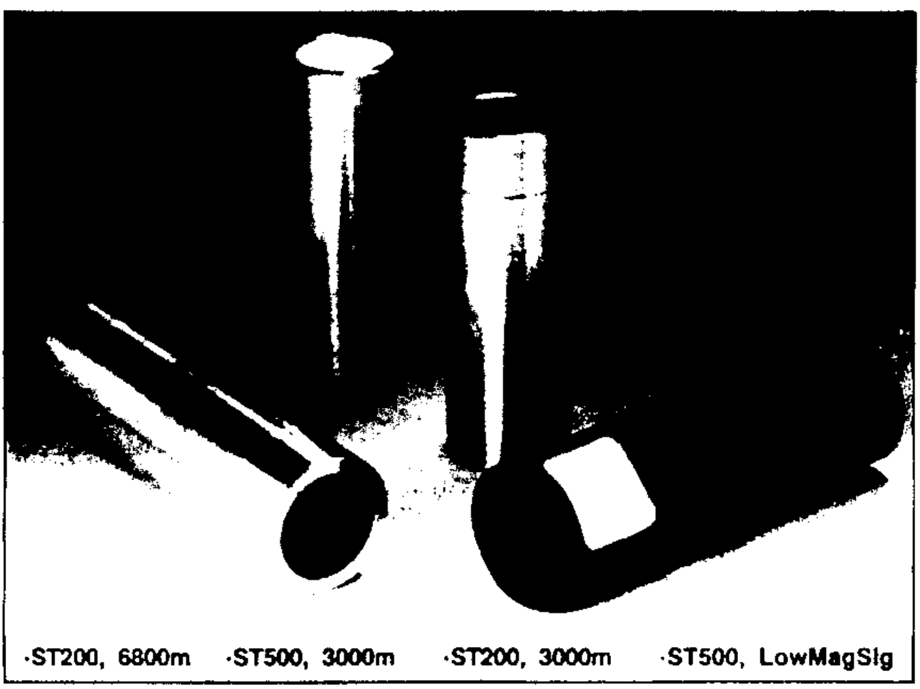


Figure 19.15 Tritech ST200 and ST500 Precision Altimeters

19.24.0 Doppler Sonar

19.24.1 The Doppler Sonar works on the principle that their transmitted frequency appears to increase or decrease if there is relative movement of the Sonar with respect to the water column or seabed to precisely determine speed and distance moved. Figure 19.16 shows the Tritech DS30 Doppler Sonar and Figure 19.17 shows the technical specifications of this sonar.

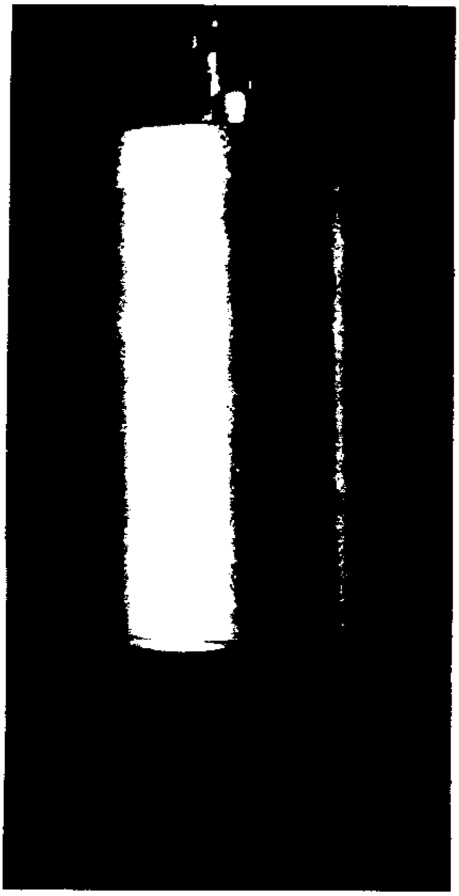


Figure 9.16 Tritech DS30 Doppler Sonar Unit

Operating frequency	1 MHz
Transducer	4 transducer JANUS array
Operating mode	Pulse Doppler
Operating range (for seabed tracking)	2 metres to 30 metres
Tracking modes	Seabed and Seawater
Operating voltage	12 VDC to 48 VDC
Velocity	±0 to 3.75 m/sec
Velocity accuracy	±2.5 cm/sec
Velocity resolution	±0.5 cm/sec
Update rate	5 updates/sec
Length (inc. connector)	365mm
Minimum diameter	95mm
Depth rating	3,000m
Weight in air	5kg
Weight in water	2kg
Communications	RS-232/RS-485
Analogue output	0-3.75 VDC

Figure 19.17 Tritech DS30 Doppler Sonar Specifications

19.25.0 Use of the Sonar

19.25.1 It is important to ensure that the Sonar is correctly installed and maintained prior to testing. In particular the transducer heads should be wiped clean as grease or oil will impair performance and if the head is oil filled this should be kept clean and water free.

19.25.2 Sonars can be tested in air by turning them on and observing that the head scans correctly, placing targets in the beam path in close proximity to the head should indicate Sonar transmit and receive circuitry is operating correctly. The Sonar manual should be referred to, prior to these tests, as some models will overheat if operated for too long in air.

19.25.3 After a successful surface test the vehicle can be deployed. Sonars will only show echoes that reflect sound back, such that hard shiny surfaces are sometimes only seen when they are at right angle to the Sonar head, and rough seabed textures can blot out smaller targets completely.

19.25.4 The plan view also does not show how high an object is unless a shadow is cast, in which case the length of the shadow is related to the height of the object, its range, and the height of the Sonar head. Interpretation of Sonar data develops with experience. Sonar reflections of isolated small objects give no indication of shape or attitude. Man made structures, such as Platforms or Pipelines tend to have regular patterns which are easier to identify.

19.25.5 Using a Sonar is rather like looking at a world made of shiny black plastic, in the dark, with only a narrow torch beam for illumination, targets only show when the beam shines on them directly at right angles.

19.25.6 Remember that when close to large objects, or in a depression in the seabed, that the viewing range may be severely limited. Very strong reflectors may give multiple echoes along a bearing line and are identified by being equispaced in range. If they persist, reduce the Gain. Fish also produce excellent echoes due to their air sacs and can often obliterate targets.

19.25.7 When searching for objects, keep the vehicle heading as steady as possible to stop the image blurring. Sit on the sea bed if necessary. If using a sidescan mode for searching, keep the vehicle steady, at longer ranges fly the vehicle a few metres above the sea bed to improve the detection range and quality. Depending on water depth and vehicle depth, there may be ring like echoes. These can be caused by surface or sea bed direct reflections and may be difficult to avoid.

19.25.8 Experience with Sonar will enable the operator to be able to quickly set the Gain, Threshold and Range controls to give as even a background as possible, without swamping the display, thus maximising the Sonars performance capabilities.

CHAPTER 20 QUALITY ASSURANCE (QA) SCHEMES

20.1.0 Background to QA Schemes

20.1.1

The revolution in the quality of Japanese products, and their consequent increase in Global market share, has brought about the general belief throughout business that 'Quality Matters'. This belief has permeated into the Offshore industry and it is now normal for Operators to require their suppliers to be registered for a recognised Quality Assurance scheme. The standard that is relevant to ROV Contractors is assessed by the British Standards Institute, a British National Accreditation Council Certified Body and is known as BS5750 Part 1 which is the same as international standard ISO9001 and the European standard EN 29001. This standard first appeared in 1979 as BS5750 which was based on the ministry of defence 05 series of standards which was updated with a less prescriptive, more flexible framework in 1987. It is this standard that is now accepted as the international standard ISO9000 which provides a practical action plan for managers to implement quality standards without becoming confused by the intangibles and vagaries of the so called 'management experts'. The remainder of this chapter will refer to this standard as ISO9000.

20.1.2

These Quality Assurance standards are a means of ensuring an agreed level of quality throughout the service contract from bidding through to job completion/reporting and serve to reassure the client that the performance of the contract will be carried out to agreed performance and reporting standards. There is a general conception offshore, that these Quality Assurance schemes are a 'paperwork exercise' and 'something that only affects the office'. It is the intention of this chapter to explain the quality management system and its relevance to offshore ROV work as a means to raising operational standards and reducing equipment 'downtime'.

20.1.3

ISO9000 is fundamentally a set of quality policy statements, management procedures and work place references, this is the accepted standard of Quality Assurance but is only part of Total Quality Management (TQM). TQM is an all encompassing ideal that includes attitude assessment and a commitment to total quality throughout an organisation. Companies that have achieved ISO9000 can further improve quality through the implementation of TQM and many ROV contractors are striving to achieve this.

20.2.0 The Quality Management System

20.2.1

The quality management system can be thought of as a three level structure as shown in **Figure 20.1.** The three levels are linked together by quality records and the auditing process.

20.2.2

Level 1 is the Senior management level where policy, plans and strategic decisions are made. The **Quality policy manual** covers the quality policies and plans coming from the Senior level of management..

20.2.3

Level 2 is the middle or operational management level which will include the Offshore Superintendent or Team Leader and the Onshore Project Manager. This key group will be responsible for the interpretation and implementation of the quality policies and the development of workable procedures for everyone to follow. The **Quality Procedures Manual** covers all the procedures which are developed and implemented at this middle level of the organisation.

20.2.4

The **Quality Policy Manual** and the **Quality Procedures Manual** together with a guide to workplace references are often referred to by the generic term:- The **Quality Management Manual**

20.2.5

The third level is the workforce which includes the operational team itself. The workforce will follow the procedures and consult the **Workplace Reference Documents**.

	Organisational level	Documentation	
Level 1	**Planning and Policy**	**Quality Policy Manual**	**Quality Management Manual**
Level 2	**Management and Procedures**	**Quality procedures or Operations manual**	
Level 3	**Task**	**Workplace References**	

FIGURE 20.1

20.3.0 The Quality Policy Manual

20.3.1 This is usually divided into six sections:-

i) Introduction

ii) Policy Statements

iii) Organisational Structure

iv) Management Responsibility and Authority

v) Management Review

vi) The Quality Management System and it relationship to ISO9000.

20.3.2

The organisations quality programme is put into context in the **introduction** by introducing the organisation and its quality management system.

20.3.3

There are usually two **Policy Statements,** the **Mission Statement** and the **Quality Policy Statement**

An example of a **Mission Statement** might be:- Company 'x' undertakes to deliver the highest technology service possible to the customers satisfaction any where in the world. 'World-wide service attempted with perfection'.

An example of a **Quality Policy Statement** might be:- It is the Policy of Company 'x' to: Provide products and services which meet our clients requirements, by the implementation and maintenance of a cost effective Quality Management system based on the concept of 'Total Quality' in which every member of staff has and accepts a personal responsibility for quality. These policy statements are usually signed by the senior management of the organisation to indicate their commitment and support for them.

20.3.4

The **organisational structure** section of the Policy Manual will describe how the organisation works. This will include an organisational chart which will show:-

i) How the lines of authority throughout the organisation are organised around projects or functions such as; sales or operations.

ii) How many lines of authority there are, and the titles of the roles in the hierarchy.

iii) What formalised direct and cross-reporting relationships exist between lines of management responsibility.

In addition to showing management roles the chart will show the roles which are important for the Quality Management system such as the Quality Manager and Quality Inspectors.

20.3.5

The **Management Responsibility and Authority** section will describe in further detail the responsibilities and reporting relationships of the roles identified in the organisational chart.

20.3.6

The **Management Review** section will describe the system by which senior management will evaluate the Quality Management system.

20.3.7

The **Quality Management system and its conformance with ISO9000 requirements** section will describe the scope of the Quality Management System and its relationship with ISO9000 requirements. The scope may be limited by the fact that only some divisions of the company are registered and by the fact that product supply and design companies are covered by ISO9001/BS5750 Part 1 whilst Production and Installation companies are covered by ISO9002/BS5750 Part 2. In the case of ROV contracting companies; the whole company is usually covered by ISO9001/BS5750 Part 1.

20.4.0 The Quality Procedures Manual

20.4.1

The **Quality Procedures Manual** is often referred to as the **Operations Manual** It is primarily intended for the use of the organisations 'middle management' and will define and describe the management processes in the organisation and the procedures that must be followed to make these processes work smoothly. This manual is the operational heart of the quality management system and sets up a detailed model of how the organisation should operate.

20.4.2

The **Management processes** section will describe the main groups of management activities such as:- Sales and marketing, contracts, project management and the role of the offshore supervisor or Team Leader who may be considered as a member of the management team. The management processes for service providers such as ROV Contractors are usually 'customer driven'. This means that the management teams will behave in a way that provides the maximum satisfaction for the client. Some areas of the organisation may also be 'technology driven' such a research and development.

20.4.3

The **Quality Management Procedures** section of the Quality Procedures manual are often referred to simply as: 'the Procedures'. The procedures are there to inform people how to implement all the management activities that are to be done in the organisation. The procedures are there to ensure that all the people across the organisation do things in the same way which fits with how other people are working. The procedures will include:-

i) How all the management activities are carried out.

ii) Who will carry out all these activities.

iii) How the activities are to be documented.

iv) A list of the workplace instructions that will be needed for reference and their location.

Procedures will be focused on management activities, such as; ensuring that contracts are carried out to the requirements of the client, and personnel selection, training and reward structures.

Training standards are considered to be extremely important, if quality procedures are to be followed, personnel must know how to follow them. It is preferred if training standards are verified by some form of external assessment to recognised standards such as National Vocational Qualification (NVQs). NVQs can be extremely useful as they are partly assessed on the ability of employees to follow workplace instructions as required by Quality Assurance schemes.

An important part of the operations manual will however be a description of the duties and responsibilities of personnel at every level. An example of a typical description of the duties of an ROV Operator/Maintainer (This is the same as Pilot/Technician and is the term preferred by Cable laying companies such as BT (Marine) Ltd from whose **Operation Manual** this was taken) is given below :-

JOB TITLE: OPERATOR/MAINTAINER

PURPOSE OF JOB: To undertake the safe operation of **Equipment** as directed by the Team Leader or Senior Operator/Maintainer.

ACCOUNTABLE TO: Senior Operator/Maintainer

DUTIES AND RESPONSIBILITIES

An Operator/Maintainer has a responsibility to:-

i) Protect personal health and safety, and to take all steps to safeguard others, in line with the BT (Marine) Health and Safety Policy.

ii) Understand the company concept of Total Quality Management, and to contribute to the continuing process of improvement.

iii) Have an awareness of the potential damage that can be caused by the various forms of environmental pollution, and to ensure that all work is carried out in accordance with the company policies on environmental protection.

iv) Undertake the safe operation of subsea **Equipment** as directed.

v) Undertake breakdown and routine maintenance work, as directed by the Senior Operator.

vi) Assist in maintaining records as required.

vii) Undertake maintenance and modification work on **Equipment**, as directed by the Senior Operator.

viii) Assist in mobilisation, as required

ix) Assist in the production of operating instructions.

xi) Assist in applying company quality assurance procedures.

x) Update stores and maintenance records as necessary.

NOTE: Equipment in the above case refers to the **Trencher, Plough, Scarab** and other specialised tools and associated equipment operated by BT (Marine) Ltd. This will vary from contract to contract and company to company depending on the equipment operated.

20.5.0 Workplace References

20.5.1

The Quality Policy and Quality Procedures manuals are provided primarily for the middle and senior management level of an organisation, and as such are unlikely to be referred to regularly by the ROV Pilot/Technician, except to gain an understanding of the policies and management procedures as they affect his job. Whilst it is important for the Pilot/Technician to be aware of these it is the workplace references that will be most essential to ensuring that he carries out his responsibilities to the prescribed quality standards.

20.5.2

The ISO9000 standard requires that personnel know exactly what reference materials they are likely to need and where to find them. It is also extremely important that these reference documents are kept up-to-date and complete.

20.5.3

Workplace references can be either **internally** or **externally** generated. Examples of **internally** generated workplace references are:-

i) Forms

ii) Technical Manuals

iii) Technical Instructions

iv) Technical Drawings

v) Instructions and Checklists

VI) Internal Specifications and Standards

vi) Methodologies for Testing

vii) Reference and Research Materials

20.5.4

Examples of **Forms** would include: Daily reports, Dive Logs and Equipment maintenance logs.

20.5.5

Examples of **Technical Manuals** would include: the Manuals provided by manufacturers for specific equipment.

20.5.6

Examples of **Technical Drawings** would include: working drawings for the equipment. NOTE: It is particularly important to modify these drawings and man[illegible] as modifications are undertaken on the systems, for the benefit of other crews.

20.5.7

Examples of **Instructions and Checklists** would include: Pre/Post Dive Checklists.

20.5.8

Examples of **Internal Specifications and standards** would include: video acceptance standards and calibration standards.

20.5.9

Examples of **Methodologies for Testing** would include: calibration and equipment test procedures, and procedures for handling non-conformance's.

20.5.10

Examples of **Reference and Research Materials** would include: Details of equipment and methods under development, and areas of specialist knowledge available within the organisation. These would also include relevant periodicals and research reports.

20.6.0

Externally Generated Workplace References are the laws, standards and guidelines set by bodies which are outside your organisation, but which influence aspects of what you do. Examples of externally generated workplace references are:-

i) Legislation.

ii) Industry standards, codes of practice and trade association guidelines.

iii) Customer Specifications

iv) National Vocational Qualifications work instructions or books such as this.

20.6.1

Examples of **legislation** would include Health and Safety legislation such as Statutory Instruments (SI)1019, the health and safety at work act SI 840 and the Control of Substances Hazardous to Health regulations (COSHH).

20.6.2

Examples of **Industry Codes of Practice** include those issued by the AODC such as 'The Safe use of Electricity underwater' and 'ROV Handling Systems'.

20.6.3

Examples of **Customer Specifications** include 'Scopes of Work' on Inspection contracts or similar specifications for Ploughing/Cable laying or drill support activities.

20.6.4

Examples of **National Vocational Qualifications** might include the EnTra engineering maintenance work instructions or similar if developed for this specific industry. They may also include training notes or handbooks such as this.

20.7.0

It is important that a **guide to workplace references** exists and is easily available at every work site. It is also important that the Quality Procedures Manual refers to the workplace references wherever they form part of the procedures and further specific procedures for modifying and updating these workplace references.

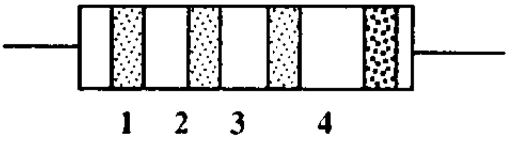
20.8.0

In conclusion it is essential for the ROV Pilot/Technician to understand the importance of following procedures, consulting workplace references and internalising the concept of 'Total Quality Management' for the successful completion of contracts to the satisfaction of the client, to ensure the safety and proper operation of the equipment and to safeguard their own welfare.

Appendices

Appendix A Resistor Colour Codes

Number	Colour
0	Black
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Grey
9	White



Band 1 = Ist Number

Band 2 = 2nd Number

Band 3 = No. of zero's

Band 4 = Tolerances

Gold = ± 5%

Silver = ± 10%

No Colour = ± 20%

Appendix B Electrical Formula

RL Circuit (Series) Impedence

$$Z = \sqrt{R^2 + (X_L)^2}$$

R, C, and L Circuit (Series) Impedance

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

1) Sine-Wave Voltage Relationships

Effective or r.m.s Value

$$E_{eff} = \underline{E_{max}} = \underline{E_{max}} = 0.707E_{max}$$

Maximum Value

$$E_{max} = \sqrt{2}\,(E_{eff}) = 1.414\,E_{eff}$$

AC Circuit Voltage

$$E = IZ = \frac{P}{1 \times P.F}$$

AC Circuit Current

$$1 = \frac{E}{Z} = \frac{P}{E \times P.F}$$

2) AC Circuit Power

Apparent Power

$$P = EI$$

True Power

$$P = EI \cos\theta = EI \times P.F.$$

Power Factor

$$P.F. = \frac{P}{EI} = \cos\theta$$

$$\cos\theta = \frac{\text{true power}}{\text{apparent power}}$$

3) Transformers

Voltage Relationship

$$\frac{E_p}{E_s} = \frac{N_p}{N_s} \quad \text{or} \quad E_s = E_p \times \frac{N_s}{N_p}$$

Current Relationships

s = Secondary

p = Primary

N = Number of turns

$$\frac{I_p}{I_s} = \frac{N_s}{N_p}$$

Parallel Circuit Impedance

$$Z = \frac{Z_1 Z_2}{Z_1 + Z_2}$$

Appendix C Formulas and Data (Hydraulic)

1. Hydraulics is a means of transmitting power. It may be used to multiply force or modify motions.

2. PASCAL'S LAW: Pressure exerted on a confined fluid is transmitted undiminished in all directions and acts with equal force on all equal areas and at right angles to them.

3. To find the area of a piston (circle), square the diameter and multiply by .7854. $A = D^2 \times .7854$.

4. The force (pounds) exerted by a piston can be determined by multiplying the piston area (square inches) by the pressure applied (PSI). $F = P \times A$

5. To determine the volume of liquid (cubic inches) required to move a piston a given distance, multiply the piston area (sq. inches) by the stroke required (inches). Vol. = $A \times L$.
   231 cubic inches = One U.S. Gallon

6. Work is force acting through a distance. WORK = FORCE × DISTANCE.
   Example: Work (in. lbs.) = Force (lbs.) × Distance (in.)

7. Power is the rate of doing work. $\text{Power} = \dfrac{\text{Work}}{\text{Time}} = \dfrac{\text{Force} \times \text{Distance}}{\text{Time}}$

8. Hydraulic oil serves as a lubricant and is practically non-compressible. It will compress approximately 0.4 of 1% at 1000 PSI and 1.1% at 3000 PSI at 120°F.

9. The weight of hydraulic oil may vary with a change in viscosity. However, 55 to 58 lbs. per cubic foot covers the viscosity range from 150 SSU to 900 SSU at 100°F.

10. Pressure at the bottom of a one foot column of oil will be approximately 0.4 PSI. To find the approximate pressure at the bottom of any column of oil, multiply the height in feet by 0.4.

11. Atmospheric pressure equals 14.7 PSIA at sea level.

12. Gauge readings do not include atmospheric pressure unless marked PSIA.

13. There must be a pressure drop (pressure difference) across an orifice or other restriction to cause flow through it. Conversely, if there is no flow, there will be no pressure drop.

14. A fluid is pushed, not drawn, into a pump.

15. A pump does not pump pressure; its purpose is to create flow. Pumps used to transmit power are usually positive displacement type.

16. Pressure is caused by resistance to flow. A pressure gauge indicates the workload at any given moment.

17. Fluids take the course of least resistance.

18. Speed of a cylinder piston is dependent upon its size (piston area) and the rate of flow into it.

    $\text{Velocity (inches/min.)} = \dfrac{\text{Flow (cu. inches/min.)}}{\text{Area (sq. in.)}}$ OR

    Flow = Velocity × Area

19. Flow velocity through a pipe varies inversely as the square of the inside diameter. Doubling the inside diameter increases the area four times.

20. Friction losses (pressure drop) of a liquid in a pipe vary with velocity.

21. To find the actual area of a pipe needed to handle a given flow, use the formula:

$$\text{Area (sq. in.)} = \frac{\text{GPM} \times .3208}{\text{Velocity (Ft./Sec.)}} \quad \text{OR}$$

$$\text{Velocity (Ft./Sec.)} = \frac{\text{GPM}}{3.117 \times \text{Area (sq. in.)}}$$

22. The actual inside diameter of standard pipe is usually larger than the nominal size quoted. A conversion chart should be consulted when selecting pipe.

23. Steel and copper tubing size indicates the outside diameter. To find the actual inside diameter, subtract two times the wall thickness from the tube size quoted.

24. Hydraulic hose sizes are usually designated by their nominal inside diameter. With some exceptions, this is indicated by a dash number representing the number of sixteenth inch increments in their inside diameter.

25. One H.P. = 33,000 ft. lbs. per minute or 33,000 lbs. raised one foot in one minute. One H.P. = 746 watts. One H.P. = 42.4 BTU per minute.

26. To find the H.P. required for a given flow rate at a known pressure, use the formula:

$$\text{Pump Output H.P.} = \text{GPM} \times \text{PSI} \times .000583 = \frac{\text{GPM} \times \text{PSI}}{1714}$$

To find the H.P. required to drive a hydraulic pump of a given volume at a known pressure, use the formula:

$$\text{Pump Input H.P.} = \frac{\text{GPM} \times \text{PSI} \times .000583}{\text{Pump Efficiency}} = \frac{\text{GPM} \times \text{PSI}}{1714 \times \text{Pump Efficiency}}$$

If actual pump efficiency is not known, use the following rule of thumb formula for Input H.P.:

$$\text{Input H.P.} = \text{GPM} \times \text{PSI} \times .0007$$

27. The relationship between Torque and H.P. is:

$$\text{Torque (lb. in.)} = \frac{63025 \times \text{H.P.}}{\text{RPM}} \quad \text{OR}$$

$$\text{H.P.} = \frac{\text{Torque (lb. in.)} \times \text{RPM}}{63025}$$

28. To determine the pump capacity (GPM) needed to extend a cylinder piston of a given area (sq. in.) thru a given distance (inches) in a specific time (seconds):

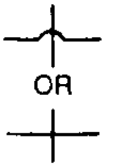
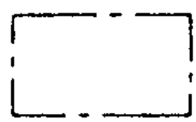
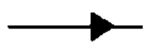
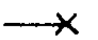
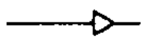
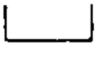
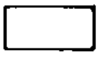
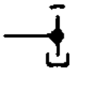
$$\text{GPM} = \frac{\text{Piston Area (sq. in.)} \times \text{Length (inches)} \times 60 \text{ sec.}}{\text{Time (seconds)} \times 231 \text{ cu. in.}}$$

Appendix D Meteric Unit For Fluid Power Application

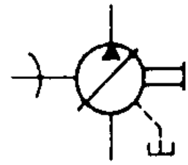
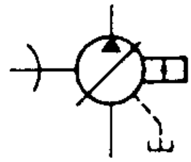
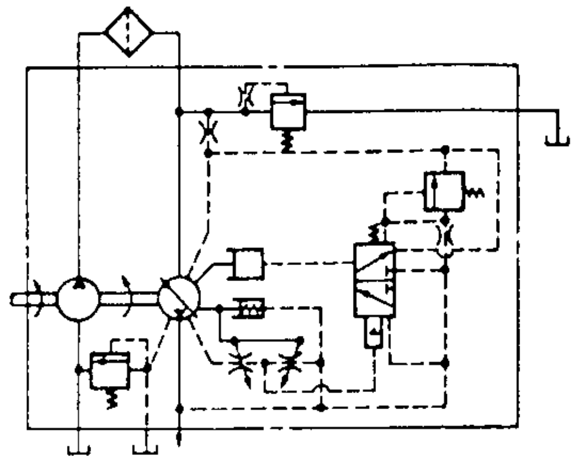
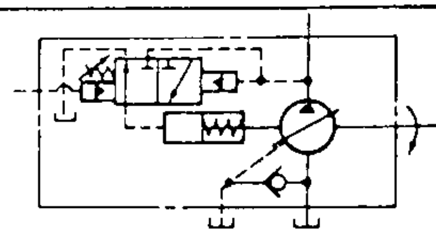
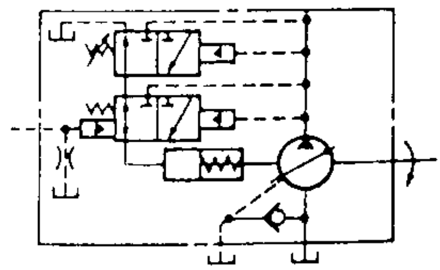
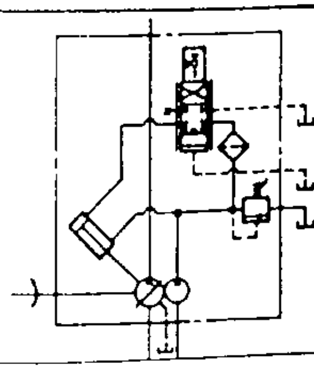
QUANTITY NAME	METRIC UNITS	SYMBOLS	U.S. CUSTOMARY SYMBOLS
Acceleration	metre per second squared	m/s^2	ft/sec^2
	degree	°	°
Angle, Plane	minute	'	'
	second	"	"
Area	square millimetre	mm2	mm2
Conductivity,Thermal	watt per metre kelvin	W/m •K	Btu/hr •ft °F
Current, Electric	ampere	A	A
hydraulic fluids & other liquids	kilogram per litre	kg/L (Note 1)	lb/gal
Density gases	kilogram per cubic m	kg/m3	lb/ft3
solids	gram per cubic cm	g/cm3	lb/ft3
Displacement pneumatic	cubic cm	cm3	in3
	litre	L	gal
(unit discharge)			
hydraulic	mm	mL	in3
Efficiency	percent	%	%
Energy, Heat	kilojoule	kJ	Btu
Flow Rate, Heat	watt	W	Btu/min
	gram per second	g/s	lb/min
Flow Rate, Mass	kilogram per second	kg/s	lb/s
Pneumatic	cubic decimetre per sec	dm3/s	ft3/min (cfm)
Flow Rate, volume	cubic centimetre per sec	cm3/S	in3/min (cim)
	Litre per minute	L/min	gal/min
hydraulic	millimetre per minute	mL/min	in3/min
Force	newton	N	lb
Force per Length	newton per mm	N/mm	lb/in
	hertz	HZ	Hz (cps)
Frequency (Cycle)		1/min	cpm
	reciprocal minute		
Frequency (Rotational)	reciprocal minute	1/min	rpm
Heat	kilojoule	kJ	Btu
Heat Capacity, Specific	kilojoule per kilogram kelvin	kJ/kg•K	Btu/lb.°F
Heat Transfer, Coefficient	watt per square metre kelvin	W/m2•k	Btu/hr•ft2•°F
inertia, Moment of	kilogram metre squared	kg•m2	lb•ft2

Appendix E Hydraulic Symbols

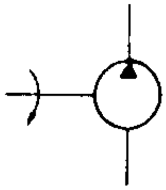
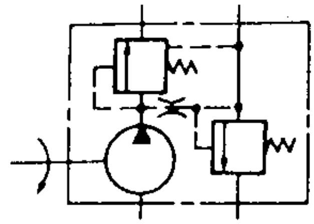
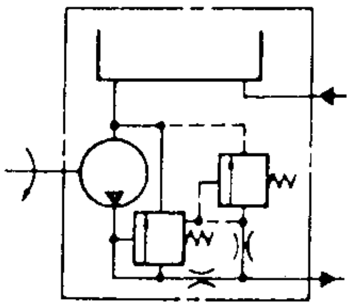
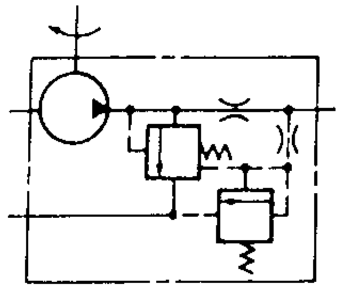
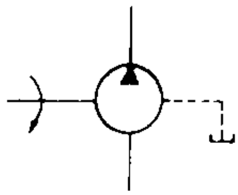
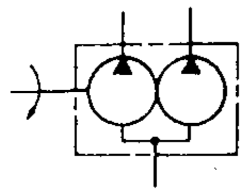
1) Lines

LINE, WORKING (MAIN)		LINES CROSSING	
LINE, PILOT (FOR CONTROL)		LINES JOINING	
LINE, LIQUID DRAIN		LINE WITH FIXED RESTRICTION	
COMPONENT ENCLOSURE		FLEXIBLE	
HYDRAULIC FLOW		STATION, TESTING, MEASUREMENT, POWER TAKE-OFF, OR PLUGGED PORT	
PNEUMATIC FLOW			
FLUID STORAGE			
RESERVOIR, VENTED		LINE, TO RESERVOIR • ABOVE FLUID LEVEL • BELOW FLUID LEVEL	
RESERVOIR, PRESSURIZED		VENTED MANIFOLD	

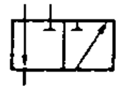
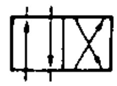
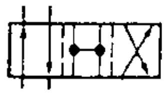
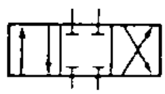
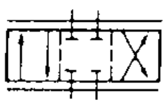
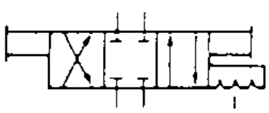
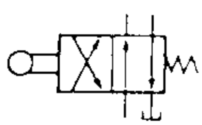
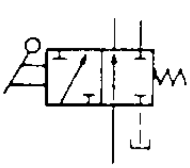
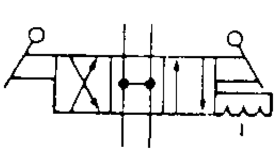
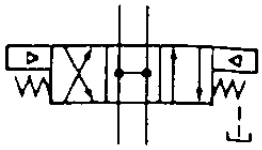
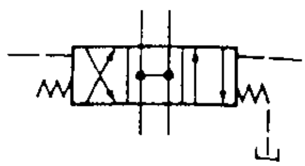
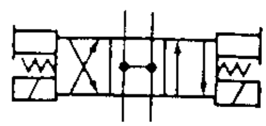
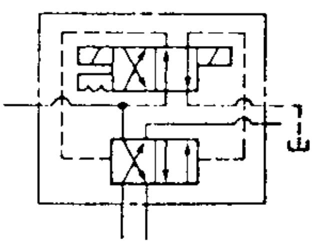
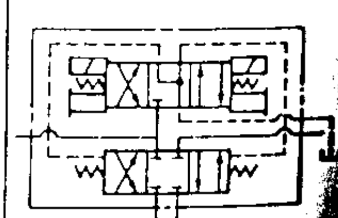
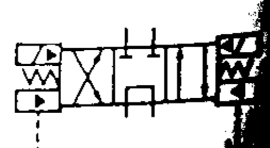
2) Variable displacement pumps

MANUAL, HANDWHEEL CONTROL	
PRESSURE COMPENSATOR CONTROL	
PRESSURE COMPENSATOR AND TORQUE LIMITER	
LOAD SENSING CONTROL	
LOAD SENSING AND PRESSURE LIMITER CONTROL	
ELECTRO-HYDRAULIC CONTROL	

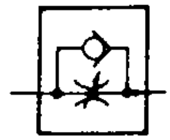
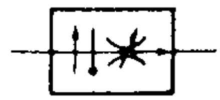
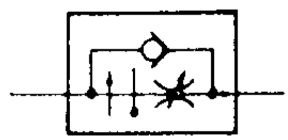
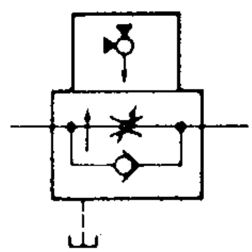
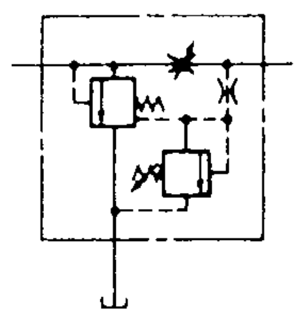
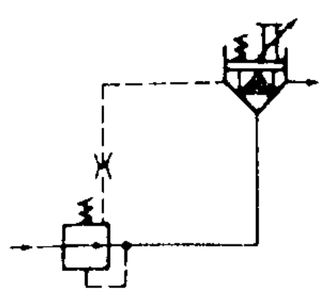
3) Fixed displacement pumps

SINGLE, VANE & GEAR TYPE		SINGLE, WITH INTEGRAL PRIORITY VALVE	
SINGLE, POWER STEERING PUMP WITH INTEGRAL FLOW CONTROL AND RELIEF VALVES		SINGLE, WITH INTEGRAL FLOW CONTROL VALVE	
SINGLE, PISTON TYPE WITH DRAIN		DOUBLE, VANE AND GEAR TYPE	

4) Directional control valves

TWO POSITION TWO CONNECTION	
TWO POSITION THREE CONNECTION	
TWO POSITION FOUR CONNECTION	
TWO POSITION IN TRANSITION	
THREE POSITION FOUR CONNECTION	
VALVES CAPABLE OF INFINITE POSITIONING (HORIZONTAL BARS INDICATE INFINITE POSITIONING ABILITY)	
NO SPRING DETENTED, MANUALLY OPERATED	
SPRING OFFSET, MECHANICALLY OPERATED	
SPRING OFFSET, LEVER OPERATED— TWO WAY	
NO SPRING WITH DETENTS, LEVER OPERATED	
SPRING CENTERED, AIR OPERATED	
SPRING OR PRESSURE CENTERED, PILOT OPERATED	
SPRING CENTERED, SOLENOID OPERATED	
SOLENOID CONTROLLED, PILOT OPERATED	
SPRING CENTERED, SOLENOID CONTROLLED, PILOT OPERATED	
PRESSURE CENTERED, SOLENOID CONTROLLED, PILOT OPERATED (SIMPLIFIED SYMBOL)	

7) Flow Control valves

FLOW CONTROL, ADJUSTABLE— NON-COMPENSATED	
FLOW REGULATOR WITH REVERSE FREE FLOW	
FLOW CONTROL VALVE	
FLOW CONTROL VALVE WITH CHECK (SIMPLIFIED SYMBOL)	
REMOTE CONTROLLED, ELECTRICALLY MODULATED WITH CHECK VALVE	
FLOW CONTROL AND OVERLOAD RELIEF VALVE	
PRESSURE COMPENSATED CARTRIDGE VALVE TYPE	

Appendix F English - Metric Conversion Factors

To convert →		Into →		Multiply by
Into ←		To convert →		Divide by
Unit	**Symbol**	**Unit**	**Symbol**	**Factor**
Atmospheres	Atm	bar	bar	1.013250
BTU/hour	Btu/h	kilowatts	kW	0.293071×10^{-3}
Cubic centimetres	cm^3	litres	l	0.001
Cubic centimetres	cm^3	millilitres	ml	1.0
Cubic feet	ft^3	cubic metres	m^3	0.0283168
Cubic feet	ft^3	litres	l	28.3161
Cubic inches	in^3	cubic centimetres	cm^3	16.3871
Cubic inches	in^3	litres	l	0.0163866
Degrees (angle)	°	radians	rad	0.0174533
Fahrenheit	°F	Celsius (centigrade)	°C	
Feet	ft	metres	m	0.3048
Feet of water	ft H_2O	bar	bar	0.0298907
Fluid ounces, US	US fl oz	cubic centimetres	cm^3	29.5735
Foot pounds f.	ft lbf	joules	J	1.35582
Foot pounds/minute	ft lbf/min	watts	W	81.3492
Gallons, US	US gal	litres	l	3.78531
Horsepower	hp	kilowatts	kW	0.7457
Inches of mercury	in Hg	millibar	mbar	33.8639
Inches of water	in H_2O	millibar	mbar	2.49089
Inches	in	centimetres	cm	2.54
Inches	in	millimetres	mm	25.4
Kilogram force	kgf	newtons	N	9.80665
Kilogram f. metre	kgf m	newton metres	Nm	9.80665
Kilogram f./sq centimetre	kgf/cm^2	bar	bar	0.980665
Kilopascals	kPa	bar	bar	0.01
Kiloponds	kp	newtons	N	9.80665
Kilopond metres	kp m	newton metres	Nm	9.80665
Kiloponds/square centimetre	kp/cm^2	bar	bar	0.980665
Microinches	μin	microns	μm	0.0254
Millimetres of mercury	mm Hg	millibar	mbar	1.33322
Millimetres of water	mm H_2O	millibar	mbar	0.09806
Newtons/square centimetre	N/cm^2	bar	bar	0.1
Newtons/square metre	N/m^2	bar	bar	10^{-5}
Pascals (newtons/sq metre)	Pa	bar	bar	10^{-5}
Pints, US	US liq pt	litres	l	0.473163
Pounds (mass)	lb	kilograms	kg	0.4536
Pounds/cubic foot	lb/ft^3	kilograms/cubic metre	kg/m^3	16.0185
Pounds/cubic inch	lb/in^3	kilograms/cubic centimetre	kg/cm^3	0.0276799
Pounds force	lbf	newtons	N	4.44822
Pounds f. feet	lbf ft	newton metres	Nm	1.35582
Pounds f. inches	lbf in	newton metres	Nm	0.112985
Pounds f./square inch	lbf/in^2	bar	bar	0.06894
Revolutions/minute	r/min	radians/second	rad/s	0.104720
Square feet	ft^2	square metres	m^2	0.092903
Square inches	in^2	square metres	m^2	6.4516×10^{-4}
Square inches	in^2	square centimetres	cm^2	6.4516

$°C = 5(°F - 32)/9$

Fluid power equivalents

1 bar = 10^5 N/m^2
1 bar = 10 N/cm^2 = 1 dN/mm^2
1 pascal = 1 N/m^2
1 litre = 1000.028 cm^3
1 centistoke (cSt) = 1 mm^2/s
1 joule = 1 wattsecond (Ws)
Hertz (Hz) = cycles/second

Prefixes denoting decimal multiples or sub-multiples

For multiples

$\times 10^{12}$	tera	T
$\times 10^{9}$	giga	G
$\times 10^{6}$	mega	M
$\times 10^{3}$	kilo	k
$\times 10^{2}$	hecto	h
$\times 10$	deca	da

For sub-multiples

$\times 10^{-1}$	deci	d
$\times 10^{-2}$	centi	c
$\times 10^{-3}$	milli	m
$\times 10^{-6}$	micro	μ
$\times 10^{-9}$	nano	n
$\times 10^{-12}$	pico	p
$\times 10^{-15}$	femto	f
$\times 10^{-18}$	atto	a

Appendix G Hydraulic Fluids

Contaminant	Character	Source and Remarks
Acidic by-products	Corrosive	Breakdown of oil. May also arise from water-contamination of phosphate-ester fluids.
Sludge	Blocking	Breakdown of oil.
Water	Emulsion	Already in fluid or introduced by system fault or breakdown of oxidation-inhibitors.
Air	Soluble Insoluble	Effect can be controlled by anti-foam additives. Excess air due to improper bleeding, poor system design or air leaks.
Other oils	Miscible but may react	Use of wrong fluid for topping up, etc.
Grease	May or may not be miscible	From lubrication points.
Scale	Insoluble	From pipes not properly cleaned before assembly.
Metallic particles	Insoluble with catalytic action	May be caused by water contamination, controllable with anti-rust additives.
Paint flakes	Insoluble, blocking	Paint on inside of tank old or not compatible with fluid.
Abrasive particles	Abrasive and blocking	Airborne particles (remove with air filter).
Elastomeric particles	Blocking	Seal breakdown. Check fluid, compatibility of seal design.
Sealing compound particles	Blocking	Sealing compounds should not be used on pipe joints.
Sand	Abrasive and blocking	Sand should not be used as a filler for manipulating pipe bends.
Adhesive particles	Blocking	Adhesives or jointing compounds should not be used on gaskets.
Lint or fabric threads	Blocking	Only lint-free cloths or rags should be used for cleaning or plugging dismantled components.

2) ISO Viscosity grades for Hydraulic Oils

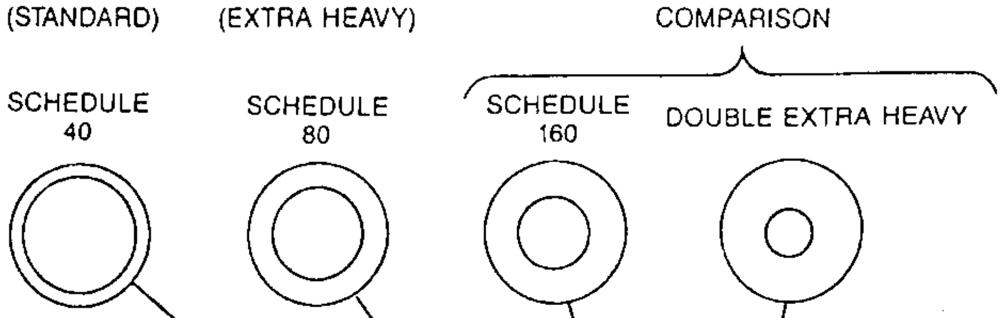
ISO Viscosity Grade	Midpoint Kinematic Viscosity cSt at 40°C	Kinematic Viscosity Limits cSt at 40°C Minimum	Maximum
ISOVG2	2.2	1.98	2.42
ISOVG3	3.2	2.88	3.52
ISOVG5	4.6	4.14	5.06
ISOVG7	6.8	6.12	7.48
ISOVG10	10	9.00	11.0
ISOVG15	15	13.5	16.5
ISOVG22	22	19.8	24.2
ISOVG32	32	28.8	35.2
ISOVG46	46	41.4	50.6
ISOVG68	68	61.2	74.8
ISOVG100	100	90.0	110
ISOVG150	150	135	165
ISOVG220	220	198	242
ISOVG320	320	288	352
ISOVG460	460	414	506
ISOVG680	680	612	748
ISOVG1000	1000	900	1100

3) Compatibility of Hydraulic fluids and sealing materials

		WATER-BASE FLUIDS		NON-WATER-BASE FLUIDS		
MATERIALS UNDER CONSIDERATION	PETROLEUM OILS	OIL AND WATER EMULSION	WATER-GLYCOL MIXTURE		PHOSPHATE ESTERS	
ACCEPTABLE SEAL AND PACKING MATERIALS	NEOPRENE, BUNA N	NEOPRENE, BUNA N, (NO CORK)	NEOPRENE, BUNA N, (NO CORK)		BUTYL, VITON*, VYRAM, SILICONE, TEFLON FBA	
ACCEPTABLE PAINTS	CONVENTIONAL	CONVENTIONAL	AS RECOMMENDED BY SUPPLIER		"AIR CURE" EPOXY AS RECOMMENDED	
ACCEPTABLE PIPE DOPES	CONVENTIONAL	CONVENTIONAL	PIPE DOPES AS RECOMMENDED, TEFLON TAPE			
ACCEPTABLE SUCTION STRAINERS	100 MESH WIRE 1-1/2 TIMES PUMP CAPACITY	40 MESH WIRE 4 TIMES PUMP CAPACITY	50 MESH WIRE, 4 TIMES PUMP CAPACITY			
ACCEPTABLE FILTERS	CELLULOSE FIBER, 200-300 MESH WIRE, KNIFE EDGE OR PLATE TYPE	GLASS FIBER, 200-300 WIRE, KNIFE EDGE OR PLATE	CELLULOSE FIBER, 200-300 MESH WIRE, KNIFE EDGE OR PLATE	CELLULOSE FIBER, 200-300 MESH WIRE, KNIFE EDGE OR PLATE TYPE (FULLER'S EARTH OR MIC[illegible] TYPE MAY BE USED ON NONADDITIVE FLUIDS)		
ACCEPTABLE METALS OF CONSTRUCTION	CONVENTIONAL	CONVENTIONAL	AVOID GALVANIZED METAL AND CADMIUM PLATING		CONVENTIONAL	

Appendix II Hydraulic Pipes

1) Pipe sizes by schedule number



NOMINAL SIZE	PIPE O.D.	INSIDE DIAMETER SCHED. 40	SCHED. 80	SCHED. 160	DOUBLE EXTRA HEAVY
1/8	.405	.269	.215		
1/4	.540	.364	.302		
3/8	.675	.493	.423		
1/2	.840	.622	.546	.466	.252
3/4	1.050	.824	.742	.614	.434
1	1.315	1.049	.957	.815	.599
1-1/4	1.660	1.380	1.278	1.160	.896
1-1/2	1.900	1.610	1.500	1.338	1.100
2	2.375	2.067	1.939	1.689	1.503
2-1/2	2.875	2.469	2.323	2.125	1.771
3	3.500	3.068	2.900	2.624	
3-1/2	4.000	3.548	3.364		
4	4.500	4.026	3.826	3.438	
5	5.563	5.047	4.813	4.313	4.063
6	6.625	6.065	5.761	5.189	
8	8.625	7.981	7.625	6.813	
10	10.750	10.020	9.564	8.500	
12	12.750	11.934	11.376	10.126	

2) Pressure rating of pipes

Nominal Pipe Size In.	Outside Diameter of Pipe -in.	Number of Threads Per Inch	Length of Effective Threads -in.	Schedule 40 (Standard)		Schedule 80 (Extra Heavy)		Schedule 160		Double (Extra Heavy)	
				Pipe ID-in.	Burst Press-PSI	Pipe ID-in.	Burst Press-PSI	Pipe ID-in.	Burst Press-PSI	Pipe ID-in.	Burst Press-PSI
1/8	0.405	27	0.26	—	—	—	—	—	—	—	—
1/4	0.540	18	0.40	.364	16,000	.302	22,000	—	—	—	—
3/8	0.675	18	0.41	.493	13,500	.423	19,000	—	—	—	—
1/2	0.840	14	0.53	.622	13,200	.546	17,500	.466	21,000	.252	35,000
3/4	1.050	14	0.55	.824	11,000	.742	15,000	.614	21,000	.434	30,000
1	1.315	11-1/2	0.68	1.049	10,000	.957	13,600	.815	19,000	.599	27,000
1-1/4	1.660	11-1/2	0.71	1.380	8,400	1.278	11,500	1.160	15,000	.896	23,000
1-1/2	1.900	11-1/2	0.72	1.610	7,600	1.500	10,500	1.338	14,800	1.100	21,000
2	2.375	11-1/2	0.76	2.067	6,500	1.939	9,100	1.689	14,500	1.503	19,000
2-1/2	2.875	8	1.14	2.469	7,000	2.323	9,600	2.125	13,000	1.771	18,000
3	3.500	8	1.20	3.068	6,100	2.900	8,500	2.624	12,500	—	—

Working pressures for various schedule pipes are obtained by dividing burst pressure by the safety factor.

3) Oil flow velocity in tubing

Figures in chart are GPM flow capacity of tubing, and were calculated from formula

$$GPM = \frac{V \times A}{0.3208}$$

V = Velocity (feet / second)

A = Inside square inch area of tube

Figures In Body of Chart are GPM Flows							
Tube O.D.	Wall Thick.	2 Ft/Sec	4 Ft/Sec	10 Ft/Sec	15 Ft/Sec	20 Ft/Sec	30 Ft/Sec
1/2	.035	.905 GPM	1.81 GPM	4.52 GPM	6.79 GPM	9.05 GPM	13.6
	.042	.847	1.63	4.23	6.35	6.47	12.7
	.049	.791	1.58	3.95	5.93	7.91	11.9
	.058	.722	1.44	3.61	5.41	7.22	10.8
	.065	.670	1.34	3.35	5.03	6.70	10.1
	.072	.620	1.24	3.10	4.65	6.20	9.30
	.083	.546	1.09	2.73	4.09	5.46	8.16
5/8	.035	1.51	3.01	7.54	11.3	15.1	22.6
	.42	1.43	2.85	7.16	10.7	14.3	21.4
	.049	1.36	2.72	6.80	10.2	13.6	20.4
	.058	1.27	2.54	6.34	9.51	12.7	19.0
	.065	1.20	2.40	6.00	9.00	12.0	18.0
	.072	1.13	2.26	5.66	8.49	11.3	17.0
	.083	1.03	2.06	5.16	7.73	10.3	15.5
	.095	.926	1.85	4.63	6.95	9.26	13.9
3/4	.049	2.08	4.17	10.4	15.6	20.8	31.2
	.058	1.97	3.93	9.84	14.8	19.7	29.6
	.065	1.88	3.76	9.41	14.1	18.8	28.2
	.072	1.75	3.51	8.77	13.2	17.5	26.4
	.083	1.67	3.34	8.35	12.5	16.7	25.0
	.095	1.53	3.07	7.67	11.5	15.3	23.0
	.109	1.39	2.77	6.93	10.4	13.9	20.8
7/8	.049	2.95	5.91	14.8	22.2	29.5	44.3
	.058	2.82	5.64	14.1	21.1	28.2	42.3
	.065	2.72	5.43	13.6	20.4	27.2	40.7
	.072	2.62	5.23	13.1	19.6	26.2	39.2
	.083	2.46	4.92	12.3	18.5	24.6	36.9
	.095	2.30	4.60	11.5	17.2	23.0	34.4
	.109	2.11	4.22	10.6	15.8	21.1	31.7
1	.049	3.98	7.96	19.9	29.9	39.8	59.7
	.058	3.82	7.65	19.1	28.7	38.2	57.4
	.065	3.70	7.41	18.5	27.8	37.0	55.6
	.072	3.59	7.17	17.9	26.9	35.9	53.8
	.083	3.40	6.81	17.0	25.5	34.0	51.1
	.095	3.21	6.42	16.1	24.1	32.1	48.2
	.109	3.00	6.00	15.0	22.4	29.9	44.9
	.120	2.83	5.65	14.1	21.2	28.3	42.4
1-1/4	.049	6.50	13.0	32.5	48.7	64.9	97.4
	.058	6.29	12.6	31.5	47.2	62.9	94.4
	.065	6.14	12.3	30.7	46.0	61.4	92.1
	.072	6.00	12.0	30.0	44.9	59.9	89.8
	.083	5.75	11.5	28.8	43.1	57.5	86.3
	.095	5.50	11.0	27.5	41.2	55.0	82.5
	.109	5.21	10.4	26.1	39.1	52.1	78.2
	.120	5.00	10.0	25.0	37.4	50.0	74.9
1-1/2	.065	9.19	18.4	45.9	68.9	91.9	138
	.072	9.00	18.0	45.0	67.5	90.0	135
	.083	8.71	17.4	43.5	65.3	87.1	131
	.095	8.40	16.8	42.0	63.0	84.0	126
	.109	8.4	16.1	40.2	60.3	80.4	121
	.120	7.77	15.5	38.8	58.3	77.7	117
1-3/4	.065	12.8	25.7	64.2	96.3	128	193
	.072	12.6	25.2	63.1	94.7	126	189
	.083	12.3	24.6	61.4	92.1	123	184
	.095	11.9	23.8	59.6	89.3	119.	179
	.109	11.5	23.0	57.4	86.1	115	172
	.120	11.2	22.3	55.8	83.7	112	167
	.134	10.7	21.5	53.7	80.6	107	161
2	.065	17.1	34.2	85.6	128	171	257
	.072	16.9	33.7	84.3	126	169	253
	.083	16.5	32.9	82.3	123	165	247
	.095	16.0	32.1	80.2	120	160	240
	.109	15.5	31.1	77.7	117	155	233
	.120	15.2	30.3	75.8	114	152	227
	.134	14.7	29.4	73.4	110	147	220

Appendix I Cylinder size selection

This chart lists the theoretical push and pull forces that cylinders will exert when supplied with various working pressures, plus theoretical piston velocities when supplied with 15 Ft./Sec. fluid velocity through SCH 80 size pipe.

Cyl. Bore Dia.	Piston Rod Dia.	Work Area Sq. In.	HYDRAULIC WORKING PRESSURE P.S.I.						Fluid Required Per In. Of Stroke		Port Size	Fluid Velocity @ 15 Ft./Sec.	
			500	750	1000	1500	2000	3000	Gal.	Cu. In.		Flow GPM	Piston Vel. In./Sec.
1-1/2	— —	1.767	883	1325	1767	2651	3534	5301	.00765	1.767	1/2	11.0	24.0
	5/8	1.460	730	1095	1460	2190	2920	4380	.00632	1.460			29.0
	1	.982	491	736	982	1473	1964	2946	.00425	.982			43.1
2	— —	3.141	1571	2356	3141	4711	6283	9423	.01360	3.141	1/2	11.0	13.5
	1	2.356	1178	1767	2356	3534	4712	7068	.01020	2.356			18.0
	1-3/8	1.656	828	1242	1656	2484	3312	4968	.00717	1.656			25.6
2-1/2	— —	4.909	2454	3682	4909	7363	9818	14727	.02125	4.909	1/2	11.0	8.6
	1	4.124	2062	3093	4124	6186	8248	12372	.01785	4.124			10.3
	1-3/8	3.424	1712	2568	3424	5136	6848	10272	.01482	3.424			12.4
	1-3/4	2.504	1252	1878	2504	3756	5008	7512	.01084	2.504			16.9
3-1/4	— —	8.296	4148	6222	8296	12444	16592	24888	.0359	8.296	3/4	20.3	9.4
	1-3/8	6.811	3405	5108	6811	10216	13622	20433	.0295	6.811			11.5
	1-3/4	5.891	2945	4418	5891	8836	11782	17673	.0255	5.891			13.3
	2	5.154	2577	3865	5154	7731	10308	15462	.0223	5.154			15.2
4	— —	12.566	6283	9425	12566	18849	25132	37698	.0544	12.566	3/4	20.3	6.2
	1-3/4	10.161	5080	7621	10161	15241	20322	30483	.0440	10.161			7.7
	2	9.424	4712	7068	9424	14136	18848	28272	.0408	9.424			8.3
	2-1/2	7.657	3828	5743	7657	11485	15314	22971	.0331	7.657			10.2
5	— —	19.635	9818	14726	19635	29453	39270	58905	.0850	19.635	3/4	20.3	4.0
	2	16.492	8246	12369	16492	24738	32984	49476	.0714	16492			4.7
	2-1/2	14.726	7363	11044	14726	22089	29542	44178	.0637	14.726			5.3
	3	12.566	6283	9424	12566	18849	25132	37698	.0544	12.566			6.2
	3-1/2	10.014	5007	7510	10014	15021	20028	30042	.0433	10.014			7.8
6	— —	28.274	14137	21205	28274	42411	56548	84822	.1224	28.274	1	33.8	4.6
	2-1/2	23.365	11682	17524	23365	35047	46730	70095	.1011	23.365			5.6
	3	21.205	10602	15904	21205	31807	42410	63615	.0918	21.205			6.1
	4	15.708	7854	11781	15708	23562	31416	47124	.0680	15.708			8.3
7	— —	38.485	19242	28864	38485	57728	76970	115455	.1666	38.485	1-1/4	60.2	6.0
	3	31.416	15708	23562	31416	47124	62832	94248	.1360	31.416			7.4
	4	25.919	12960	19439	25919	38878	51838	77757	.1122	25.919			8.9
	5	18.850	9425	14137	18850	28275	37700	56550	.0816	18.850			12.3
8	— —	50.265	25133	37699	50265	75398	100530	150795	.2176	50.265	1-1/2	83.0	6.4
	3-1/2	40.644	20322	30483	40644	60966	81288	121932	.1759	40.644			7.9
	4	37.699	18850	28274	37699	56548	75398	113097	.1632	37.699			8.5
	5-1/2	26.507	13253	19880	26507	39760	53014	79521	.1147	26.507			12.0
10	— —	78.540	39270	58905	78540	117810	157080	235620	.3400	78.540	2	139	6.8
	4-1/2	62.636	31318	46977	62636	93954	125272	187908	.2711	62.636			8.5
	5-1/2	54.782	27391	41086	54782	82173	109564	164346	.2371	54.782			9.8
	7	40.055	20027	30041	40055	60082	80110	120165	.1734	40.055			13.4
12	— —	113.10	56550	84825	113100	169650	226200	339300	.4896	113.10	2-1/2	199	6.8
	5-1/2	89.34	44670	67005	89340	134010	178680	268020	.3867	89.34			8.6
	7	74.62	37310	55965	74620	111930	149240	223860	.3230	74.62			10.3
	8	62.84	31420	47130	62840	94260	125660	188520	2720	62.84			12.2
14	— —	153.94	76970	115455	153940	230910	307880	461820	.6664	153.94	2-1/2	199	5.0
	7	115.46	57730	86595	115460	173190	230920	346380	.4998	115.46			6.6
	8	103.68	51840	77760	103680	155520	207360	311040	.4488	103.68			7.4
	10	75.40	37700	56550	75400	113100	150800	226200	.3264	75.40			10.2

Oil consumption in gallons per minute = Gallons per inch × inches per minute of piston travel.
1 gallon = 231 cubic inches. Cylinder bore diameters and piston rod diameters are in inches.

Appendix J Heavy, Medium and Lightweight ROVs (As vessel specifications are liable to change, please refer to manufacturer for current specifications.)

a) AN/SLQ-48(V) Mine Neutralisation System

Manufacturer. Alliant Techsystems Inc.

Work capabilities. Intended to neutralise bottom and moored lines. Also survey operations.

Dimensions. Length 3.70m
Breadth 1.20m
Height 1.20m
Weight in air 1,247kgs
Construction GRP frame

Operating depth. 1000m.

Propulsion. Twin 15hp. 4 x thrusters, 2 horizontal, 1 lateral, 1 vertical.

Instrumentation and tools. Manipulator and cable cutter, 2 low light level cameras and lights. High resolution sonar and tracking system.

b) Boxer Compact

Manufacturer. Seaeye Marine Ltd.

Work capabilities. Inspection and survey.

Dimensions. Length 0.725m
Breadth 0.65m
Height 0.50m
Weight in air 70kgs
Construction. POlypropylene with stainless steel fasteners.

Operating depth. 300m

Propulsion. 4 x dc brushless thrusters. 2 horizontal and 2 vertical.

Instrumentation and tools. 1 function manipulator optional. CP probe, FMD optional.
Colour CCD camera, 2 x 150w halogen lamps of varying intensity. Additional TV cameras optional. Fluxgate gyro with compass, depth sensor, auto pilot for depth and heading, sonar optional.

c) Diablo

Manufacturer. Hydrovision Ltd.

Work capabilities. General subsea support, drilling and construction support, survey and inspection.

Dimensions. Length 2.10m
Breadth 1.50m
Height 1.70m
Weight in air 1980kgs

Construction. HE30 aluminium channel space frame, specially designed to give through frame lift capability of 3 tonnes.

Operating depth. 1000m

Propulsion. 75hp. 6 x HT300 Curvtech hydraulic thrusters, 2 axial, 2 lateral, 2 vertical.

Instrumentation and tools. 1 x 7 function manipulator, 1 x 5 function grabber, low pressure water jet. Depth sensor, water alarms. 1 x Osprey 1323d SIT camera, 2 x Osprey 1360 colour cameras, 1 x Osprey CCD BSW low light camera, 8 x 250w lights, 2 x 400w wide flood lights. Sonar and gyrocompass.

d) Examiner

Manufacturer. SubSea Offshore Ltd.

Work capabilities. Subsea engineering, subsea completion support, pipeline support, platform inspection and drill rig support.

Dimensions. Length 2.00m
Breadth 1.95m
Height 1.80m
Weight in air 1,700kgs
Construction. Aluminium frame

Operating depth. 500msw.

Propulsion. HPU 75 hp, 8 x hydraulic inner space thrusters. 4 x vertical, 2 x lateral, 2 x horizontal.

Instrumentation and tools. 7 function manipulator, 5 function manipulator, provision for specific tooling packages.
Sensors. 2 x hydraulic pressure, 2 x hydraulic temperature, hydraulic flow, variable buoyancy pressure, water ingress, compensator vacuum, power supply voltages, cable IRs.
Provision for 6 cameras with separate focus and on/off controls. Expandable to 12 with video switching, provision for fibre optic video multiplexing.
Obstacle avoidance sonar, depth sensor, heading sensor, pitch and roll sensors.
Auxiliary power supplies. Auxiliary hydraulic system. HPU 18.75Kw(25hp).

Additional data / special features. An eyeball ROV can be incorporated into the system and mounted within the main ROV frame.

e) Hydra 20 / 40

Manufacturer. Oceaneering production systems.

Work capabilities. Drilling and construction support tasks.

Dimensions. Length 1.80m
Breadth 1.20m
Height 1.30m
Weight in air 862kgs
Construction 6061 T6 aluminium frame, stainless steel fittings.

Operating depth. 1000m - 2,500m

Propulsion. 7 x thrusters (2 fore / aft, 2 lateral, 3 vertical)

Instrumentation and tools. 1 x 7 function manipulator, 1 x 5 function. ! Osprey 1323 SIT camera, 1 x Osprey OE 1335 colour camera, 1x Osprey 1352 CCD, Photosea 1000, 2000 or NDT 4000.
Auto depth and heading control, fluxgate magnetic compass, digital depth meter,high resolution sonar and acoustic tracking.

f) Hysub 5000

Manufacturer. International Submarine Engineering Ltd.

Work Capabilities. Research and salvage operations.

Dimensions. Length 2.54m
Breadth 1.52m
Height 1.68m
Weight in air 2,091kgs
Construction. Anodised aluminium frame.

Operating depth. 5,000m

Propulsion. 40hp hydraulic power pack, 6 x hydraulic thrusters.

Instrumentation and tools. 1 x 5 function rate arm, 1 x 7 function manipulator, sample skid for geophysical tools and sample collection.
GESPAC computer system, depth gauge. 1x Osprey SIT 1323 video camera, 1 x Osprey colour CCD 1361 video camera, 4 x 250 w lights, gyro compass and Mesotech sonar.

NB Also available are Hysub 25, Hysub ATP 10, Hysub ATP 40, Hysub ATP 50 and
Hysub ATP 150.

g) MiniROVER MK11

Manufacturer. Benthos Inc.

Work capabilities. Inspection, observation and light work capabilities.

Dimensions. Length 86cm
Breadth 50cm
Height 42cm
Weight in air 34kgs
Construction. Aluminium hull, PVC motor housing, rectangular keel skids.

Operating depth. 305m

Propulsion. Electric thrusters, 1 x lateral, 1 x vertical, 2 horizontal.

Instrumentation and tools. Low light high resolution video camera, 2 x 150w quartz halogen lamps.

NB Also available Max ROV MK 1, MKII, MKIII and MicroVER.

h) MRV (Multi Roll Vehicle)

Manufacturer. Slingsby Engineering Ltd.

Work Capabilities. Survey, drill support,intervention, construction, cable burial recovery, salvage (work package available to suit customer requirements.

Dimensions. Length 1.92m
Breadth 1.50m
Height 1.56m
Weight in air 1,590 - 2,250kgs (basic vehicle)
Construction High strength aluminium space frame, stainless steel fasteners.

Operating depth 600m / 1,000m / 2,000m deeper on request.

Propulsion Up to 200hp. 4 x horizontal,2 x vertical, additional thrusters can be fitted on request.

Instrumentation and tools SEL offer a range of tooling packages. Maximum of 5 cameras, mono, colour, stills or SIT, 3.5kw max lighting, spot or flood with dimming facility.
Auto altitude, auto depth, pitch and roll, heading, trim. Digiquartz depth gauge, gyro / fluxgate compass, sonar to suit customer requirements, emergency pinger and flasher.

i) Offshore Hyball

Manufacturer Hydrovision

Work capabilities Inspection and observation.

Dimensions Length 0.575m
Breadth 0.77m
Height 0.575m
Weight in air 60kgs
Construction Fibreglass, stainless steel fittings.

Operating depth 300m

Propulsion 4 electric thrusters, 2 fore / aft and rotational movement, 2 lateral and vertical movement.

Instrumentation and tools Manipulator interface kit fitted as optional extra. Digital depth indicator, leak detection system, microphone to provide audio feedback to the operator, ground fault interrupter and circuit breakers to protect surface equipment and vehicle, CP interface standard
Remote focus low light CCD camera mounted on 360° rotating chassis. 2 x 100w quartz halogen lights, 2 x 75w lights on chassis. AC6000 super short base line tracking system optional. AC9000 sonar optional, magnetic compass and rate gyro compass.

NB Offshore Hyball is a more powerful version of Hyball having 100% more power.

j) Phantom Ultimate

Manufacturer. Deep Ocean Engineering

Work capabilities. Inspection

Dimensions. Length 1.81m
Breadth 1.17m
Height 0.97m
Weight in air 363kgs
Construction. Full perimeter polypropylene with stainless steel crash frame protecting all components, recessed and hardened camera ports.

Operating depth 610m. test depth 762m

Propulsion. Electric. 4 x horizontal thrusters, 3 x vertical thrusters, 2 x lateral thrusters.

Instrumentation and tools. Compatible with almost all manipulator systems. Options include cable cutter, tools and sampling devices.
Instrumentation includes audio feedback reflecting vehicle condition. CP optional. PAL/NTSC, colour high resolution, low light CCD camera, built in video switch for optional second camera. Camera / instrument platform with 360° tilt. 2 x 250w dimmerable tungsten halogen lights.
Fluid gimballed fluxgate compass, depth transducer. Options include sonar, tracking system and altimeter.

NB Also available are Phantom 300, 500, Phantom DHD2, Phantom DS4, Phantom HD2, Phantom HVS4 and Phantom pipeline.

k) Pioneer

Manufacturer. SubSea Offshore Ltd.

Work capabilities. Drill rig support, general survey and inspection work, guiding drill string, leak checking, bullseye checking and debris removal.

Dimensions. Length 1.65m
Breadth 1.65m
Weight in air 1,315kgs
Construction. Polymer buoyancy, aluminium frame.

Operating depth 1,525m

Propulsion. 50hp power hydraulic power pack (pioneer plus has 75hp). 5 x proportionally controlled thrusters

Instrumentation and tools. 1 x 7 function manipulator with position feedback control and 1 x 5 function manipulator. Vehicle status sensors, hydraulic pressure and temperature, water ingress alarms at 12 points, telemetry status panel, low oil alarms, 1 x low light camera with facility for up to 3 additional cameras. 6 x 250w lights. Depth sensor, heading sensor (slaveable gyro), auto depth, heading and altitude, acoustic pinger, emergency flasher, obstacle avoidance sonar with hydraulic tilt,vehicle turns indicator, pitch and roll sensors, optional transponder.

l) Recon IV SIA

Manufacturer. Perry Tritech Inc.

Work capabilities. Drill support, construction support, pipeline survey.

Dimensions. Length 2.06m
Breadth 0.90m
Height 0.85m
Weight in air 467kgs

Operating depth. 300msw

Propulsion. Electric. 2 x axial, 1 x lateral and 1 x vertical.

Instrumentation and tools. 2 function manipulator, cable cutter, marine growth cleaning package, 5 or 7 function Hercules manipulator, 5 or 6 function Schilling manipulator. CP probe. High resolution black and white camera with option for colour and SIT camera, pan and tilt. 2 x 250w variable intensity lights, sonar, auto heading and tracking system.

m) Rigworker MK 4 R3000

Manufacturer. Hydrovision Ltd.

Work capabilities. Drill support plus full range of work tasks.

Dimensions. Length 2.10m
Breadth 1.40m
Height 1.50m
Weight in air 1,650kgs

Operating depth 1,000m

Propulsion. Hydraulic power pack. 2 x forward / reverse, 3 lateral thrusters, 2 vertical thrusters.

Instrumentation and tools. Interface for all propriety of manipulators, typically 1 x7 and 1 x 5 function. Comprehensive range of tooling also available. Interface for 4 cameras including pan and tilt.
Auto depth, altitude and heading. Provision to fit proprietary obstacle avoidance sonars. Optional interface for a full range of survey sensors including bathymetric system, dual scanning profile and pipe / cable tracker and gyro.
NB Also available, Rigworker 3000I / R3000S.

n) Scarab IV

Manufacturer. Oceaneering Production Systems.

Work capabilities. Telecommunication cable burial and repair.

Dimensions. Length 4.00m
Breadth 2.00m
Height 2.00m
Weight in air 2,722kgs

Operating depth 1,850m

Propulsion. Hydraulic, 150hp

Instrumentation and tools. 2 x 7 function manipulators, cable gripper and cable cutter.
4 x SIT cameras, 1 colour CCD camera and variable intensity lighting.
Cable tracking magnetometer system, acoustic positioning system, high resolution sonar, altimeter, fluxgate compass, pitch and roll sensors, depth transducers.

o) **Super Scorpio**

Manufacturer. Perry Tritech

Work capabilities. Survey and inspection, including platform and pipeline, Pre installation surveys and as laid surveys, diver support and sub sea remote intervention.

Dimensions. Length 2.50m
Breadth 2.50m
Height 1.90m
Weight in air 2,100kgs

Operating depth 1,000msw (other depths optional)

Propulsion. 62hp. 5 x hydraulic thrusters. 2 axials, 2 lateral and 1 vertical.

Instrumentation and tools. Manipulators, grabbers, suction arms. Standard survey junction box, options include CP probe, bathymetric sensor.
Cameras include pan and tilt and colour with suitable lighting. Auto heading, depth, pitch and roll. Options Sonar, Digiquartz, responder.

Appendix K Properties Of Cable Conductors

1) Copper conductors

Diameter (mm)	AWG number	Loop resistance(Ω / Km)	Attenuation dB / Km	Impedance Ω @ 1kHz
0.255	30	680	2..54	1645
0.30	30	492	2..23	1400
0.32	28	433	2..03	1313
0.40	28	277	1.62	1050
0.405	26	270	1.61	1036
0.50	26	177	1.30	839
0.511	24	170	1.27	822
0.60	24	123	1.08	700
0.644	22	107	1.01	652
0.70	22	90	0.92	597
0.80	22	69	0.81	524
0.90	22	55	0.72	468
0.91	19	53	0.71	460
1.00	19	44	0.65	418

Resistances are based on pure copper and do not take into account cable make up

Attenuation and impedances assume absenceof impedance irregularities

2) Coaxial cable Characteristics

Type	overall diameter. (mm)	impedance (Ω)	capacitance pF / m	Max dc voltage(kV)	Max RF peak voltage kV	Attenuation dB/10m @100MHz
M 43	5	50	100	21	2.6	1,3
M67	10.3	50	100	40	6.5	0.68
M70	5.8	75	67	14	1.8	1.5
M76	5	50	100	21	2.6	1.6
RG58C/U	5	50	100	_	3.5	3.1 *
RG59B/U	6.15	75	68	_	6	1.3
RG174A/U	2.8	50	100	6	1.5	4.2 *
RG178B/U	1.8	50	96	4	1	4.4
RG179B/U	2.5	75	100	4	1	3.2
RG213/U	10.3	50	100	5	3.25	0.62
RG214/U	10.8	50	96	5	3.25	0.76
RG223/U	5.5	50	96	1.9	0.450	1.58
RG316/U	2.6	50	102	1.7	0.400	36.0

* – Attenuation dB / 10m @200MHz

Appendix K Properties Of Cable Conductors

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Diameter (mm)	AWG number	Loop resistance(Ω / Km)	Attenuation dB / Km	Impedance Ω @ 1kHz
0.255	30	680	2..54	1645
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0.70	22	90	0.92	597
0.80	22	69	0.81	524
0.90	22	55	0.72	468
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Resistances are based on pure copper and do not take into account cable make up

Attenuation and impedances assume abscenceof impedance irregularities

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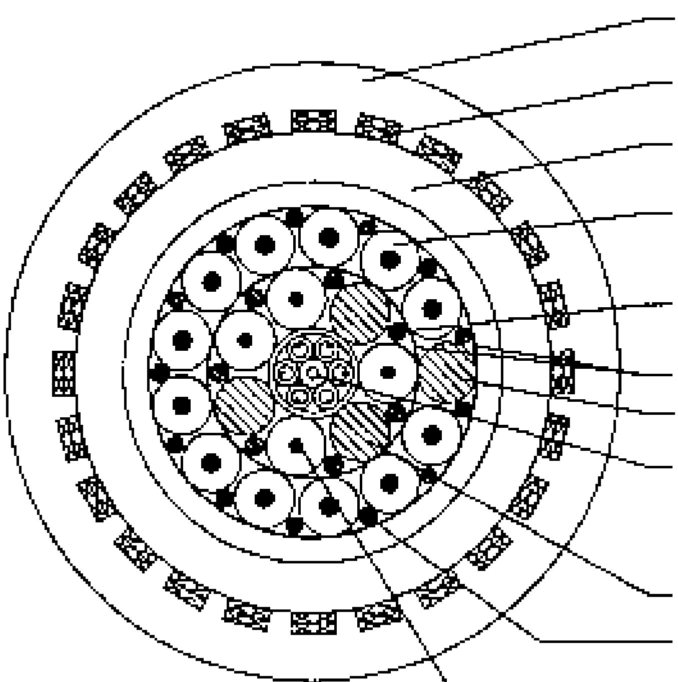
Type	overall diameter. (mm)	impedance (Ω)	capacitance pF / m	Max dc voltage(kV)	Max RF peak voltage kV	Attenuation dB/10m @100MHz
M 43	5	50	100	21	2.6	1.3
M67	10.3	50	100	40	6.5	0.68
M70	5.8	75	67	14	1.8	1.5
M76	5	50	100	21	2.6	1.6
RG58C/U	5	50	100	_	3.5	3.1 *
RG59B/U	6.15	75	68	_	6	1.3
RG174A/U	2.8	50	100	6	1.5	4.2 *
RG178B/U	1.8	50	96	4	1	4.4
RG179B/U	2.5	75	100	4	1	3.2
RG213/U	10.3	50	100	5	1.25	0.62
RG214/U	10.8	50	96	5	1.25	0.76
RG223/U	5.5	50	96	1.9	0.450	1.58
RG316/U	2.6	50	102	1.7	0.400	36.0

* = Attenuation dB / 10m @200MHz

D) MRV Tether



Cable diameter : 49 mm.

Optical Fibre Properties : *)

Component	Mode	Numerical Aperture	Band Width MHz*km	Attenuation at 850 nm dB/km
50/125	Mult	0.2	400	4

"Interstices filled"

"The weight in seawater applies to an assumed seawater density of 1026 kg/m3."

*) Note : The values are corrected for the overlength of the elements.

Electrical Properties : *)

Components	Rcond	Rinsul 500 V DC	Volt. Rating Uo/U 1)	High Volt. test at 5 min.
	Ohm/km	Mohm*km	kV	kV
0.75 mm2	26.3	500	2/3.5	12
1.34 mm2	15.1	500	2/3.5	12
1 mm2	22.0	drainwire	---	---
1.34 mm2	17.0	drainwire	---	---

1) Note: Uo is voltage to earth
U is line-to-line-voltage

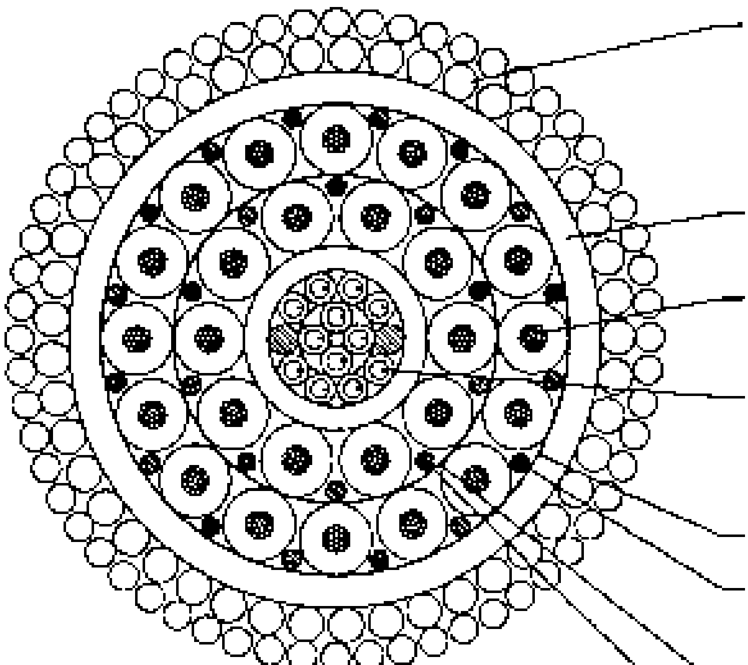
Mechanical Properties :

Breaking strength	Bending radius		Weight	
calculated	recommended min.		calculated	
	static	dynamic	air	seawater
kN	mm	mm	kg/km	kg/km
76	–	–	1925	–9

Current rating	
Core	current
1.34 mm2 Power	5.8 Amp
0.75 mm2 Power	4.0 Amp
1.34 mm2 drain	5.8 Amp
1 mm2 drain	4.8 Amp

conditions:
water; ambient temperature 25 deg C
continuous operation
(5) layers of cable on winch
max conductor temperature 85 deg C

2) MRV Umbilical



Cable diameter : 43.6 mm.

Optical Fibre Properties : *)

Component	Mode	Numerical Aperture	Band Width MHz*km	Attenuation at 850 nm dB/km
50/125	Multi	0.2	400	4

Electrical Properties : *)

Components	Rcond	Rinsul 500 V DC	Volt. Rating Uo/U 1)	High Volt. test at 5 min.
	Ohm/km	Mohm*km	V	kV
2 mm2	10.2	500	2.2/3.8	12
1 mm2	20.8	drainwire	---	---
1) Note: Uo is voltage to earth U is line-to-line-voltage				

Mechanical Properties :

Breaking strength	Bending radius		Weight	
calculated	*recommended min.*		*calculated*	
	static	dynamic	air	seawater
kN	mm	mm	kg/km	kg/km
594	–	–	4770	3235

"Interstices filled"

*) Note : The values are corrected for the overlength of the elements.

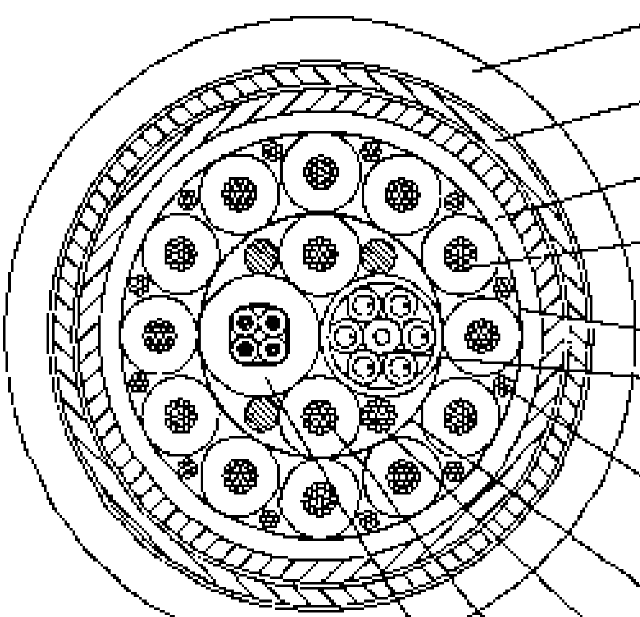
"The weight in seawater applies to an assumed seawater density of 1026 kg/m3."

Current rating	
Core	current
2 mm2 Power	6.1 Amp
1 mm2 drain	3.9 Amp

conditions:

still air; ambient temperature 45 deg C
continuous operation
(5) layers of cable on winch
max conductor temperature 85 deg C

3) Lightweight ROV Umbilical



Cable diameter : 37 mm

"Interstices filled"

*) Note : The values are corrected for the overlength of the elements.

"The weight in seawater applies to an assumed seawater density of 1026 kg/m3."

Electrical Properties : *)

Components	Rcond	Rinsul 500 V DC	Volt. Rating	High Volt. test at 5 min.
	Ohm/km	Mohm*km	V	kV
2.4 mm2	6.9	500	2200	10
2.4 mm2	8.6	500	3300	16
2.4 mm2	9.3	drainwire	---	---
0.88 mm2	24	drainwire	---	---
TQ 0.5 mm2	41	500	60	---

Optical Fibre Properties : *)

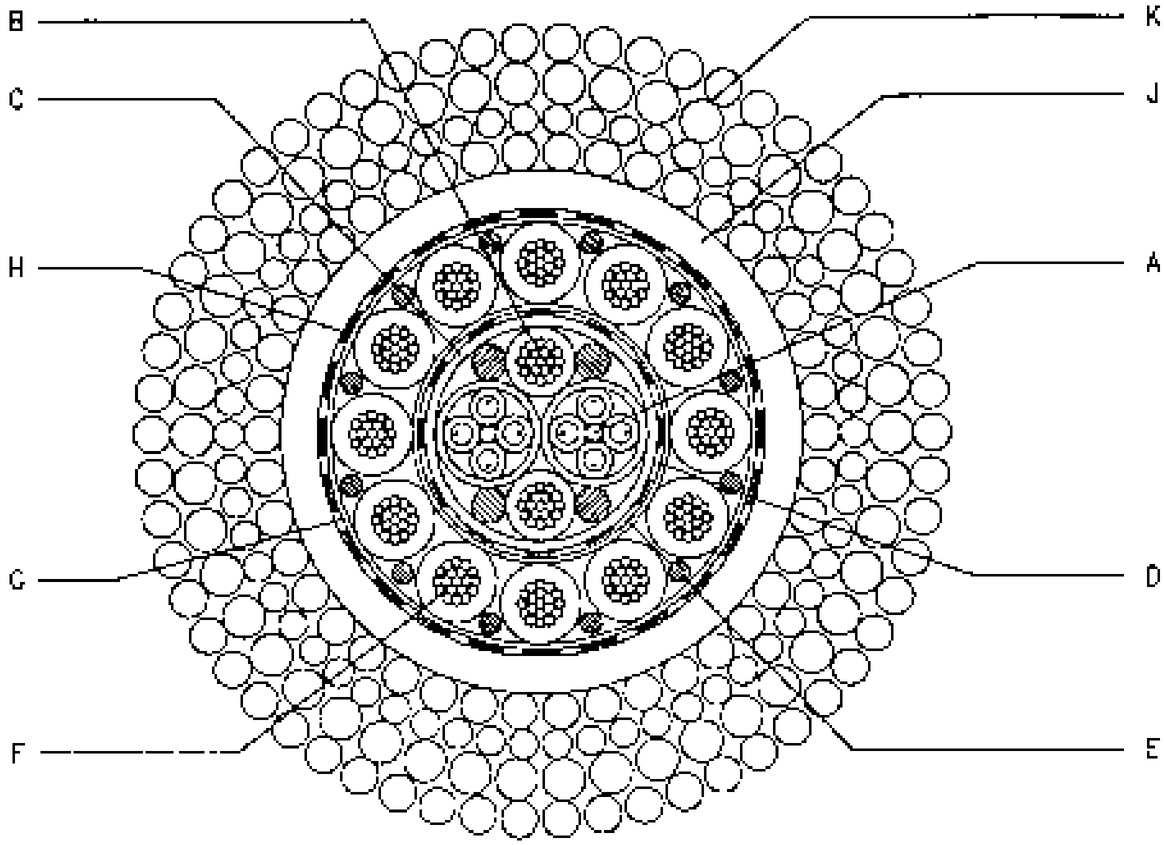
Component	Mode	Numerical Aperture	Band Width MHz*km	Attenuation at 850 nm dB/km
50/125	Multi	0.2	400	4

Mechanical Properties :

Breaking strength	Bending radius		Weight	
calculated	recommended min.		calculated	
	static	dynamic	air	seawater
kN	mm	mm	kg/km	kg/km
195	-	608	1425	320

Component: power cores 2.4 mm2	
Current rating: 5.5 Amp	
conditions: still air. continuous operation. ambient air temperature: 45 deg C max. conductor temperature: 75 deg C 5 layers of cable on winch.	
Voltage drop (V/km): 83.8	48.4
Supply voltage (V): 2292 (1-ph) frequency (Hz): 60 conductor temp. (deg C): 70 current per conductor (A): 5	3353 (3-ph) 60 57 3.5

4) MRV Conductor identification



Cable diameter: 44.2 mm

"Interstices filled"

"The weight in seawater applies to an assumed seawater density of 1026 kg/m3."

*) Note : The values are corrected for the overlength of the elements.

Optical Fibre Properties :

Component	Mode	Numerical Aparture	Band Width MHz/km	Attenuation at 850 nm dB/km
50/125	Multi	0.2	1200	4

Mechanical Properties :

Breaking strength	Bending radius		Weight	
calculated	recommended min		calculated	
	static	dynamic	air	seawater
kN	mm	mm	kg/km	kg/km
887		551	6800	5200

Electrical Properties :

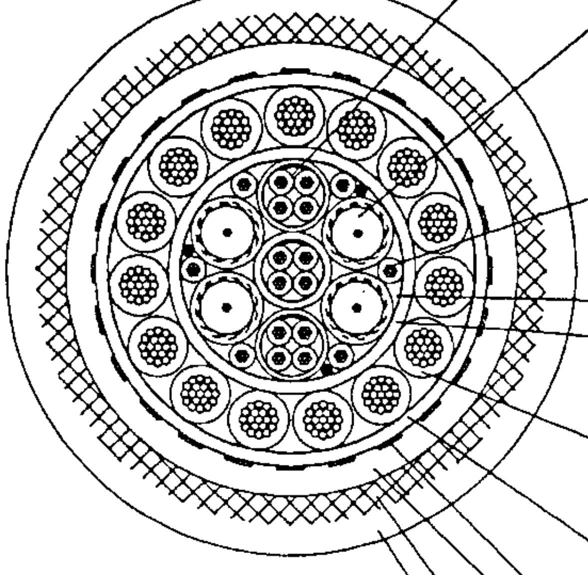
Components	Rcond	Rinsul 500 V DC	Volt. Rating	High Volt. test at 5 min.
	Ohm/km	Mohm*km	V	kV
4 mm2	5.2	500	2000	10
4 mm2	5.2	500	3150	15

ITEM	NUMBER	DESCRIPTION
A	2	Fiber-optic units, each comprising:
	4	Optical fibres in gel-filled loose tube. Tube size: ID = 0.8 mm, OD = 2.0 mm Stranded around a central steel wire ø 0.9 mm PE jacket, ø 5.8 mm
B	2	Power cores 4 mm2 - 2 kV Conductors: plain copper 19x0.52 mm, ø 2.6 mm Insulation: PP, ø 3.8 mm
C		PE jacket, ø 12.7 mm jacket thickness: 0.5 mm
D		Plain copper wire / polyester yarn braid, ø 13.4 mm Plain copper 12x8x0.2 mm / Polyester 12x2x1100 dTex Coverage of copper part: 64 %
E	1	Layer of non-woven tape 0.2 mm, lapped.
F	12	Power cores 4 mm2 - 3 kV Conductors: plain copper 19x0.52 mm, ø 2.6 mm Insulation: PP, ø 4.4 mm
G	1	Layer of non-woven tape 0.2 mm, lapped.
H		Plain copper wire / polyester yarn braid, ø 24.3 mm Plain copper 24x9x0.25 mm / Polyester 24x2x1100 dTex Coverage of copper part: 65 %
J		PUR jacket, ø 28.4 mm jacket thickness: 2 mm approx
K	4	Contrahelical layers of preformed, greased, galvanised steel wires 1960 N/mm2 First layer: 42 wires ø 2.0 mm Second layer: 59 wires ø 1.6 mm Third layer: 45 wires ø 2.3 mm Fourth layer: 58 wires ø 2.0 mm The layers are balanced to minimise torque & rotation, ø 44.2 mm

5) Super Scorpio Umbilical

•) Note : The values are corrected for the overlength of the elements.

"Interstices filled."



3 x Twisted Shielded Quad 2xø4.8mm, 1xø5.1mm
Conductor : 0.5mm2 Plain Copper [7/.3]
Insulation : Polyethylene to ø1.65
Shield : Ali–Polyester Tape & DW
Jacket : Polyethylene to ø4.8/5.1mm

4 x 75 Ohm Coaxial ø4.8mm
Centre : 0.22mm2 Plain Copper [7/0.2]
Dielectric : Solid Polyethylene to ø3.5mm
Screen : PC Braid [Cover 95%]
Jacket : Polyethylene to ø4.8mm

6 x Low Power Cores ø1.7mm
Conductor : 0.5mm2 Plain Copper [7/0.3]
Insulation : Polyethylene to ø1.7mm

Tape Shield : Ali–Polyester & Drain Wire

Inner Jacket
Material : Polyethylene to ø16.4mm
Thickness : 0.8mm Radial

15 x Power Cores ø4.0mm
Conductor : 4.0mm2 Plain Copper [19/0.52]
Insulation : Polypropylene to ø4.0mm

Bedding Jacket
Material : Polyethylene to ø26.2mm
Thickness : 0.8mm Radial

Spiral Screen Plain Copper Wires over Cu Tape

Bedding Sheath
Material : Polyurethane to ø30.6mm
Thickness : 1.9mm Radial

Strength Member
Braid : Standard Modulus Aramid

Outer Jacket
Material : Polyurethane to ø38mm
Thickness : 1.9mm Radial

Nom Cable diameter : 38.0mm.

"The weight in seawater applies to an assumed seawater density of 1026 kg/m3."

Electrical Properties : •)

Components	Rcond	Rinsul 500 V DC	Volt. Rating	High Volt. test at 5 min.
	Ohm/km	Mohm•km	V	kV
PC 4.0 mm2	5	> 500	3000	5
PC 0.5 mm2	43	> 500	60	1
Coax Centre	94	> 500	600	3.6

Mechanical Properties :

Breaking strength	Bending radius		Weight	
calculated	*recommended min.*		*calculated*	
	static	dynamic	air	seawater
kN	mm	mm	kg/km	kg/km
98	–	–	1966	803

Coaxial Properties : •)

Components	Capac. at 1 kHz	Imped. at 10 MHz	Attenuation		
			dB/100m		
	pF/m	Ohm	1 MHz	3 MHz	10 MHz
75 Ohm Coax	71	75	1.45	2.45	4.3

Commonly accepable TV camera Formats in various countries

Country	B&W Standard	Colour Standard
Antilles Netherlands	RS-1170	NTSC
Argentina	CCIR	PAL
Australia	CCIR	PAL
Bahamas	RS-170	NTSC
Belgium	CCIR	PAL
Brazil	CCIR	PAL
Brunei	CCIR	PAL
Bulgaria	CCIR	SECAM
Canada	RS-170	NTSC
Chilie	RS-170	NTSC
China	CCIR	PAL
Columbia	CCIR	SECAM
Czechoslovakia	CCIR	SECAM
Denmark	CCIR	PAL
Finland	CCIR	PAL
France	CCIR	PAL
Germany	CCIR	PAL
Greece	CCIR	SECAM
Hong Kong	CCIR	PAL
Hungary	CCIR	SECAM
India	CCIR	PAL
Indonesia	CCIR	PAL
Italy	CCIR	PAL
Japan	RS-170	NTSC
South Korea	RS-170	NTSC
Malaysia	CCIR	PAL
Mexico	RS-170	NTSC
Netherlands	CCIR	PAL
New Zealand	CCIR	PAL
Norway	CCIR	PAL
Peru	RS-170	NTSC
Philippines	RS-170	NTSC
Poland	CCIR	SECAM
Portugal	CCIR	PAL
Romania	CCIR	SECAM

Country	B&W Standard	Colour Standard
Saudi Arabia	CCIR	SECAM
Singapore	CCIR	SECAM
South Africa	CCIR	PAL
Spain	CCIR	PAL
Sweden	CCIR	PAL
Switzerland	CCIR	PAL
Taiwan	RS-170	NTSC
Thailand	CCIR	PAL
United Kingdom	CCIR	PAL
United States	RS-170	NTSC
U.S.S.R.	CCIR	SECAM
Venezuela	RS-170	NTSC
Yugoslavia	CCIR	PAL

Specifications For Typical Underwater Video Cameras

Osprey 1382 CCD camera

i) Electrical	
Resolution	320 lines
Sensitivity	0.9 Lux (faceplate)
Pick up Device	Interline transfer CCD (q inch format)
Signal to noise ratio	> 48 dB
Scan	625 line / 50Hz PAL format
Horizontal Frequency	15.625KHz
Auto light compensation	15,000 : 1
Power	Constant Voltage 16 - 24V dc (0.6A)
Video Output	1.0V PK-PK
ii) Environmental	
Water depth	1000 metres (deeper ratings available)
Temperature	Operating -5^0 C to +40^{0}C
Optical	
Standard Lens	8.5mm f:1.6
Iris	Automatic
Focus	Remote via telemetry 10mm to infinity
Angle of view	60^0 Diagonal (in water)

iii) Mechanical

Size	Length: 327mm Diameter: 104mm
Weight	Air 3.9Kg. Water 0.8Kg
Connector	Sea-Con (Branter) XSL-5-BCR
Connections	Pin 1. Ground Pin 2. Positive Supply Pin 3. Telemetry (+) Pin 4. Telemetry (-) Pin 5. Video
Port Guard	Removable stainless steel mesh

Osprey 1323 S.I.T Camera

i) Electrical

Resolution	>600 television lines
Sensitivity	5 x 10^{-4} Lux
Tube type	1 ins. S.I.T.
Signal to noise ratio	40dB
Scan	625 / 50Hz, 525 / 60Hz available
Horizontal frequency	15.625KHz, 15.75KHz
Auto light compensation	75,000 : 1
Power	Constant voltage 16 - 24 v dc (650mA)
Video output	1.4 volts PK-PK into 75W
Bandwidth	12MHz (- 3dB)

ii) Environmental

Water depth	1000m
Temperature	-5°C to +40°C

iii) Optical

Standard lens	5.5mm f : 1.5
Iris	Automatic motorized
Angle of view	110° diagonal in water

iii) Mechanical

Size	298mm long, 100mm diameter
Weight	Air 3.7Kg, Water 1.1Kg
Connector	5 pin Sea-Con (Branter) type
	XSL - 5 -BCR
Connections	Pin 1. Ground
	Pin 2. Positive supply
	Pin 3. Focus (N/A)
	Pin 4. Focus (N/A)
	Pin 5. Video

NB Dimensions are excluding connector.

Appendix N Dive Exercises

Dive Exercise 1. Surface Navigation And Control Familiarity

Refer to the diagram showing the Wray Castle ROV Operational Training Area.

The objectives of this exercise is to practice communications between the Deck Officer and the Pilot, and to gain familiarity with ROV controls and their effects, particular attention should be given to directional orientation and field of view/scale of video cameras.

i) Pilot the ROV on the instructions of the Deck Officer to the most Easterly leg of the wooden Jetty (Target Area A). The ROV should be on a Westerly Heading.

ii) Pilot the ROV to the most Northerly leg and back again to survey the South Easterly side of the Jetty. Care should be taken to allow for the reduction in target size due to the effect of the camera lens, it is important to manoeuvre the vehicle away from the target to avoid 'snagging'. A video recording of each Jetty leg should be made with descriptive commentary.

ii) Following the instructions of the Deck Officer manoeuvre the ROV into the middle of the area between the Jetty and the wet dock, then follow his instructions to take the ROV on the surface out on a heading of 010º for at least 50 metres then turn and return to the launch point.

NOTE: At the discretion of the instructor the student can be encouraged to use the vertical control on the jetty legs or on returning from the last manoeuvre by following the Lake bed back to the launch point. This can only be encouraged where the student has demonstrated competence with the exercises on the surface.

Dive Exercise 2 Tronic ROV Mini Ce Connector 'stab-in'

Refer to the diagram of the Operational Training Area, the connector receptacle is Target Area C.

The objective of this exercise is to practice control co-ordination on a typical intervention problem.

i) Referring to the diagrams of the Tronic ROV mini CE Plug and receptacle, attach the plug to the Viking ROVs manipulator ensuring that the locating lug is on the correct side to match the receptacles orientation. Position the manipulator such that the plug will be horizontal and in view of the video camera when submerged.

ii) Launch the vehicle and navigate under the instruction of the Deck Officer to the target area. Align the vehicle with the plate and become familiar with distance/ video image relationship (Camera perspective) whilst under the instruction of the Deck officer and the vehicle is on the surface.

iii) Using the vertical thruster control, dive the vehicle to the correct depth and, allowing for perspective, align the plug with the receptacle. Gain full control of the vehicle before attempting to locate the plug at this stage and set the trims to maintain position as accurately as possible.

iv) GENTLY move the vehicle forward maintaining alignment and place the connector. It is important to allow for the vehicles momentum and apply reverse thruster BEFORE actual contact to avoid hitting the target with any significant force and damaging the connector.

v) Remove the plug by maintaining the vehicle trim and alignment then applying a sharp full reverse thruster action. Return the vehicle to a stand off position at the discretion of the Deck Officer.

Dive Exercise 3. Structural Survey

Refer to the Diagrams showing the Operational Training Area and the structural drawings. The structure is located at target area B.

The objective of this exercise is to plan, carry out, and record a full structural survey.

i) The team should meet and plan the operation in detail.

ii) The Safety boat should proceed to the target area and drop a marker buoy in the vicinity of the structure.

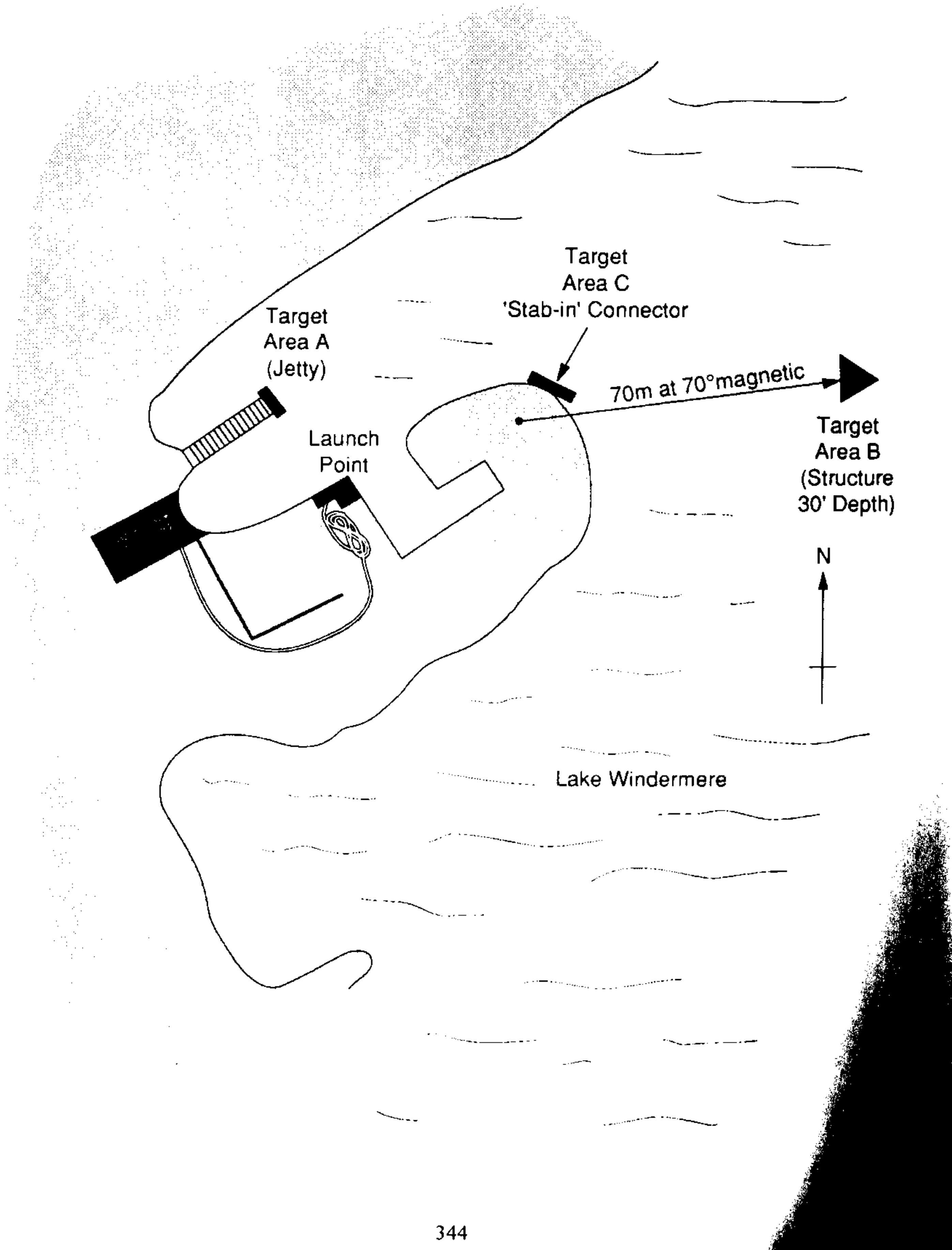
iii) The vehicle should be launched and under the directions of the Deck Officer be navigated to the marker buoy. The vehicle should be dived following the marker buoy line to within sight of the lake bed. Using the marker buoy as a reference and the vehicle sonar and compass the structure is to be located and the position with reference to the marker buoy recorded.

NOTE: During all operations the safety boat is to remain in the vicinity of the Target to warn off approaching recreational Lake users.

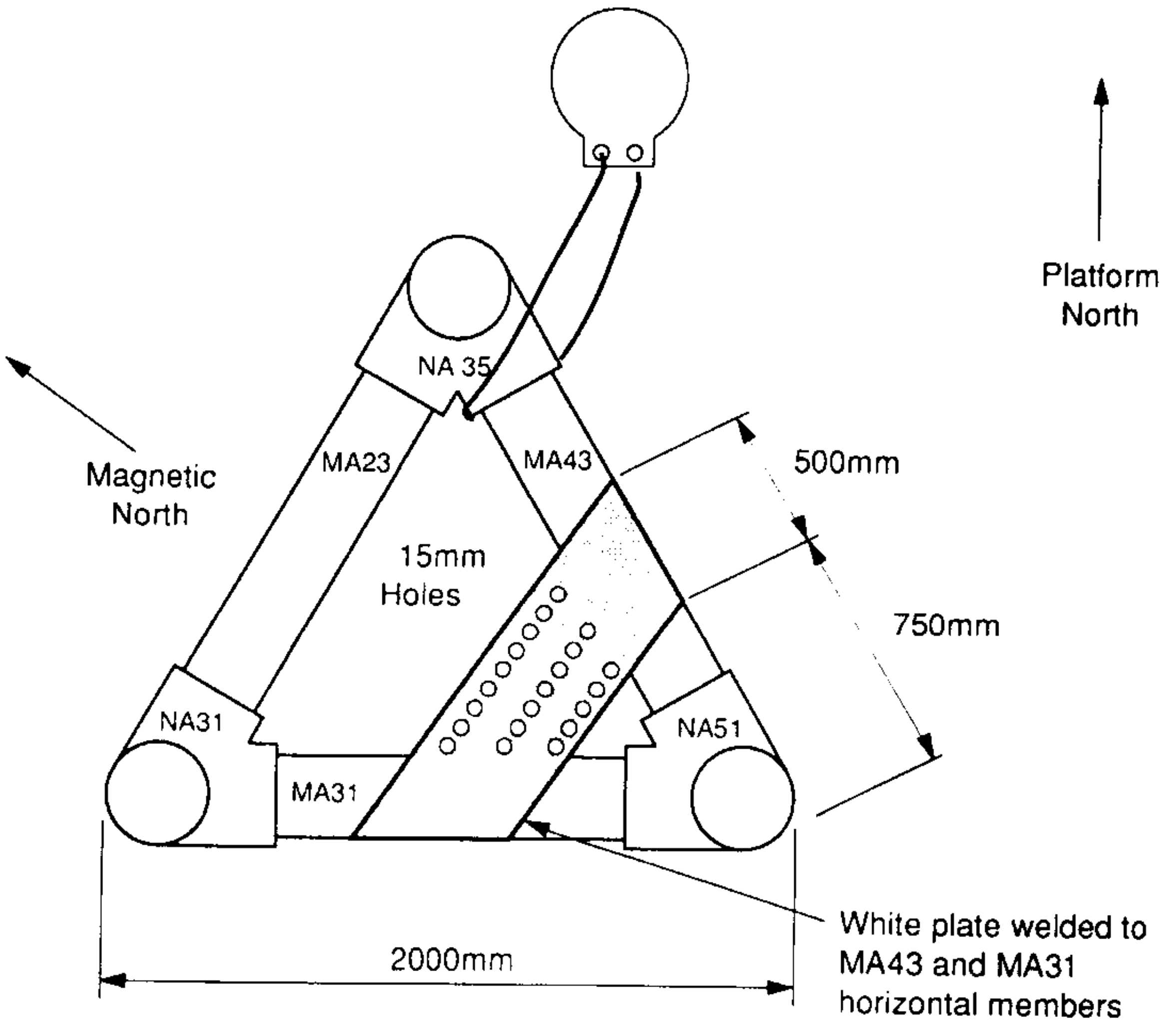
iv) A logical survey of the structure is to be undertaken recording as much detail as possible in the time allowed including CPP where appropriate. The instructor will give guidance on established inspection principles and recording methods as the exercise progresses.

v) On completion the vehicle should be recovered and all drawings, data, logs and video tapes given to the instructor for assessment.

WRAY CASTLE ROV OPERATIONAL TRAINING AREA

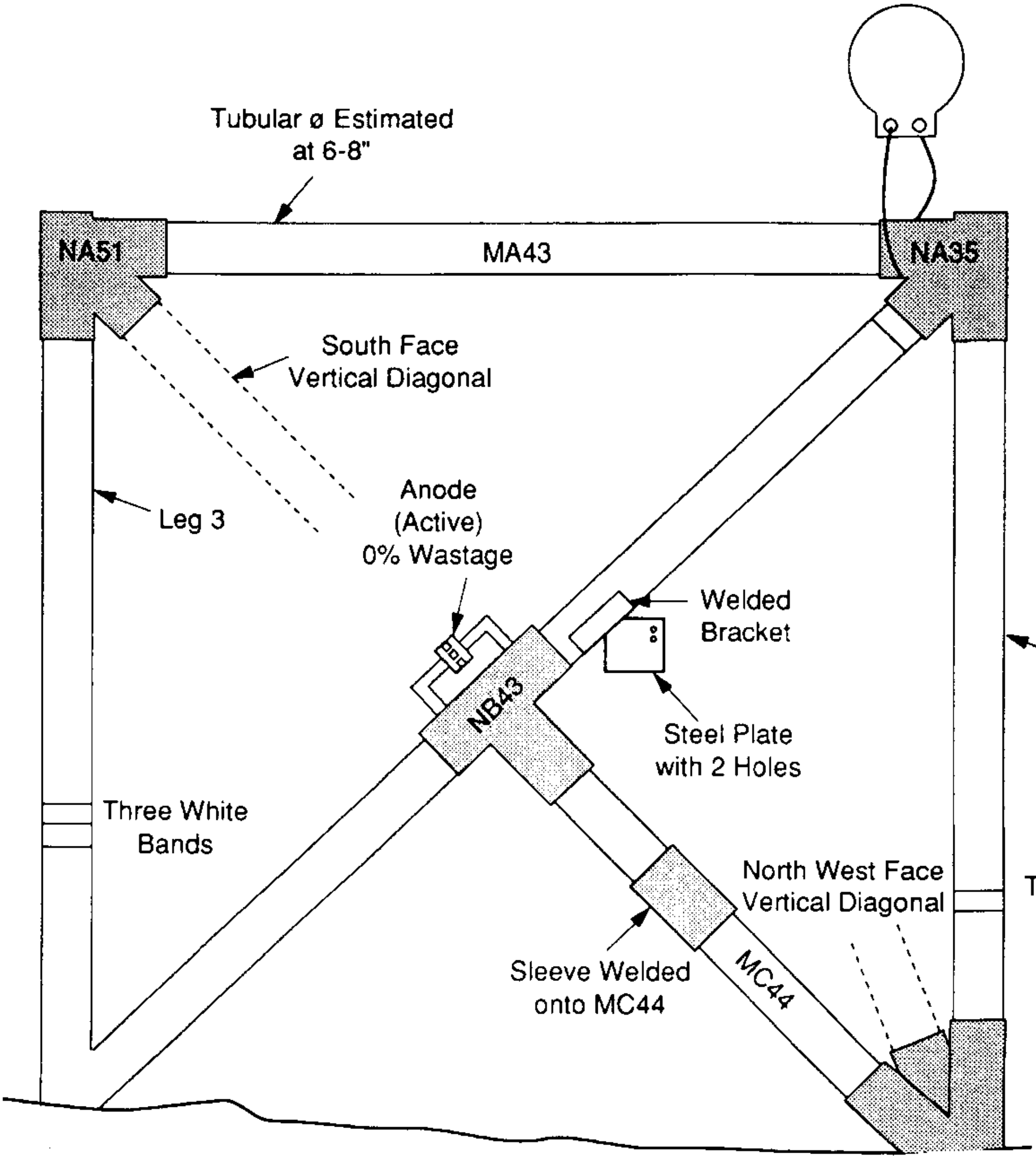


Target B - Steel Structure



Plan View
(as seen from above)

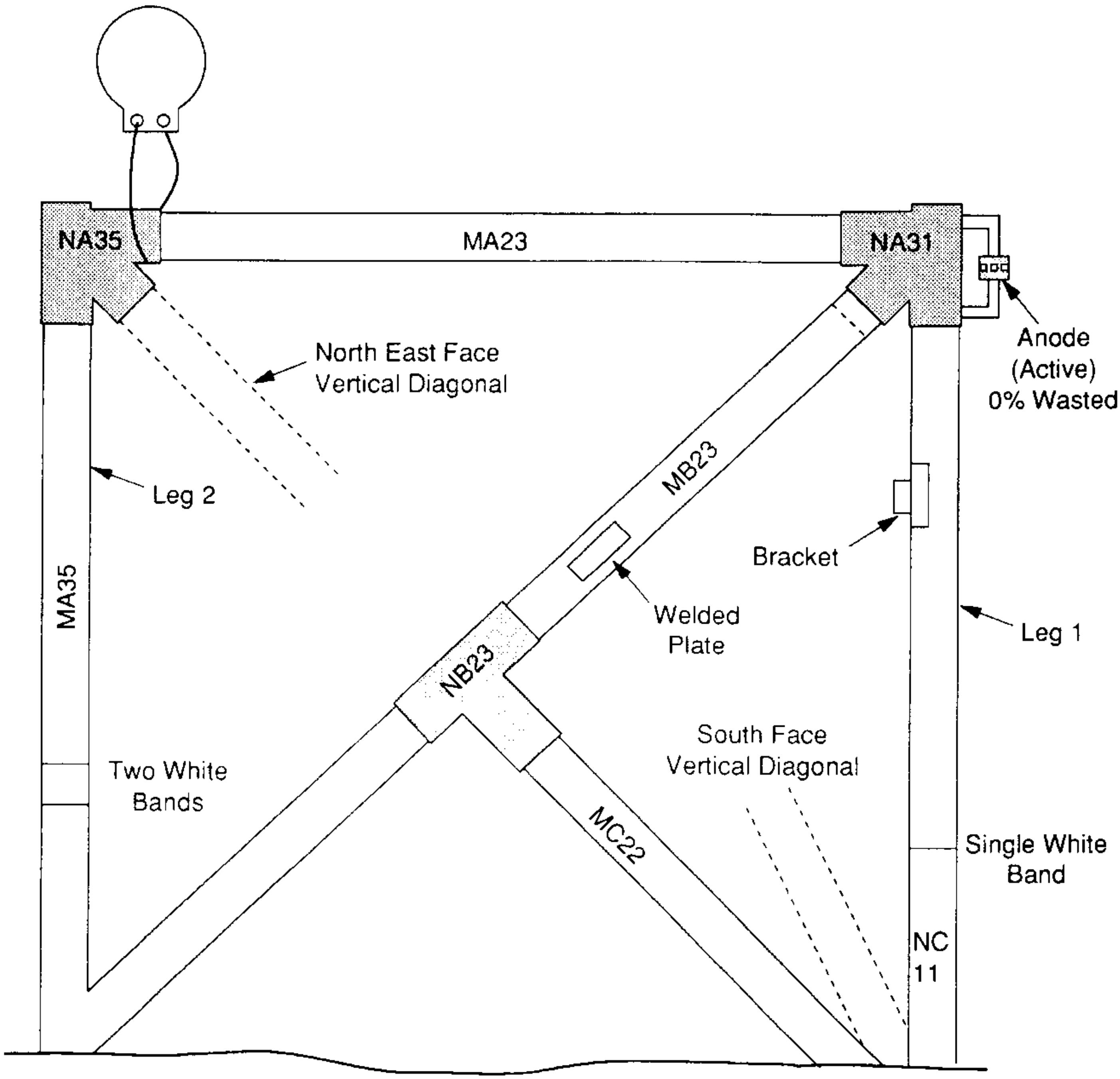
Platform North East Face



Bottom Node Obscurred by Mud Suspect Structure
Settled into Sea Bed on Leg 3

Fine Silty Bottom
No Evidence of Scour or Seabed Errosion

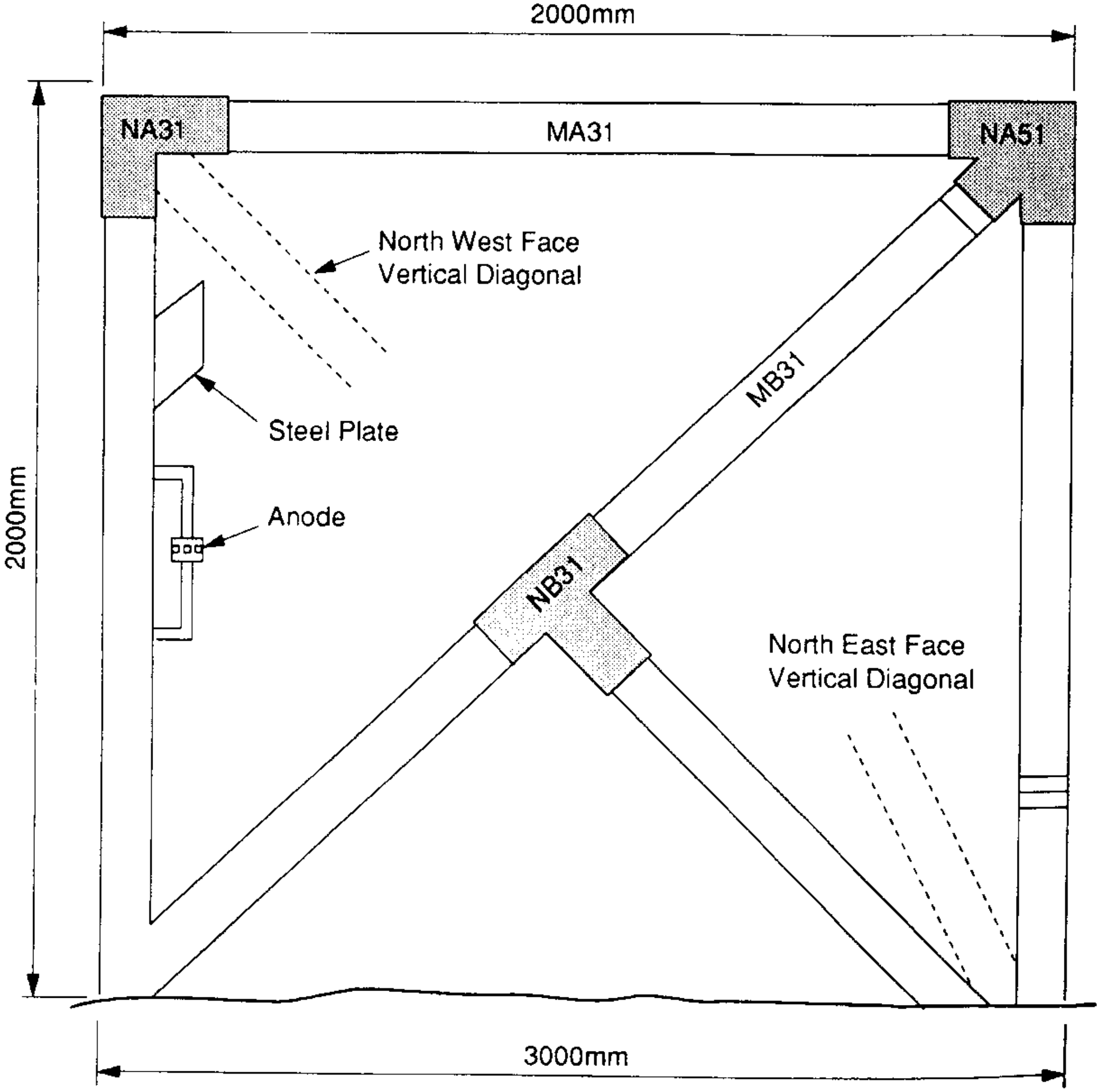
Platform North West Face



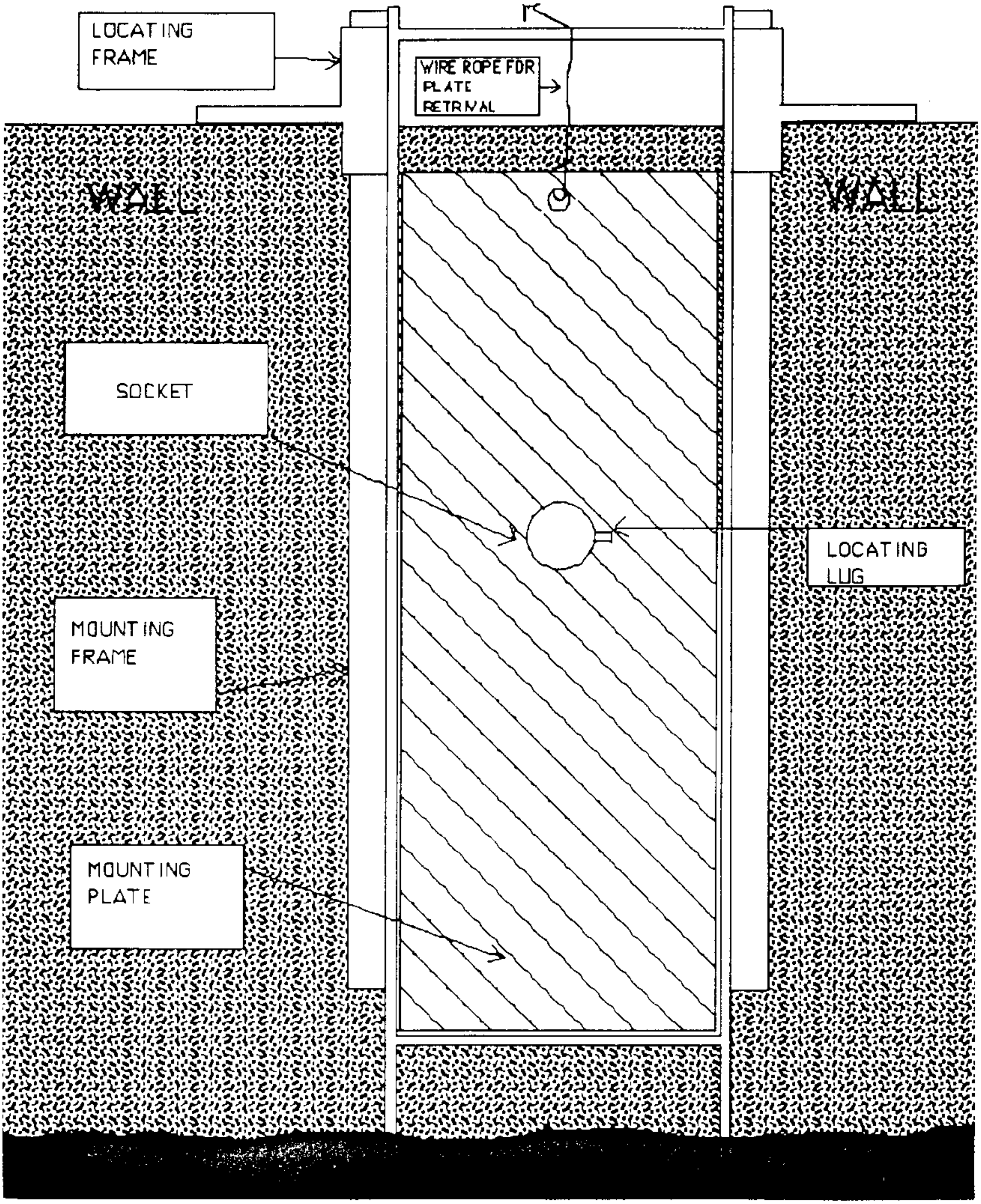
Both Leg 1 and Leg 2 Bottom Nodes Buried in
Silt Suspect South East Face Settled into Sea Bed

Fine Silty Bottom
No Evidence of Scour or Seabed Errosion

Platform South Face



Fine Silty Bottom
No Evidence of Scour or Seabed Errosion


LOCATING FRAME
WIRE ROPE FOR PLATE RETRIVAL
WALL
WALL
SOCKET
LOCATING LUG
MOUNTING FRAME
MOUNTING PLATE

Appendix O Examples of Exercises

Question 1

With the aid of the service manual carry out a full inspection of the F11 fixed displacment pump/motor. On completion compile a report indicating the following:-

a What components were inspected?

b What condition they were in?

c The effect of faulty components on the operation of the unit

Question 2

Using the technical manual briefly explain the test that can be carried out in situ on the F11-5 pump/motor to determine its general condition of operation. Include typical results in your explanation.

Question 3

Briefly explain the purpose of the inlet and outlet ports and the two case drain ports with reference to the operation of the ROV

Task 1

a Purpose.

This particular assessment is designed to assess three main abilities:-

Firstly the students theoretical knowedge of the unit is being assessed. In order to explain the effects of the various components on the operation of the unit the underpinning theoretical knowledge must be present.

Secondly the students ability to apply information obtained from a technical manual to a practical situation is being assessed.

Lastly the students ability to inspect mechanical components and appreciate the effects mechanical wear can have on the operation of the unit.

b Validity.

During the course the students have carried out inspections on various hydraulic units. These have been carried out by refering to technical manuals as well as discussing the effect of wear on general performance.

This assignment is designed to assess all these points and is therefore valid to the course.

The tasks carried out in the assignment are typical of tasks undertaken in the ROV industry. This assignment is therefore valid in that some of its contents can be applied in the workplace.

Appendix P Task 2 Fit Co-ax Connector

Detailed notes on Co-ax connectors are given under the video section of the course notes. Read these carefully before attempting this exercise.
Equipment required:-

1 BNC Kit

Solder Iron and Holder

Snips

Wire Strippers

Multimeter

Identify the type of connector and co-ax cable you have been provided with.

Follow the instructions given in the notes and carefully fit the connector to the co-ax

NOTIFY THE INSTRUCTOR

Appendix R Teeside Valve and Fitting Company Ltd

Teeside Valve and Fitting Company Ltd is a privately owned company, founded in October 1977 as an exclusive authorised distributor, for fluid system components manfactured by the Swagelok group of comapnies. The service territory for the company is the counties of Northumberland, Durham, Tyne and Wear, Cleavland,Cumbria, North Yorkshire and North and outh Humberside.

Teeside Valve and Fitting Company also provide training to customers for various products in the range. As part of this training, we provide installation seminars for the correct installation of Swagelok tube fittings. For the last 5 years we have been associated with Subserve at Wray Castle in this role On the ROV Pilot/Technician's Course.

Appendix Q Task 3 Repair of Underwater Cable

You are required to make a waterproof repair/join to the cable provided to you by the instructor. You are to employ the following procedure:-

a Cut and stagger the conductors to prevent a large bulge at the splice

b Cut 1/4" of insulation back from each conductor

c Place the correct size heat shrink over the conductors

d Solder the conductors together ensuring each is of the same length to ensure strain is equally applied

When you have completed all the necessary tasks to this stage *TELL THE INSTRUCTOR*

e Apply heat to the heat shrink tubing

f Clean and roughen the cable insulation

g Apply self-amalgamating tape to each join of the conductor

h Either:-

i Apply self-amalgamating tape over the whole connection

or

ii prepare within a potting box for potting

Note: in either case i or ii ensure a minimum of air is trapped in the cavities.

NOTIFY THE INSTRUCTOR

WEIGHT AND BREAKING LOAD TABLES

Cargo Handling Gear

6 x 19 Galvanised	Fibre Core			Steel Core	
Round Strand Rope Right-hand Ordinary Lay	**Size** Nominal Diameter	**Weight**	Minimum **Breaking** **Load** at 145		
	mm	kg/100m	tonnef		
	18	109	14.4		
Applications:	20	134	17.8		
Topping Ropes, Guy	22	163	21.6		
pendants	24	193	25.7		
6 x 19	18	100	13.2		
	20	124	16.2		
	21	136	17.9		
	22	150	19.7		
	24	178	23.4		

6 x 36 &6 x 41 Galvanised			at 180 Grade		at 180 Grade
	mm	kg/100m	tonnef	kg/100m	tonnef

Round Strand Ropes	16	94.5	15.2	104	16.4
Right-hand Ordinary Lay	18	120	19.2	132	20.7
	19	133	21.4	146	23.1
	20	148	23.8	163	25.7
Applications:	22	179	28.7	197	31.0
Topping Ropes, Cargo	24	213	34.2	234	36.9
Purchases for Derrick	26	250	40.1	275	43.3
Cranes and Deck Cranes.	28	289	46.6	318	50.3
Preventer Guys, Standing	32	378	60.8	416	65.7
Rigging	35	452	72.7	497	78.5
	36	478	77.0	526	83.2
	38	533	85.7	586	92.6
	40	591	95.0	650	10.3
	44			787	124
	48			935	148
	52			1100	174
	56			1280	201

17 x 7			
Multi-strand Rope	16	95.2	14.7
Right-hand Lang's Lay	18	120	18.6
Applications:	19	134	20.7
Cargo Purchases for	20	149	22.9
Derrick	22	180	27.8
Cranes, Deck Cranes where	24	214	33.0
non-rotating properties are	26	251	38.8
desirable			

Cargo Handling Gear

12 x 6 over 3 x 24

Size **Weight** Minimum

Multi-Strand Rope Right-hand Lang's Lay	Nominal Diameter mm	kg/100m	**Breaking Load** at 180 Grade tonnef
Applications:	16	92.6	13.8
Cargo Purchases for Derrick	18	117	17.5
Cranes, Deck Cranes where	19	131	19.5
non-rotating properties	20	145	21.6
are desirable	22	175	26.2
	24	208	31.1
	26	245	36.5
	28	284	42.4
	32	370	55.3

Standing Rigging - Shrouds, Stays, Hanger Ropes

6 x 19 Galvanised **Steel Core**

Round Strand Rope Right-hand Ordinary Lay (180 grade steel)	**Size** Nominal Diameter mm	**Weight** kg/100m	Minimum **Breaking** **Load** at 180 Grade tonnef
	22	193	31.1
	24	229	37.0
	26	270	43.5
	28	312	50.4

7 x 19 Galvanized			Minimum **Breaking** **Load** at 145 Grade tonnef
Round Strand Rope Right-hand Ordinary Lay (145 grade steel)	32	380	53.9
	36	481	68.2
	40	594	84.2
	44	719	102

Preventer Guys **Fibre Core**

Round Strand Rope Right-hand Ordinary Lay	**Size** Nominal Diameter mm	**Weight** kg/100m	Minimum **Breaking** **Load** at 145 Grade tonnef
	20	134	17.8
	22	163	21.6
	24	193	25.7
	26	227	30.1

Slewing Guy Falls

	Size Diameter mm	**Weight** Kg/100m	 kg/220m	Minimum **Breaking** **Load** tonnef
Polypropylene Ropes ('Fibrefilm' or Staplespun	16	19	42	3.5
	18	22	49	4.5
	20	27	61	5.4
	22	33	73	6.5
	24	40	88	7.6
	28	53	118	10.1

Manila Ropes - Grade 1	16	19	42	2.05
	18	22	49	2.45
	20	27	61	3.25
	22	33	73	3.85
	24	40	88	4.55
	28	53	118	6.10
	16	19	42	1.80
Sisal Ropes	18	22	49	2.15
	20	27	61	2.85
	22	33	73	3.40
	24	40	88	4.05
	28	53	118	5.35

METRIC FORMULAE FOR BREAKING STRESSES OF NATURAL AND SYNTHETIC FIBRE ROPE, STEEL WIRE ROPE AND CHAIN

1). Fibre Rope 3 Strand Hawser Laid

Material	Diameter	Breaking Strain Factor
Grade 1 manila	77mm - 144mm	$2D^2/300$
High grade manila	7m - 144mm	
Polythene	4m - 72mm	$3D^2/300$
Polypropylene	7mm - 80mm	
Polyester (Terylene)	4mm - 96mm	$4D^2/300$
Polyamide (Nylon)	4mm - 96mm	$5D^2/300$

2). Flexible Steel Wire Rope

Material	Diameter	Breaking Strain Factor
6 x 12	(4mm to 48mm)	$15D^2/500$
6 x 24	(8mm to 56mm)	$20D^2/500$
6 x 37	(8mm to 56mm)	$21D^2/500$

3). Stud Link Chain

Material	Diameter	Breaking Strain Factor
Grade 1	(12.5mm to 120mm)	$20D^2/600$
Grade 2	(12.5mm to 120mm)	$20D^2/500$
Grade 3	(12.5mm to 120mm)	$43D^2/600$

4). Open Link Chain

Material.	Diameter	Breaking Strain Factor
Grade 1	(12.5mm to 50mm)	$20d^2/600$
Grade 2	(12.5mm to 50mm)	$30D^2/600$