CCO Ltd

Diving management studies
Study No 6

Reflections regarding umbilical lengths when diving from a DP vessel

02 September 2020

Page left blank intentionally

Author: Christian Cadieux - CCO Ltd

52/2 moo 3 tambon Tarpo
65000 Phitsanulock
Thailand

Contact: Tel: +66 857 277 123
+66 900 314 585
E mail: info@ccoltd.co.th

Tables of contents

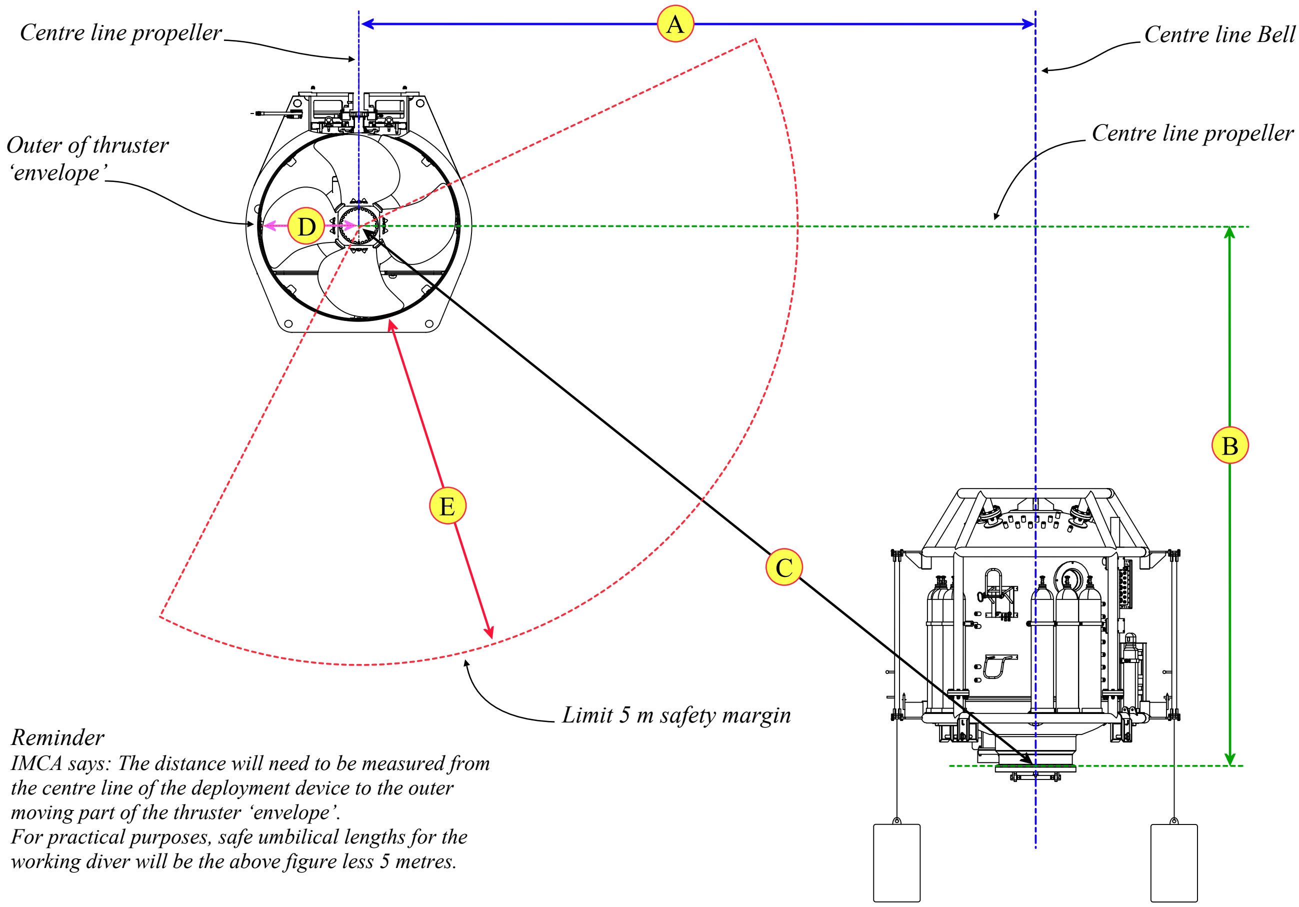
Purpose

The rules described by IMCA and ADCI regarding the safe distance of divers from propellers and other hazards when diving from a dynamic positioning vessel have probably saved numerous lives. However, these guidelines do not indicate elements such as the possibility to adjust the draft of the diving support vessel, the fact that new ships are equipped with azimuth thrusters that rotate 360 degrees, and that currents and a sudden loss of position can impact the position of the bell and so corrupt the initial umbilical calculations.
The main reason is that these guidelines have been emitted since dynamic positioning vessels arrived in the diving industry, and have not been changed from this time.
Based on the fact that events that have not happened yesterday may happen one day, common sense dictates that something has to be done to plug this existing gap, even though professional organizations do not publish modification of the existing rules.
For this reason, I have thought of a method of calculation that is easy to implement and increase the safety level of the divers working shallow.

1 - Calculate the divers' umbilicals lengths

The Pythagorean theorem is normally used to calculate the distance of the umbilical according to the recommendations indicated by IMCA and ADCI.

This theorem, which is also called the "Pythagorean equation", says that the square of the hypotenuse is equal to the addition of the squares of the two other sides. So, to obtain the hypotenuse "C" of the lengths "A" & "B" in the drawing below, we can use the formula "$A^2 + B^2 = C^2$ ", and then extract the square root of "C^2" to obtain the real value of "C".



Reminder
IMCA says: The distance will need to be measured from the centre line of the deployment device to the outer moving part of the thruster 'envelope'.
For practical purposes, safe umbilical lengths for the working diver will be the above figure less 5 metres.

The calculation of the umbilical length of the working diver consists of finding the hypotenuse *(Distance C)* of the distances A & B, from which the radius of the thruster *(Distance D)* and the safety margin (5 m) from the "outer moving part of the thruster envelope" *(Distance E)* are removed:

- The distance "A" is the distance from the center of the thruster to the center of the deployment device
- The distance "B" is the center of the thruster to the point of deployment of the umbilical
- The distance between the centre of the thruster and the waterline (surface of the sea along the hull) must be measured. Note that for a precise calculation of the hypotenuse, the computation must be performed using the vertical distance from the centre of the thruster to the point of deployment at depth (distance B). However, the gap between the centre of the thruster and the waterline must be taken into account to obtain rounded depths starting from the waterline because the recommended reference to adjust the bell is its depth from the surface of the sea. For example, if the centre of the propeller is at 4.5 m below the waterline, the 10 m depth from the waterline is 5,5 m below the centre of the thruster, and the 20 m depth is at 15.5 m from the centre of the propeller, etc. Besides, the distance of the reference point on deck, which is the point from which the length of umbilical deployed is measured, should also be evaluated.
- When the distances are evaluated, apply the formula $A^2 + B^2 = C^2$
- Extract the square root of C^2 to obtain the distance C
- When the distance "C" is obtained, remove the distance "D" *(Radius Thruster)* and "E" *(5 m safety margin)* to obtain the maximum distance of umbilical that can be deployed.
- As the vertical distance "B" of the umbilical is calculated from the centre of the propeller, the distance from this point to the waterline must be added to obtain the depths to be indicated on the drawing. Using the previous example, 5.5 m from the centre of the propeller is 10 m from the waterline (surface of the sea), so the distance to indicate on the reference drawing. Also indicate the distances of the reference point on deck.

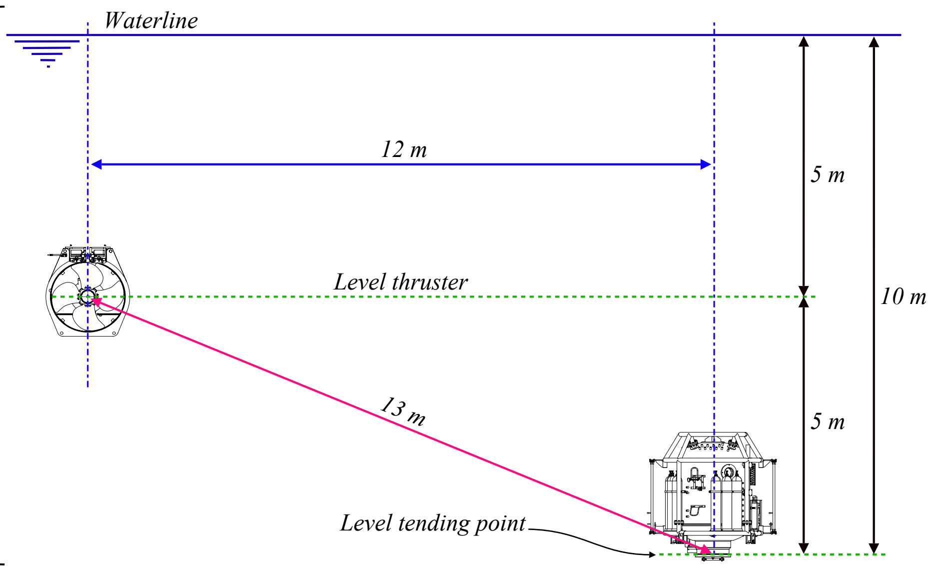
The same method can be used for the calculation of the maximum allowable distance of the rescue diver except that the safety margin is 3 metres instead of 5 m, or by adding 2 metres to the working diver umbilical lengths.

Note that this model does not take into account the fact that the vessel can be ballasted or de-ballasted during the diving operations, which will change the draft of the ship, and so the parameters used for the umbilical length calculation. Because the vertical reference used is the depth of the bell, the hypotenuse can vary as the actual depth of the bell can be above or below the level initially taken for reference. That can be visualized using the following example:

Initial status:

- *The gap between the centre of the thruster and the waterline is 5 metres.*
- *The horizontal of the bell distance from the centre of the thruster is 12 m,*
- *When the bell is lowered at 10 metres, the gap between the centre of the thruster and the tending point in the bell is 5 metres.*

As a result, the length of the hypotenuse is 13 metres.

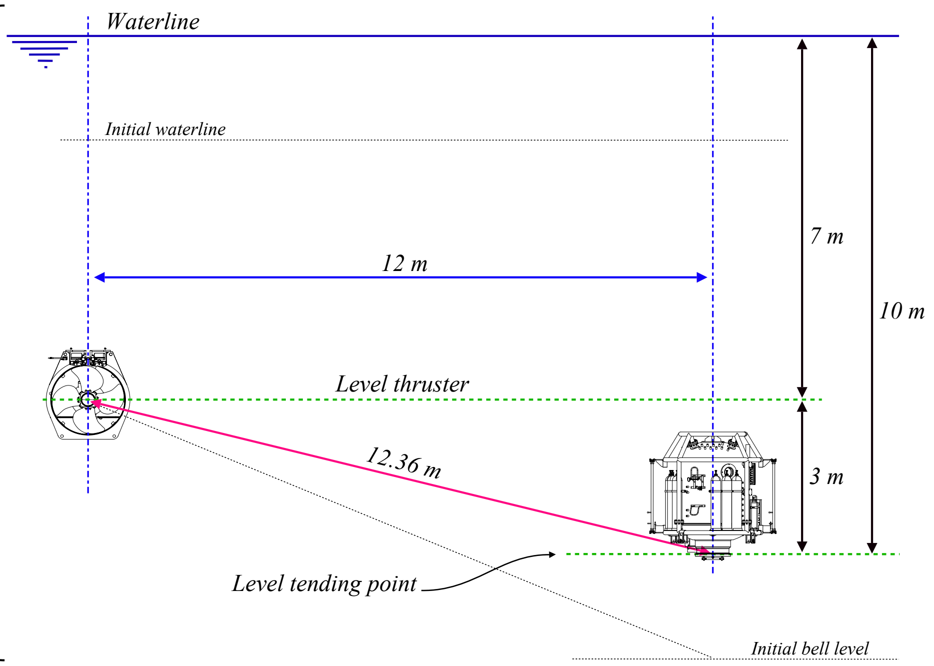


If the vessel is ballasted 2 m deeper the initial status:

- *The draft of the ship is increased of 2 m.*
- *The waterline is 2 m closer to the deck.*
- *The thruster is 2 m deeper.*

Thus, the gap between the centre of the thruster and the waterline is 7 metres, and when the bell is lowered at 10 metres below the waterline, the distance between the centre of the thruster and the tending point in the bell is 3 metres.

As a result, the length of the hypotenuse is 12.36 metres instead of 13 metres. So, the initial distance is longer.

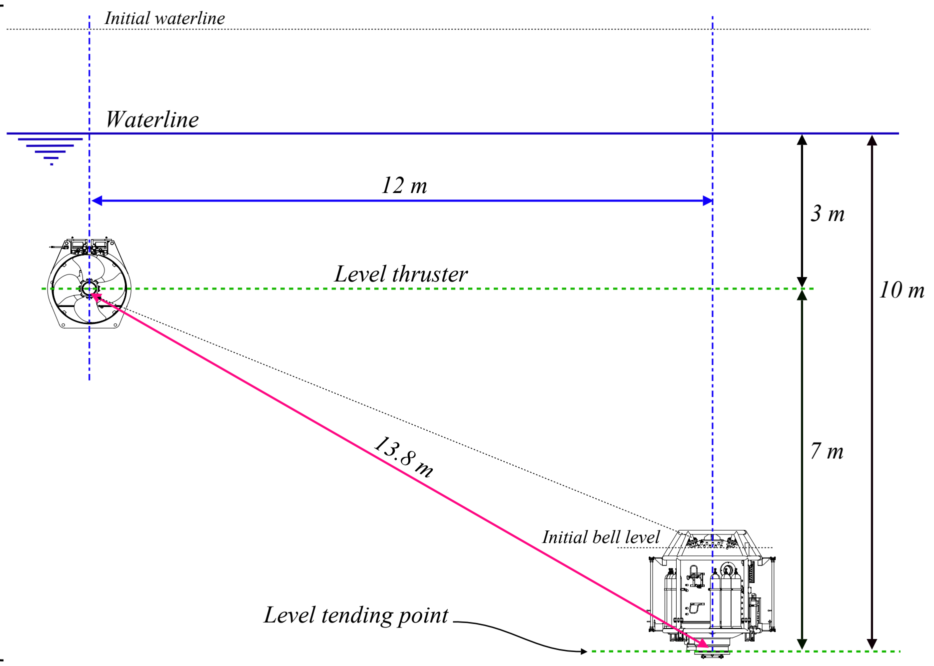


If the vessel de-ballasted 2 metres above the initial status:

- *The draft of the ship is 2 m shallower.*
- *The distance from the waterline to the deck is increased of 2 m.*
- *The thruster is 2 m shallower.*

Thus, the gap between the centre of the thruster and the waterline is 3 metres, and when the bell is lowered at 10 metres below the waterline, the distance between the centre of the thruster and the tending point in the bell is 7 metres.

As a result, the length of the hypotenuse is 13.8 metres instead of 13 metres. So, the initial distance is shorter.



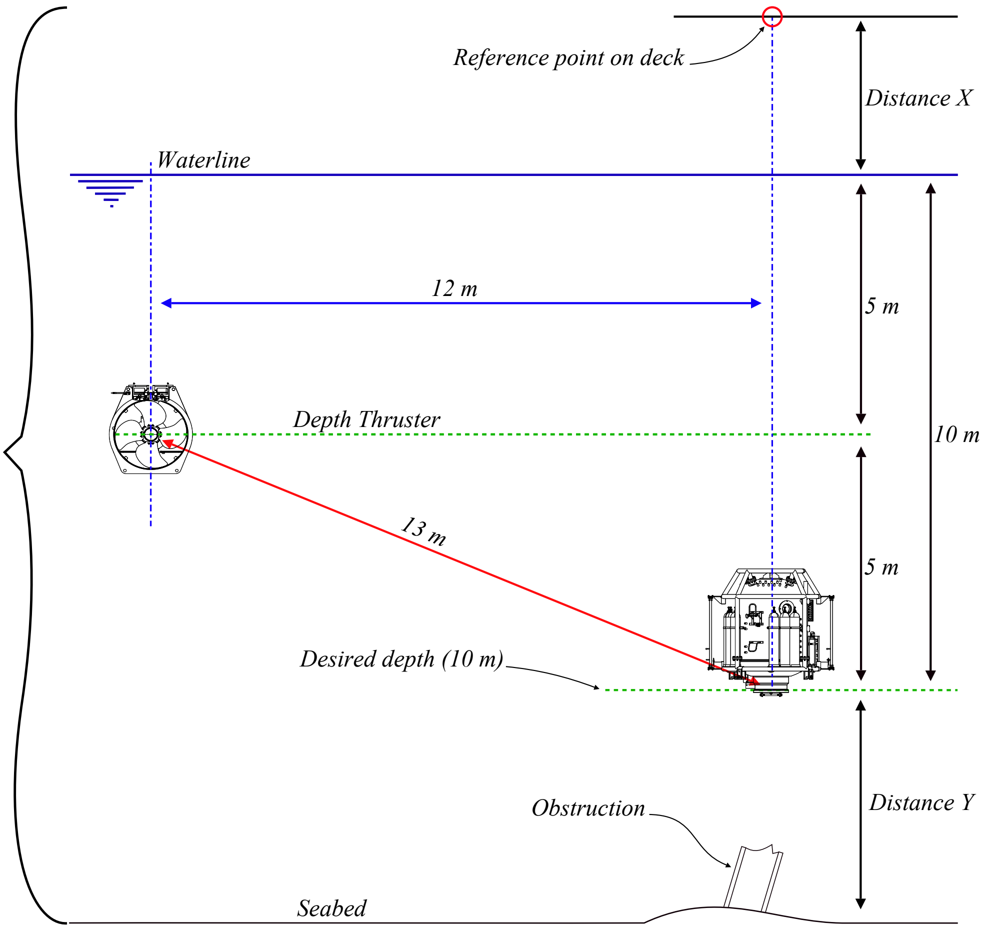
As a conclusion of the above, calculate specific deployment depths for each situation is too complicated and would be confusing for the team. So, the solution is to publish a document that can be used safely, whatever the draft of the vessel. For this reason, when a ship is subject to ballasting and de ballasting, the waterline to select for the calculation of the incremental depths should be the one when the boat is at its maximum draft.

Note that it is usual to check the depth of deployment of the bell using the length of cable deployed from the reference point on deck. However, in the case of a vessel ballasting and de-ballasting, this reference must be adjusted according to the draft of the boat to deploy the bell at the desired depth. If this modification is not implemented, the draft of the vessel varies, and the depth at which the bell is deployed varies accordingly because the length of cable deployed remains the same. As an example, if the vessel is ballasted to have two more metres draft, the reference point on deck is also lowered 2 m, so the bell is 2 metres deeper than calculated initially if it is not readjusted *(see in the scheme below)*. The bell can also be two metres above the planned depth if the boat is de-ballasted 2 m. As a result, the reference on deck is not a valid reference for the depth of deployment of the bell at the desired depth if it remains unchanged.

Initial status:

- *The gap between the centre of the thruster and the waterline is 5 metres.*
- *The horizontal distance of the bell from the centre of the thruster is 12 m.*
- *When the bell is lowered at 10 metres, the gap between the centre of the thruster and the tending point in the bell is 5 metres.*
- *The length of the hypotenuse is 13 metres.*
- *The distance between the thruster and the reference point on deck is always the same. On the drawing , this reference point is 3 m above the waterline (distance X).*

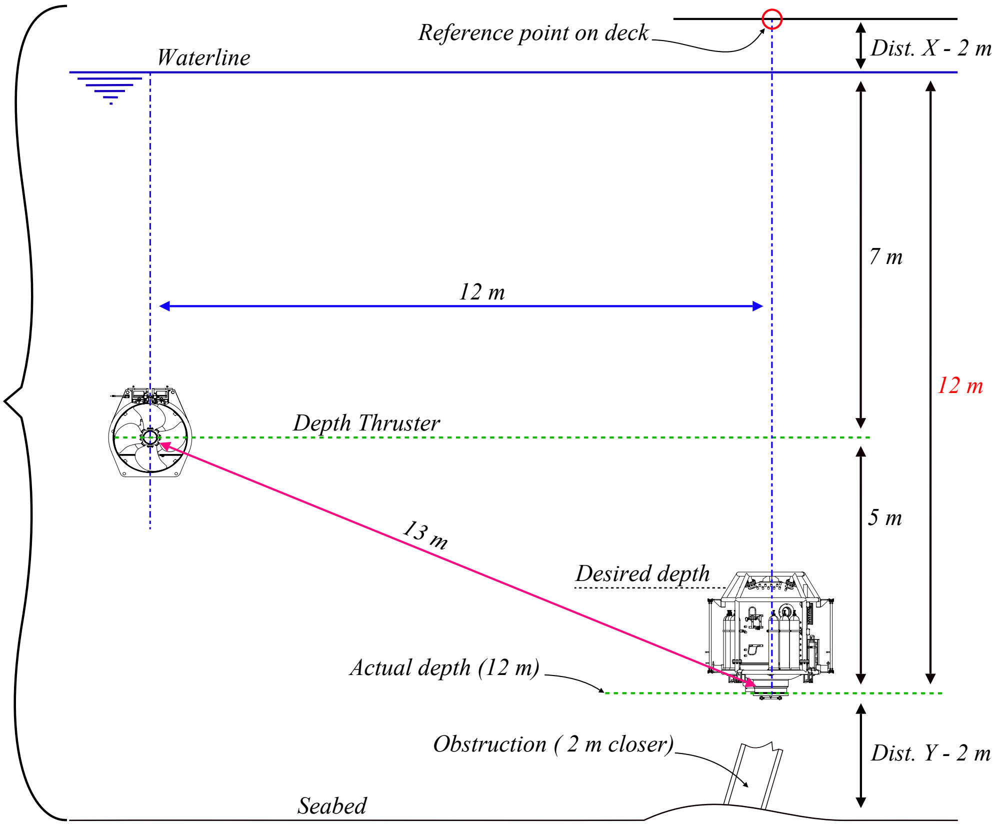
As a result, the bell is deployed at 10 m and its gap from the seabed is the distance Y.



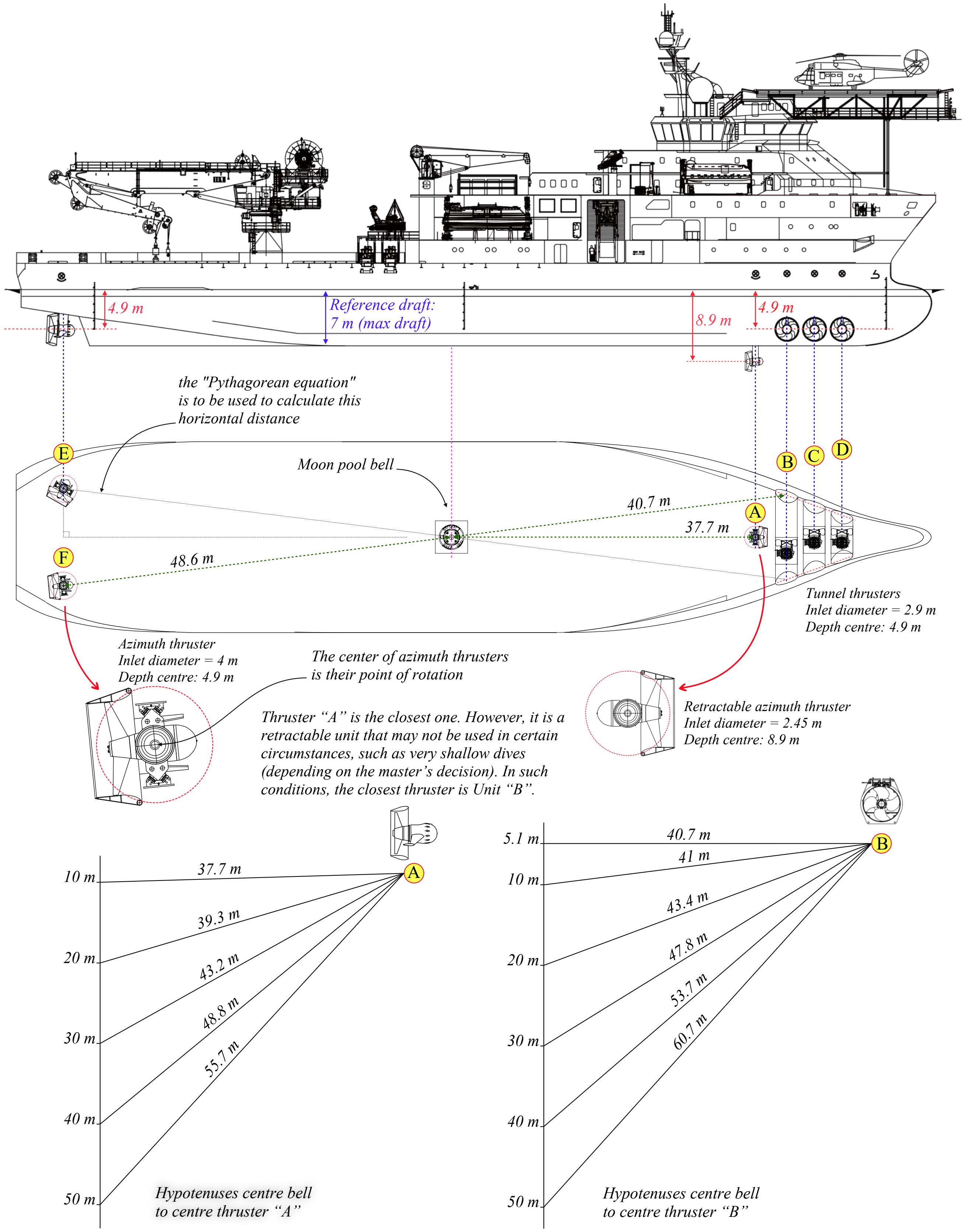
If the draft of the vessel is increased of 2 m:

- *The gap between the centre of the thruster and the waterline is now 7 metres.*
- *The horizontal distance of the bell from the centre of the thruster is unchanged,*
- *The gap between the centre of the thruster and tending point in the bell is still 5 metres.*
- *The length of the hypotenuse is still 13 metres.*
- *The distance between the thruster and the reference point on deck is always the same.*
- *The reference point is now 1 m above the waterline (distance X - 2 m).*
- *As the length of cable deployed is not modified, the bell is now at 12 m instead of 10 m.*

As a result, the gap from the seabed is the distance Y minus 2 m and the bell is closer to hazards.



Another problem that must be taken into account is to verify the exact position of the thrusters to evaluate which one is the closest to the bell.
The lateral view of the vessel is insufficient for this calculation as the thrusters have to be located horizontally and vertically. For this reason, a plan view of the bottom of the ship is to be used to see their exact horizontal position. In complement, the depth of each propeller must be evaluated, so we can have an idea of their position in three dimensions.
As an example, we can see in the plan view below that the thrusters E & F are not aligned with the moonpool of the bell, so their exact distance is to be calculated using the "Pythagorean equation". Note that the point from which the horizontal distance of the azimuth thrusters to the centre of the moon pool is to be calculated is their point of rotation.
When the thrusters are located horizontally, the depth of the centre of their propeller is to be used to locate them on the vertical axis.
Note that, as indicated previously, the hypotenuses are calculated from the centre point of each device, and the safety limits are added later.



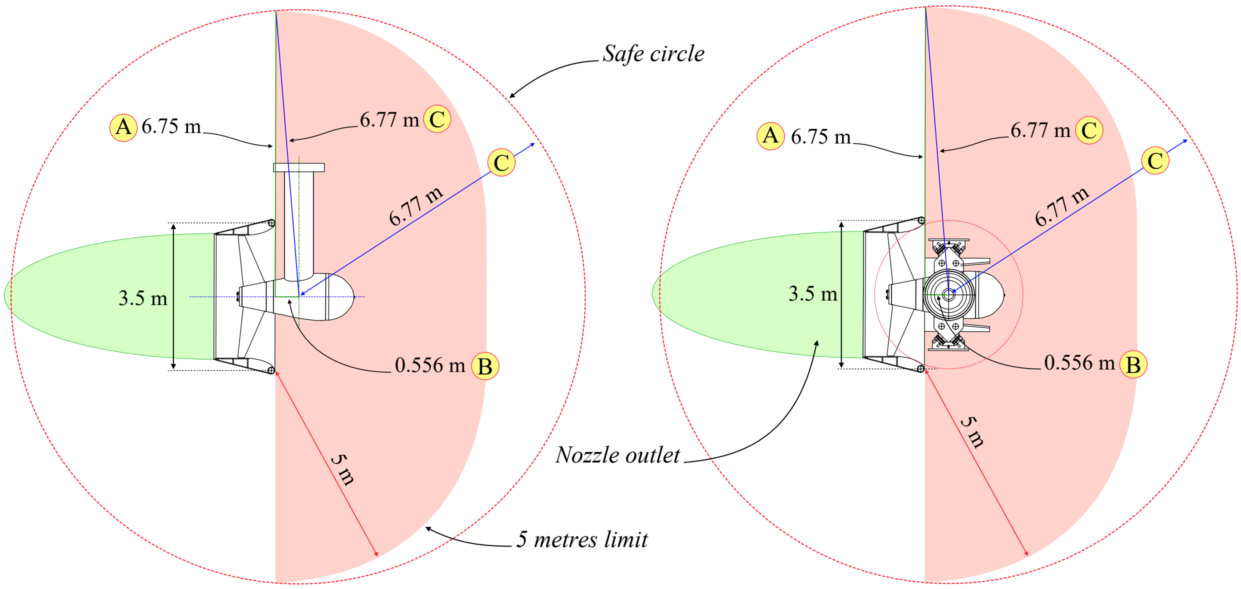
When the thrusters are located, the hypotenuses of the closest thruster are to be calculated for every 10 metres from the first level of deployment and up to the depth where the propellers are too far to represent a danger. This depth also depends on the length of umbilical available in the bell. Usually, the calculation is halted between 60 and 80 metres.

Note that if the closest thruster is retractable, as in the example on the previous page, the nearest unit if this retractable thruster is not used (based on the decision of the master) becomes the reference. Also, even though the diver umbilical must be restricted to the closest thruster, it is wise to calculate the distances for the other thrusters as strong currents or sudden vessel moves may push the bell toward them.

When the lengths axis to axis are calculated, the safety precautions indicated by IMCA and ADCI *(external envelope of the moving parts and 5 m limit),* and mentioned previously must be implemented.
Regarding this point, note that azimuth thrusters rotate 360º around their axis and that their propellers are installed eccentric so that the procedure to evaluate the safe distance from these propellers is different from the one used with tunnel thrusters and fixed propellers. For this reason, the drawings from the manufacturer should be used to evaluate the safe limit into which the thruster can rotate and always be inside a 5 m safety margin as a minimum.
Note that, depending on the model of the thruster, the propeller can be installed on the back of the pivoting point, or on the front of it, which influences the procedure of calculation.

- 1 - Procedure for a thruster with the propeller installed on the back of the pivoting point:

- The first step consists of drawing the limit of the propeller "envelope", and the 5 metres safety limit from this "envelope". Note that if the diver is forward the inlet of the propeller, he will be drawn to it. For this reason, the 5 m limit from the inlet of the propeller is outlined in red in the drawing below. However, if the diver is behind the propeller, so roughly in the area figured in green, he will be violently ejected. The spaces between these two zones are sectors that are also to be considered unsafe.
  Note that the 5 m limit from the envelope of the propeller is similar on a vertical and horizontal axis. So we can imagine that the 5 m limit is a flatted half-sphere in which the center point is the crossing of the axis of the propeller with the horizontal rotation axis.
- When the propeller envelope and the 5 m limit are evaluated the circle into which the thruster can rotate without being at less than 5 m from this limit must be evaluated. For thrusters with the propeller on the back of the pivoting point, the proposed procedure is the following:
  - Calculate the distance "A" from the axis of the propeller to the external of the 5 m limit: In the example below, 5 m limit + radius propeller "envelope" (1.75 m) = 6.75 m . .
  - Calculate the distance "B" from the edge of the propeller "envelope" to the pivoting point of the thruster. In the example below, it is 0.556 m.
  - Calculate the hypotenuse "C" of "A" and "B".
  - The Hypotenuse "C" obtained is the radius of the safe circle into which the thruster can rotate.

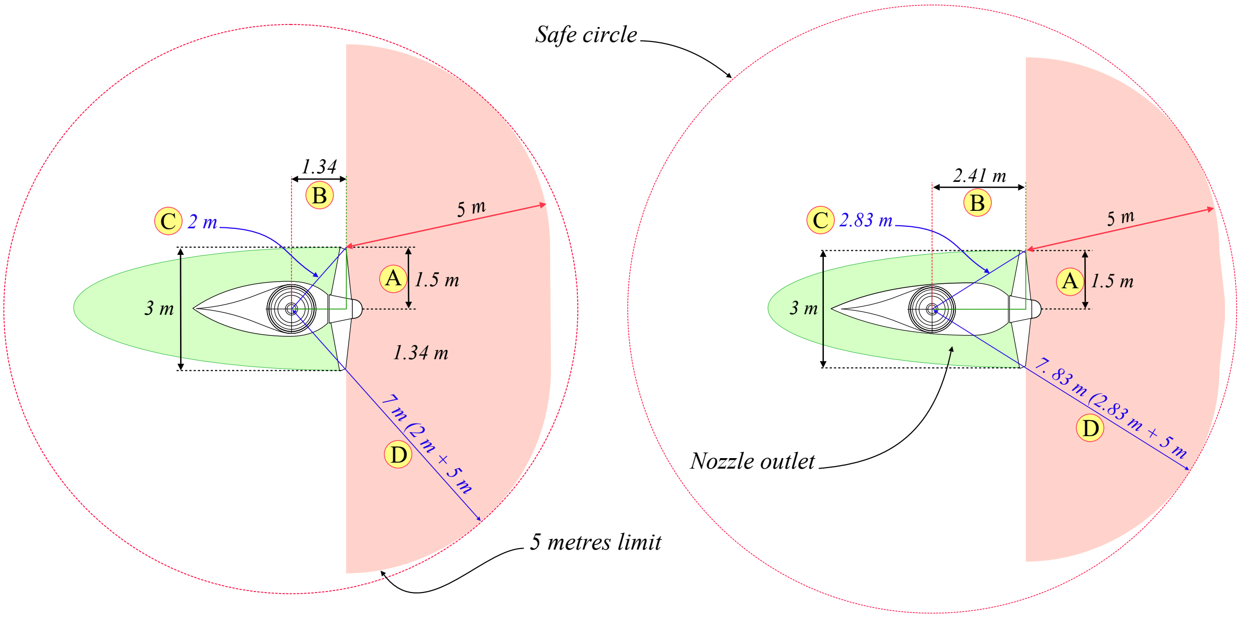


Side view thruster: Vertical axis *Plan view thruster: Horizontal axis*

- 2 - Procedure for a thruster with the propeller installed on the front of the pivoting point:

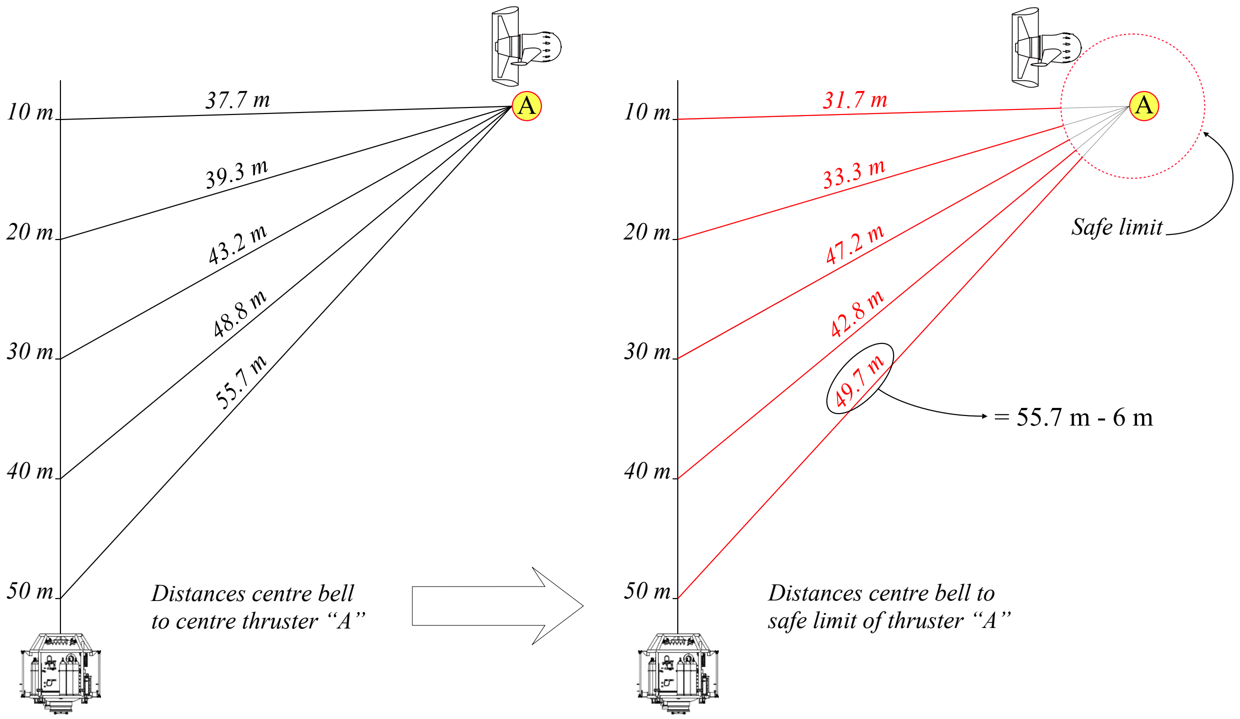
- The first step is similar to the one implemented with thrusters with the propeller installed on the back of the pivoting point. Note that for convenience in the example below, the edge of the blade is taken as reference of the external limit of the envelope of the moving parts.
- When the propeller envelope and the 5 m limit are evaluated the circle into which the thruster can rotate without being at less than 5 m from this limit must be calculated. The proposed procedure is the following:
  - Calculate the distance "A" from the axis of the propeller to the external limit of the envelope of the moving parts: In the example #1 & #2 below, this distance is 1.5 m.
  - Calculate the distance "B" from the edge of the propeller "envelope" to the pivoting point of the thruster. In the example #1 below, it is 1.34 m, and in the example #2, it is 2.41 m.
  - Calculate the hypotenuse "C" of "A" and "B".

- The length of Hypotenuse "C" obtained is added to the 5 m limit: That gives a distance of 7 m in the example #1, and a distance of 7.83 m in the example #2.
- The distance "D" obtained is the radius of the safe circle into which the thruster can rotate.



Example #1   Example #2

When the sphere into which the thruster can rotate within the 5 m safety limit is established, its radius must be removed from the hypotenuse of the axis of the bell to the central point of the thruster, as performed with tunnel thrusters or fixed propellers. As an example, if the radius of the safe circle is 6 m, this distance is merely removed from the hypotenuse as in the drawing below:



When the maximum umbilical lengths are calculated, it often happens that the distances found are precise at the centimetre, and sometimes the millimetre. For practical reasons, these values should be rounded to the immediate shorter decimetre. Example: 49.766 m should be turned to 49.7 m.

The installation of the safety fastenings of the umbilicals should be prepared before launching the bell. The restrictions for the rescue diver are those indicated previously for fixed propellers and tunnel thrusters. Thus 2 m is to be added to the limits established for the working divers. These distances should be shown in the scheme and the table where the maximum umbilical lengths are displayed.
Regarding the deployment of the rescue diver, it is usual to plan it from the bell as the depth where it is stored is often too far for an intervention from the surface. However, it may happen that during shallow dives, a surface orientated standby diver is ready to intervene. In this case, the procedures to prevent him from coming within three metres of the nearest hazard must be implemented as well.

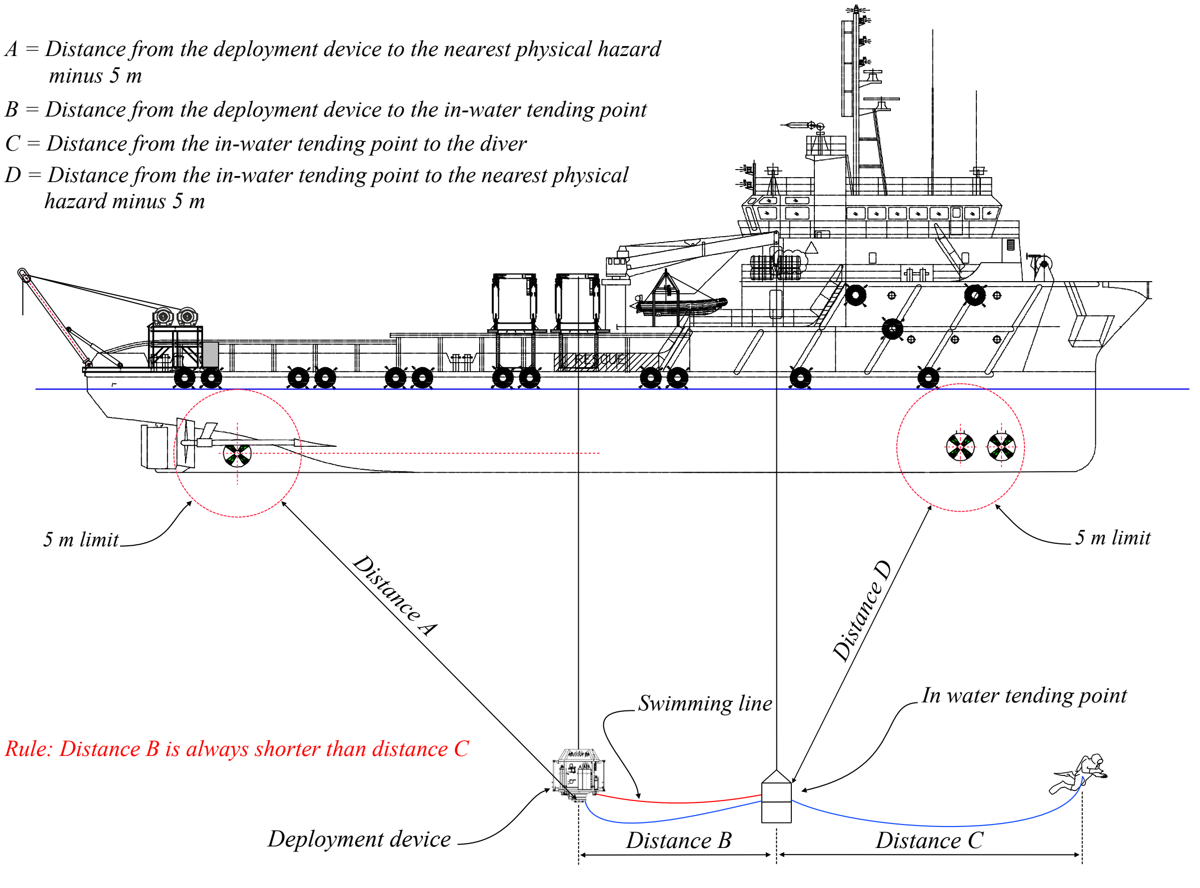
Note that the calculations indicated above should be provided by the manufacturers of Diving Support Vessels. It is, unfortunately, not always the case. The problem is more complicated with boats of opportunity because they are multipurpose ships that are not specifically designed for diving. In case that these evaluations are missing, they must be performed when selecting the vessel as the distance between propellers and the bell is a criterion of selection.

2 - Deployment of divers using in-water tending points

The length of umbilical deployed should be kept to a minimum. So when it is possible to do it, it is preferable to move the vessel above a target instead of extending the umbilicals to their maximum ranges. Also, at depths below 60 m, the distance from the bell the diver can go does not depend on the proximity of the thrusters, but on the length of umbilical available in the bell and on the capacity of his bailout to allow for a safe return to the bell.
However, shallow dives near facilities can be disturbed by problems of access of the boat to some areas due to elements such as platform overhangs, flare towers, lifeboats launching area, bridges, and others.
For this reason, it may be necessary to deploy the divers beyond the calculated safe umbilical length. As indicated in IMCA D 10, that can be performed using a 2nd tending point, which can be a basket or a piece of similar equipment such as a squared frame, suspended from a crane, or a similar deployment device located on the vessel. The diver usually passes through this structure to encage his umbilical so that it is secure and can continue sliding. Then, the diver can move forward from this point to the job site *(see the drawing in point 8.4.1.2)* without the risk to be drawn to the closest propeller, despite the extra umbilical length deployed.
The device used to deploy the 2nd tending point must be able to hold a static position when deployed. “A-frame” shaped deployment devices are considered very safe for this reason, and are also simple to implement.

IMCA D 010 provides useful guidelines regarding the methods to be implemented for the safe operation of a 2nd tending point. As indicated in point 8.4.1.2, this guideline classifies the additional tending points into “active” and “passive” tending points, and thus says the following rules:

- 1- Active in-water tending point (manned):
  An active tending point is the arrangement described above with a diver acting in it as intermediate in-water tender. the following criteria should be met:
  - The tending point is held in a static position relative to the vessel that should be confirmed by a beacon.
  - The length of the umbilicals must be restrained as indicated in the previous points.
  - A swim line is fixed between the deployment device and the manned in-water tending point.
  - The working diver’s umbilical is secured to the swim line between the deployment device and the manned in-water tending point at the maximum allowable excursion distance from the in-water tending point.
  - The in-water tender’s umbilical and that of any standby diver is secured to the swim line between the deployment device and the manned in-water tending point at the calculated maximum excursion distance for the working diver from the in-water tend point plus two metres.
  - In the event of the tender becoming incapacitated, the working diver should have sufficient length of umbilical to return to the deployment device without disconnecting his umbilical from the swim line. For this reason, his maximum allowable excursion beyond the in-water tending point is always greater than the distance from the deployment device to the in-water tending point *(see below)*.



- Procedures should be in place to allow for the recovery of a diver in an emergency.
- A risk assessment should be carried out, and the additional measures identified should be implemented.

- 2- Passive in-water tending point (unmanned):

A passive tending point is the arrangement described above but without a diver acting in it as intermediate in-water tender. The procedures that should be applied are the same as those of active tending point except the following:

- The bellman's umbilical and that of any standby diver is secured to the swim line between the deployment device and the unmanned in-water tending point at the calculated maximum excursion distance for the diver from the in-water tending point plus two metres.
- If a problem begins to arise when two divers are on passive tending, then one diver should return to the tend point and revert to active tending.

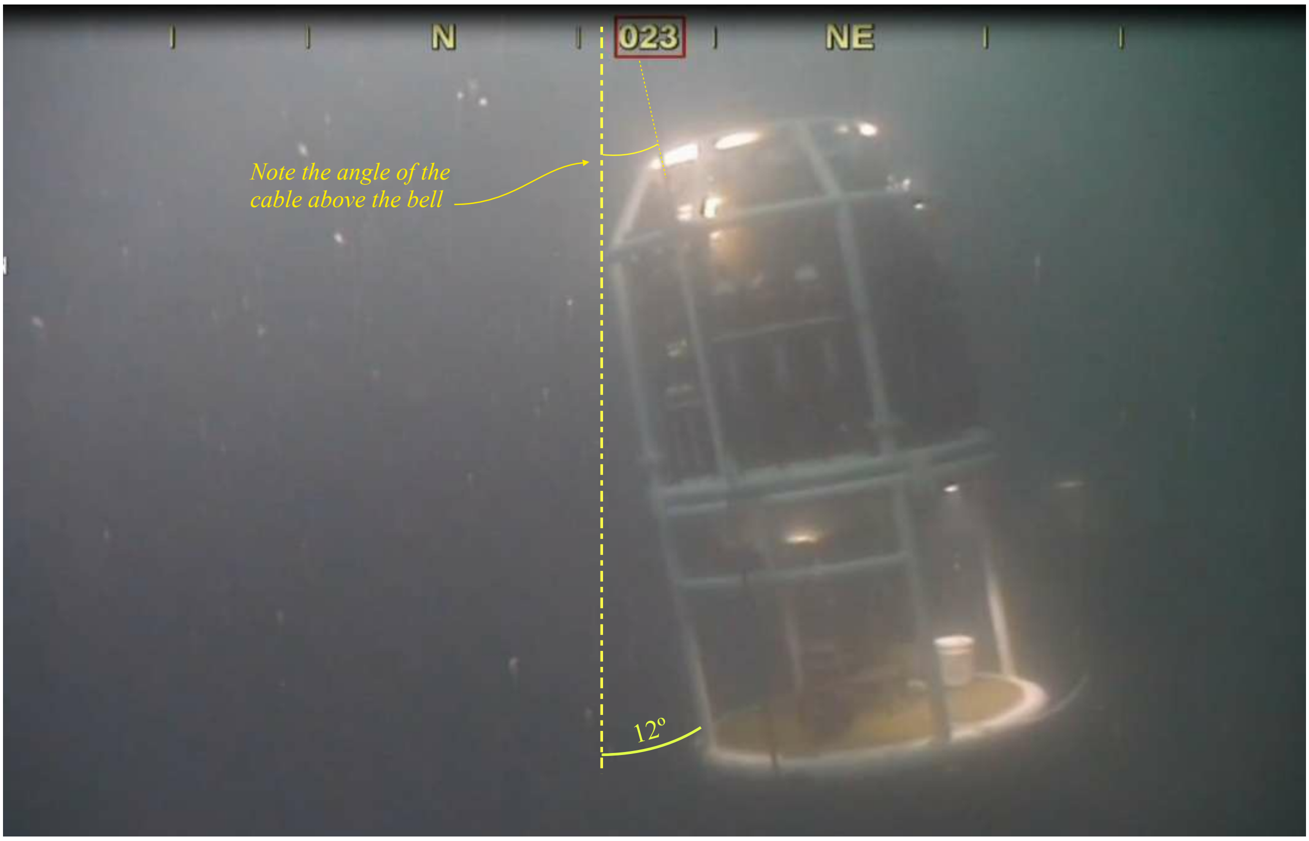
3 - Influence of the underwater currents and sudden moves of the ship on the bell and its umbilical

Underwater currents that can push the bell and its umbilical may establish during the diving operations. Also, due to the density of the water, the bell cannot follow an unexpected move of the boat vertically and thus is hung with an angle during these periods.

The action of the current on the main umbilical can result in a large buckle, and an excessive length deployed. This problem is usually solved with the last generation bells that are provided with a dynamic tensioning system of the umbilical that permanently recovers the excess of slack, and maintains it in tension *(see point 2.3.10 in the document "Description of a saturation system" published by "Diving & ROV Specialists").*
However, most old generation systems are not equipped with such devices, and their umbilicals are often partly deployed manually. For this reason, the umbilical of such systems should be secured to the bell wire at regular intervals along its length to prevent it from being attracted by the thrusters. The whips that are used to secure the umbilical should be designed such that they do not damage it and must be able to slide easily along the cable. Also, the distances where these whips are installed on the umbilical must be recorded. Usually, endless soft slings or rope slings with large carabineers that are installed on the main cable of the bell are used for this purpose.

IMCA says that when securing the umbilical along the cable is not an appropriate solution, a risk assessment should identify the maximum safe length of umbilical, which can be deployed in relation to the depth of the bell.

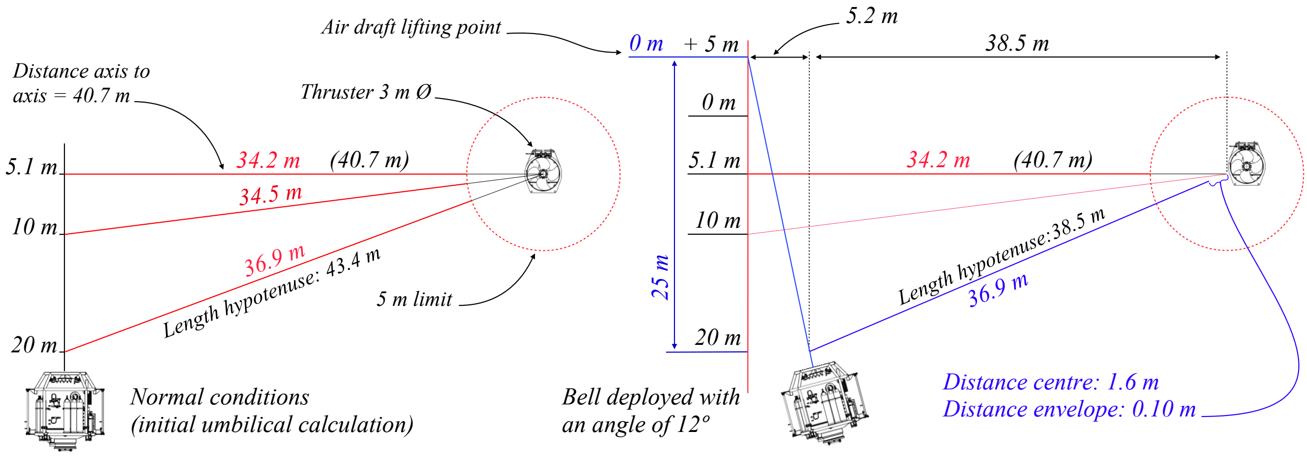
Another problem linked to strong currents is that they can push the bell, which is lowered with an angle as in the photo below instead of vertically. As a result, the bell is not at the planned location, and the initial calculation for the deployment of the divers' umbilicals can be significantly altered. A similar effect may happen in the case of an unexpected violent move of the vessel.



Note that in such cases, the deployment cable usually forms a catenary. However, this catenary varies with the pressure resulting from the current, the depth of the bell, or the force of the sudden pull of the vessel. So, it is challenging to predict its exact curve, and for this reason, only the angle is considered.
Considering the photo above taken at a depth of 50 m, so 60 m below the lifting point, and the visible angle of the bell of 12 degrees, we can evaluate its horizontal distance from the "vertical" of the moon pool to approximately 12.6 m.

The photo of this example has been taken when the bell was descending to a deeper depth where there was no current. So the only problem was to make corrections to be close to the worksite. However, a bell that is not deployed vertically may become a serious problem during shallow dives, due to the proximity of the propellers.
To illustrate it, we can take the example of a bell with a lifting point at 5 m above the waterline, the center point of the nearest tunnel thruster of 3 m diameter at 5.1 m below the waterline, and a horizontal distance of 40,7 m from the center of the bell. So, the 5 m safety limit at 6,50 m from the center of this thruster.

- Under "normal" conditions (initial calculation), the length of umbilical available at 20 m is 36.9 m, and the vertical distance from the pulley of the A-frame is 5 m (air draft)+ 20 m (water depth)= 25 m.
- If the bell is lowered with an angle of 12º from a vertical distance of 25 m, it is shifted 5,2 m from the vertical point. Thus the hypotenuse from this new position to the center of the thruster is 38.5 m.
- If the diver keeps the initial umbilical length of 36.9 m, the end of his umbilical is at 1.6 m from the centre of the thruster and 10 cm from the "envelope". Thus, we can say that this thruster can catch the diver.

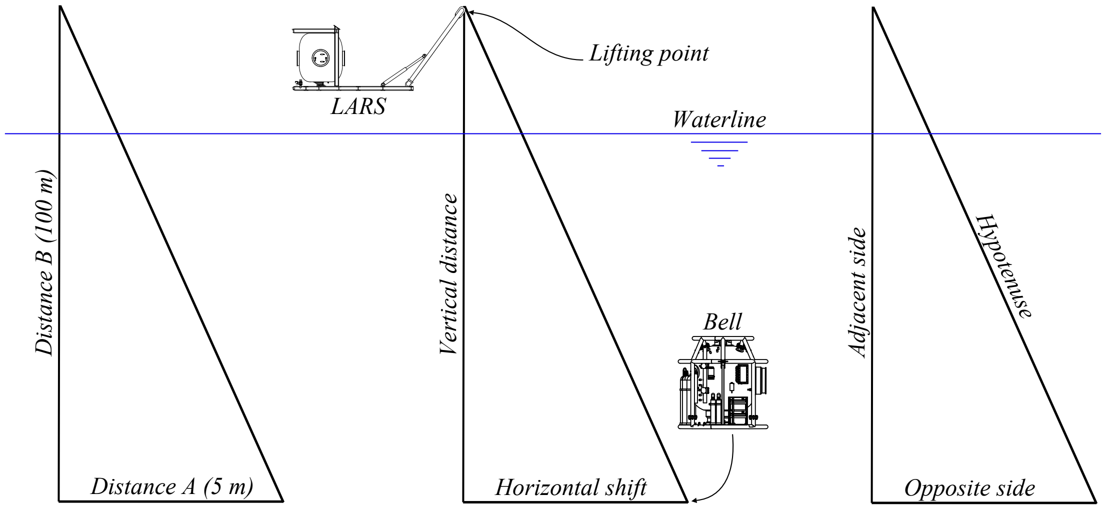


The table below shows the horizontal the deviations resulting from the angles at various distances from the lifting point.

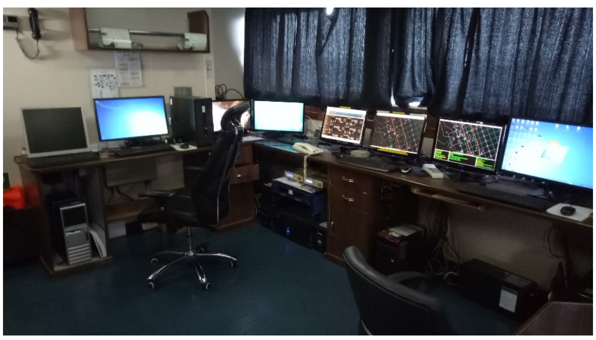
		Angle							
		2°	**4º**	**6°**	**8º**	**10º**	**12º**	**14º**	**16º**
Vertical distance	**5 m**	0.2 m	0. 3 m	0.5 m	0.7 m	0.9 m	1 m	1.2 m	1.4 m
	10 m	0.3 m	0.7 m	1 m	1.4 m	1.7 m	2.1 m	2.4 m	2.8 m
	15 m	0.5 m	1 m	1.6 m	2.1 m	2.6 m	3.1 m	3.7 m	4.2 m
	20 m	0.7 m	1.4 m	2.1 m	2.8 m	3.5 m	4.2 m	4.9 m	5.6 m
	25 m	0.9 m	1.7 m	2.6 m	3.5 m	4.4 m	5.2 m	6.1 m	7 m
	30 m	1 m	2.1 m	3.1 m	4.2 m	5.2 m	6.3 m	7.3 m	8.4 m
	35 m	1.2 m	2.4 m	3.7 m	4.9 m	6.2 m	7.3 m	8.5 m	9.8 m
	40 m	1.4 m	2.8 m	4.2 m	5.6 m	7.2 m	8.4 m	9.8 m	11.2 m
	45 m	1.6 m	3.1 m	4.7 m	6.3 m	8.2 m	9.4 m	11 m	12.6 m
	50 m	1.7 m	3.5 m	5.2 m	7 m	9.2 m	10.5 m	12.2 m	14 m
	55 m	1.9 m	3.8 m	5.8 m	7.7 m	10.2 m	11.5 m	13.4 m	15.4 m
	60 m	2.1 m	4.2 m	6.3 m	8.4 m	11.2 m	12.6 m	14.7 m	16.7 m
	65 m	2.3 m	4.5 m	6.8 m	9.1 m	12.2 m	13.6 m	15.9 m	18.1 m
	70 m	2.4 m	4.9 m	7.3 m	9.8 m	12.2 m	14.7 m	17.1 m	19.5 m
	75 m	2.6 m	5.2 m	7.9 m	10.5 m	13.1 m	15.7 m	18.3 m	20.9 m
	80 m	2.8 m	5.6 m	8.4 m	11.2 m	14 m	16.7 m	19.5 m	22.3 m
	85 m	3 m	5.9 m	8.9 m	11.9 m	14.8 m	17.8 m	20.8 m	23.7 m
	90 m	3.1 m	6.3 m	9.4 m	12.6 m	15.7 m	18.8 m	22 m	25.1 m
	95 m	3.3 m	6.6 m	9.9 m	13.3 m	16.6 m	19.9 m	23.2 m	26.5 m
	100 m	3.5 m	7 m	10.5 m	14 m	17.4 m	20.9 m	24.4 m	27.9 m

There are several methods that can be used to calculate the horizontal shift from the vertical of the launching point:

- The table displayed on the previous page gives approximate horizontal shifts resulting from angles from 2º to 16º, calculated from the vertical alignment of the launching system on deck. Calculating the height of this launching point on deck is very important: It can be found by adding the height of the final pulley of the Launch And Recovery System (LARS), to the air draft of the deck where it is installed.
  This table gives measurements up to 100 m from the point of deployment above the deck. Deeper depths can be evaluated by adding the differential values to the 100 m limit of the table: As an example, for 120 m, add the value for 20 m to the one for 100 m.
- Trigonometry can be used for more precise evaluations. The procedures proposed are similar to those used by carpenters to calculate the slope of a roof. Note that a slope can be displayed in % and in degrees.
  - The procedure proposed to calculate the slope of the deployment device in % consists to divide the horizontal shift by the vertical length, and to convert it in percentage. So, using the drawing below, (distance A / distance B) x 100. As an example, if a bell is 100 m below the last pulley of the LARS, and is shifted 5 m from the theoretical vertical point, the percentage of the "slope" is 5% , which values are 100 (5/100). If the shift is only 4 m, the percentage of the "slope" is (4/100) x 100= 4% .



  - To calculate the slope in degrees, 1st calculate the tangent: Tangent = opposite side / adjacent side, which is in fact the distance of the shift divided by the vertical distance. Thus for a bell that is 100 m below the last pulley of the LARS that is shifted 5 m from the theoretical vertical point, we divide 5 metres by 100 metres to obtain 0.05, which is a value in radians (the real value is 0,0499583957).
    Then, we need to to convert the radians into degrees: To do it apply the formula 0.05 x 180 x 3.14 (Pi). The result obtained is 2.8624, which is the value in degrees with minutes in decimals.
    To covert the decimal value into a sexagesimal value, consider that 2.8624 is 2 + 0.8624. To convert 0.8624, merely multiply it by 60. Thus, 0.8624 x 60 = 51.744, which is the value of the minutes.
    Then, using the same formula, the decimal seconds are converted into sexagesimal seconds: 0.744 x 60 = 44.64. So, the value of 0.05 radians is 2° 51' 44".
  - To find the horizontal shift resulting of an angle in degrees, convert the values in degrees into radians by proceeding the opposite way of the procedure above, and then multiply the value in radian by the vertical distance B.
- The procedures above have some limitations during the diving operations as checking the angle of a cable is not an easy task without adequate tools. As a result, parallax errors may occur. Parallax errors occur when the measurement of an object's length is more or less than the true length because of the eye of the observer is being positioned at an angle instead to be adequately aligned.
  For these reasons, the use of a hydroacoustic beacon seems the best procedure to check the exact position of the bell during the dive. Note that bells are today equipped with such devices and it is also the case of divers.
  Also, surveying and mapping technicians are used to collect data to make maps of the worksite, and provide the position of divers, Remotely Operated vehicle, and every item lowered to the worksite. Thus they are highly qualified to indicate the exact position of the bell and its angle of deployment if needed.



Survey station

Hydroacoustic beacons

To conclude on the procedures to be used to calculate the shift of the bell from the theoretical vertical point, it must be taken into account that the underwater current may establish suddenly, or significantly reinforce during a dive and that a failure of the positioning system is unpredictable, despite the improvements manufacturers have made. Also, obliging the diving supervisor to perform such calculations during the operations is a bad idea as he has many things to manage during the dive.

For these reasons, the maximum acceptable angle of the bell and the resulting shift from the theoretical vertical point should be entered into the calculations made for the maximum allowable umbilical lengths taking into account:

- The maximum angle of the bell during diving operations with current speeds conform to those recommended in AODC 47.
- The maximum angle that may result from a sudden loss of position of the vessel.

4 - To conclude

People calculating the umbilical lengths and those managing the dives must have common sense and wiseness.

- When performing umbilical lengths calculations, it is preferable to be a bit restrictive rather than looking to very optimum lengths. It must be considered that the 5 metres and 3 metres limits are the extreme points beyond which the divers are considered endangered. There is no law that forbids giving some more safety margins.
- The preparation of the project is an important phase where the umbilical length calculations are to be performed accurately using the construction drawings of the Diving Support Vessel. Uncertainties regarding the design and the position of the thrusters must be solved during this period.
- Also, supervisors should be prudent and avoid using the maximum allowable umbilical lengths during the diving operations. That can be done by an appropriate study of the worksite and the possible movements of the ship, in addition to the option to use a 2nd tending point.
- The design of the vessel used for the operations is also essential: Propellers are not a big problem when the worksite is very deep, but they become a hazard during shallow operations. Thus, large boats are preferable for shallow dives. Instead, deep dives can be performed from more reduced supports.

Note that there are uncertainties regarding the distances at which the water ejected from azimuth thrusters can affect a diver. That is linked to the power deployed, the diameter, and the rotations per minute of the propeller. However, it seems that no specific study exists at this time.