BURIAL CONSIDERATIONS & STUDY CASE OF CABLE PROTECTION IN THE ARCTIC

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Abstract: ASN identifies the technical & contractual barriers associated with the current fixed depth of burial requirement and proposes an alternative methodology from engineering to implementation phases. This will lead to a more economical approach to cable burial still providing the necessary and sufficient protection to a submarine system during its entire life. Finally, this paper provides a case study of deep burial recently performed by ASN in the Arctic as protection against the threat of grounding ice in coastal Stamukhi and pack ice zones in comparison with other conventional threats from fishing & anchors.

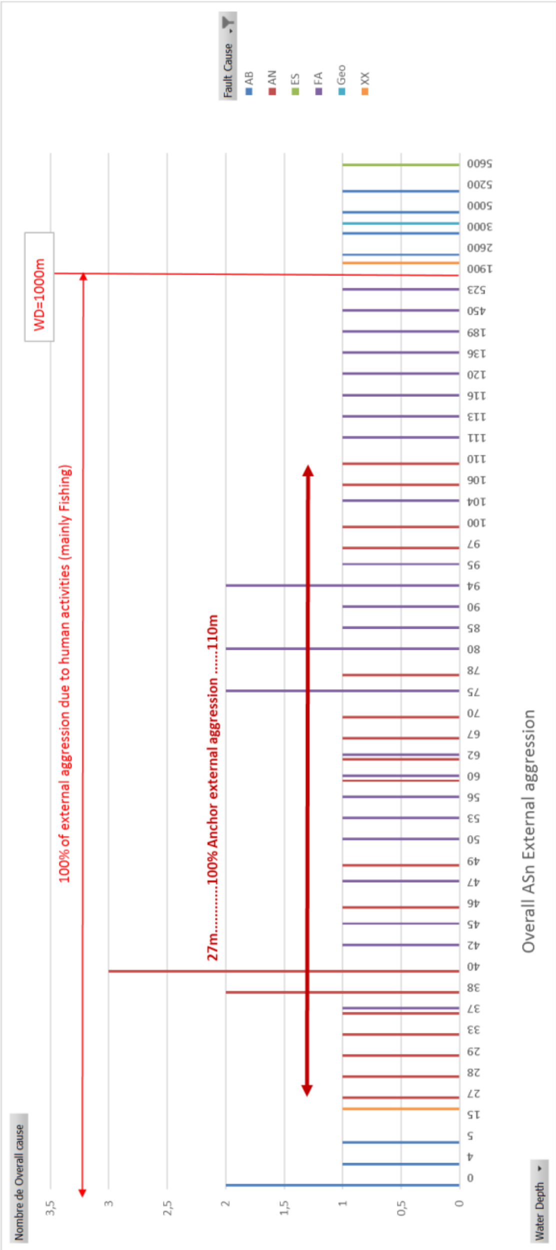
1. INTRODUCTION: CURRENT BURIAL SPECIFICATIONS

It has long been established that the best protection for submarine cables against fishing and anchoring threats in shallow waters is burial. However, if you pick up a typical submarine network construction contract, you will see that the technical specification calls for a fixed depth of burial into the sea bed, historically 1 meter and, more recently, 1.5 meters or even 3 meters in certain regions. There is no attempt to specify the depth of burial requirements in terms of the threat to the cable or the protection level afforded by the soil type encountered along the route. Water depth is also an important factor when considering the threat: for example, if you wish to protect a cable against aggression from ships anchors by specifying burial to 3 meters, ships do not anchor in water depths greater than around 100m, so why specify 3 meters burial beyond the 200 metres contour?

Specifying a fixed depth of burial can lead to over protection, resulting in unnecessary increased time and cost of burial or armouring; equally, in certain soil types it may lead to under protection which will lead to additional costs for repairs in the future. We have seen some recent acceptance of this potential under protection in the form of depth specifications calling for 3 metres burial in very soft seabed in parts of Asia exposed to threat.

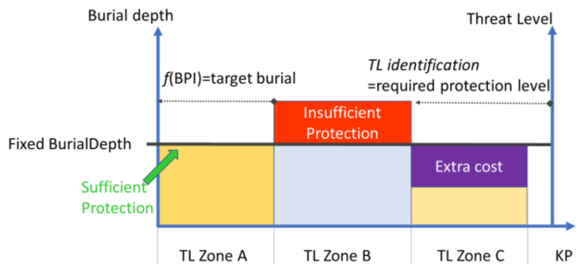
The following graph (graph 1 & appendix) illustrates the analysis over the last 60 repairs (2 years) where the root cause has been identified as external aggression in 2 areas (namely North-East Asia & Atlantic region). We can see all anchor aggression happening within 110 m water depth and the majority of human activities aggression within 1000m water depth (1 unknown root cause at 1900m water depth as damaged cable was not recovered).
Faults Categories analysed:
Overall cause: external aggression
AB: Abrasion
AN: Anchor
ES/GEO: Earthquake/Geologic

FA: Fishing Activity
XX:Unknown



Graph 1: fault type by water depth

Knowing that anchors can penetrate deeper than conventional fishing gear, it seems there is a way to provide a more adapted protection to the cable depending on the risk which can occur related to the area of the planned cable route. As illustrated in the graph below, such mechanism can not only generate better protection but potentially save cost during the implementation of the system.



Graph 2: Fix burial depth vs TL

Therefore, ASN is proposing to introduce a Threat Level definition which could be studied in a workshop. After having been adopted as a standard for the industry, it could be introduced in the requests for quotation for providing a possibility for fair evaluation of proposal submitted by suppliers.

2. ANALYSIS OF DEPTH VS THREAT VS PROTECTION AND CABLE TYPE RELATIVE TO RISK

The concept of the Burial Protection Index (BPI) has been around for nearly 30 years **[1]**. Protection of a cable by means of burial is seen as the most efficient method of protection. The only parameter in the design of the burial protection is the burial depth. It has always been recognised that “stronger” seabed soils provide a greater protection than a “softer” soil for a cable buried to similar depth. In 1997(Mole et al, **[1]**) the Burial Protection Index (BPI) was introduced to account for such soil characteristics. The chart produced by Mole et al is reproduced here.

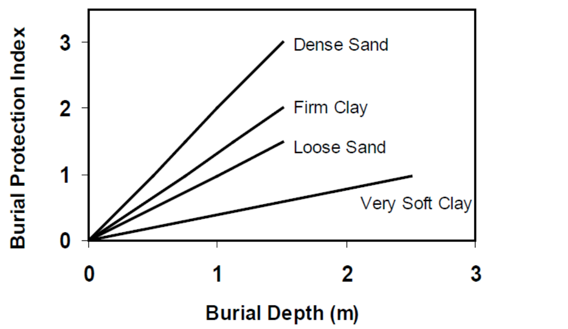


Figure 1: BPI standard definition

BPI index definition **[1]** using a standard telecom plough:

BPI 1 : Protection from fishing activities using conventional fishing gear
BPI 2 : Protection from typical anchors
BPI 3 : Protection from larger anchors

P. Allen gave a further definition of the BPI in 1998 **[2]**. It is an attempt to link burial depth with the protection offered by different soil types, so for example, if a BPI of 1 is determined as 1 meter burial in sands, then to achieve a BPI of 1 in very soft clays, you would need to bury the cable up to 3 meters into the sea bed. The BPI number is also intended to reflect the level of threat, so a BPI of 2 would indicate a higher level of threat giving rise to the need for increased burial depth. However, this BPI concept has never been fully developed in terms of empirical specifications defining threat levels and soil strengths beyond the initial definition of a BPI of 1 which was considered as sufficient protection against a fishing threat from bottom trawling in sands with a relative density of 60% or clays with a shear strength of 40 kPa.

The following indexing was given **[2]**:

BPI = 1 Depth of burial consistent with protecting a cable from normal fishing gear only. Would be appropriate to water depths greater than say 50 to 100m, where anchoring of ships is unlikely.

BPI = 2 Depth of burial will give protection from vessels with anchors up to approximately 2 tons. This may be adequate for normal shipping activity, but would not be adequate for larger ships (e.g. tankers, large container ships)

BPI = 3 Depth of burial sufficient to protect from anchors of all but the largest ships. Suitable for anchorages with adjustments made to suit known ship/anchor sizes.

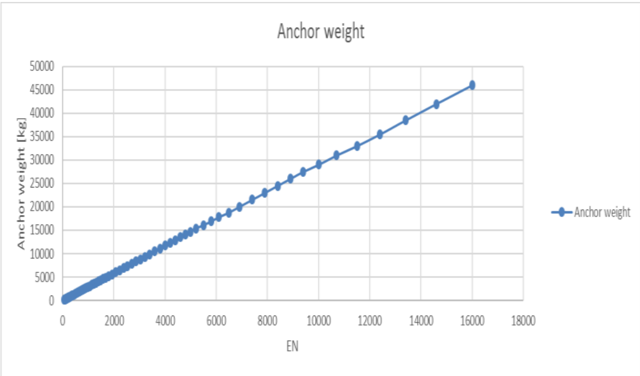
3. FROM BURIAL PROTECTION INDEX (BPI) TO THREAT LEVEL (TL) DEFINITIONS

Threat Levels.

To take the BPI concept further, we first need to define what the Threat Levels (TL) are. For example, these could be categorised as follows:

- TL = 1 – trawling and water depths greater than 100m (beyond the threat of anchoring)
- TL = 2 – stow net anchors and anchors of ships up to 10,000t DWT (50% worlds shipping fleet)
- TL = 3 – anchors of ships up to 100,000t DWT (90% worlds shipping fleet)
- TL = 4 –anchors of VLCCs and large container ships.

Relationship exists between vessel size and its anchor weight (refer to below example using equipment number from DNV rules**[4])**. Therefore, it is possible to define a Threat Level asssociated to the anchor depth penetration of vessel more likely to be present in the vicinity of the cable route.



Graph 3: Anchor weight vs Eqpt Number

In practice, we would probably not try and protect against a threat level of 3 or 4, we would choose to re-route the cable where possible. However, it will not always be possible, Singapore is a prime example of a threat level 4.

Levels of Protection.

Next, we need to consider the level of protection afforded by different soil types. Some studies have been performed concerning the penetration of various types of ships anchors into different soil types [**3**] but today, more detailed geotechnical modelling is available to help us define protection available from different soil types. Such modelling could result in a protection-burial matrix looking something like this:

Clays	Sands	TL=1	TL=2	TL=3	TL=4
10 kPa or less	20% RD	2m	3m	5m	10m
20 kPa	40% RD	1.5m	2.5m	4m	7m
40 kPa	60% RD	1m	2m	3m	5m
80 kPa	80% RD	0.5m	1m	2m	3m
160 kPa	100% RD	0.3m	0.5m	1m	2m

**RD Relative Density*

Table 1: proposal for TL definition

Defining the required target depth of burial.

This would be a two stage process. Firstly, the Cable Route Study (DTS) will define the threat levels along the route. The second stage comes from the results of the Burial Assessment Survey, where Cone Penetrometer Tests are used to classify shear strength or relative density. Thus, with reference to the protection-burial matrix, the required depth of burial can be defined. This means that accepting reasonable variations of burial target during the early stage of implementation will result in a more effective protection. Any tendering assumptions can be modified post contract in the usual post survey variation mechanism.

4. STUDY CASE: DEFINING THE DEPTH OF BURIAL TO MEET THE THREAT IN THE ARCTIC

This case study details the deep burial performed recently by ASN in the Arctic as protection against the threat of grounding ice in coastal zones as a comparison to conventional threats from fishing/anchoring.

Arctic ice threats

This case describes the specific engineering approach identified to protect a section of submarine cable installed in the Arctic Beaufort Sea which is subject to three specific ice threat conditions.

1. Inshore sea ice in shallow water
2. Stamukhi pack ice transient zone parallel to the shore line
3. Seafloor iceberg scarring

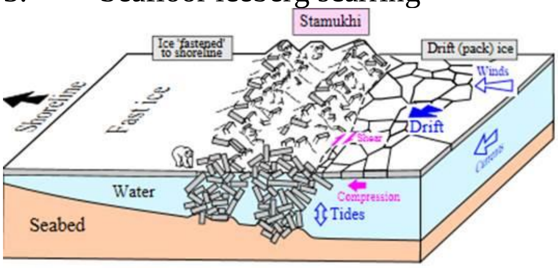


Figure 2: illustration of Beaufort sea ice

Seafloor gouging along this route results from two different sources:

Inshore and Stamukhi seafloor gouging

Inshore and Stamukhi scaring is the result of a grounded accumulation of sea ice rubble that typically develops along the boundary between fast ice and the drifting pack ice, or becomes incorporated into the fast ice interacting and scaring the seafloor out to a water depth of around 15-20 meters in the Prudhoe Bay area. The depth of Stamukhi seafloor scaring impact depends on the size and thickness of the buckled sea ice and the local tide and wind forces creating the dynamic effect and pressure zones. Stamukhi seafloor scaring grooves or troughs are generally less than one meter in depth.

Iceberg generated seafloor scaring and gouging

The evidence of relic seafloor scaring and gouging from isolated floating ice masses are seen from the offshore edge of the Stamukhi zone to water depth s of 60 to 70 meters. In these deeper waters, the seafloor scaring has been generated by the grounding of either large multiyear ice floes or icebergs that have calved from Ellesmere Island glaciers or the Ward Hunt Ice shelf. These larger ice bodies drift with the current and wind into shallower areas and their keel comes into contact with the seabed creating gouges on the seafloor. The main concentration of iceberg gouging is evident for 20 to 60 km offshore on this cable route.

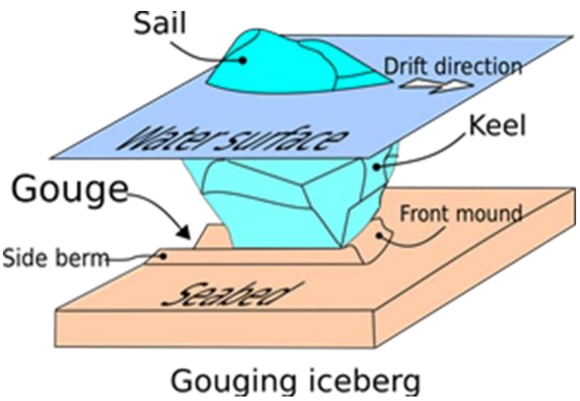
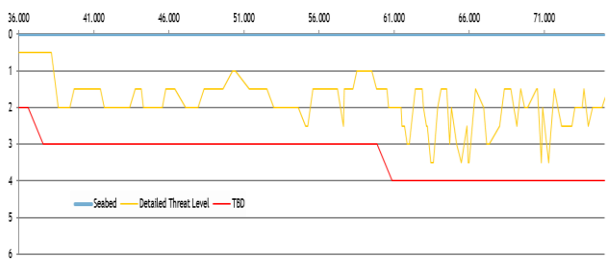


Figure 3: illustration of iceberg gouging

The cable route passes through a primary chaotic ice gouge zone where an estimated 300 gouges had to be crossed. The Ice keel gouge depths range from 1 – 3.5 metres deep with gouge widths of up to 10 meters. Analysis of the survey data resulted in a detailed picture of the threat level along the route:



Graph 4: Practical case TL analysis

Out to KP 36, a target burial depth (TBD) of 2m was considered sufficient protection, increasing to 3m up to KP 61 and finally 4m up to the end of burial

To ensure long-term protection for the cable system through this area a specific engineering approach was identified consisting of multiple pre-trenching passes to achieve 3 and 4 metre depth of burial.

Previous sea trials performed in these areas featuring the most chaotic seabed proved that the HD3 plough based equipment was capable of maintaining stability in the trial area up- down- and side slopes with full shear penetration during passage of up to 3.5m deep ice scars and berms. These trials showed that by steering the HD3 plough very accurately the subsea crew could perform consecutive passes maintaining the plough share in the pre-cut trench. The ability to realign the share into the trench became key for this procedure – These trials lead to the development of the full-scaled 2 & 4 metre capable multi-pass burial principle.

The geotechnical conditions on this route for the multi-pass section comprises of top sediments of soft glacial tils and soft clays with deeper units of dense clayey sand and very stiff clays. At 3.5 – 4 meters, shear strengths range from 100 – 400 KPa.

A unique plough share interface design feature was developed allowing the interchangeability of a set of aggressive shares at sea. This allowed for the deployment to two main pre-trenching multi-pass tools.

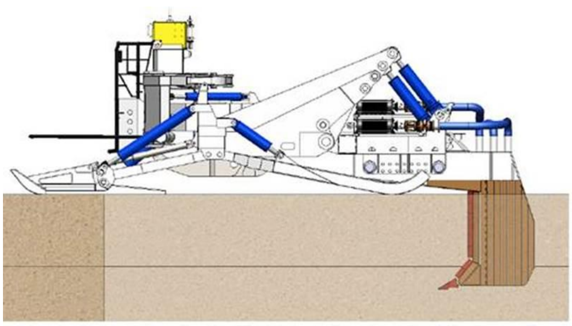


Figure 4: illustration of ASN plough

A high-performance jetting 2 metre pre-trenching share was manufactured to perform the prerequisite pre-trench in preparation for the full 4 metre pre- trenching phase. Once the 2m pre-trench was formed, then an aggressive 4m “C” shaped high-performance jetting share was deployed to create the 3m and 4m pre-trench.

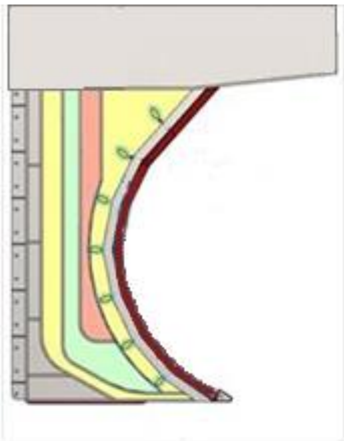


Figure 5: illustration of ASN share

Finally, on completion of the pre-trenching operations the cable was installed to the required depth of burial by connecting a lay extension and depressor to the rear of the 4m share.

5. CONCLUSION

Specifying a fixed depth of burial can result in over protection and additional unnecessary cost and time or lead to areas of under protected cable. An alternative approach would be to determine the required depth of burial by reference to the threat level that the cable is exposed to and the protection afforded by the soil into which the cable is to be buried. This will require a different contractual approach and it will result in reduced cost and better protection. This concept is used to set the target burial depth. The actual level of protection can be determined by analysing the results of the plough burial operation. There is a direct correlation between the plough tow force and the protection afforded to the cable. Therefore in areas where the target burial depth was not achieved due to the presence of hard ground, it can still be demonstrated that adequate protection has been achieved.

6. REFERENCES

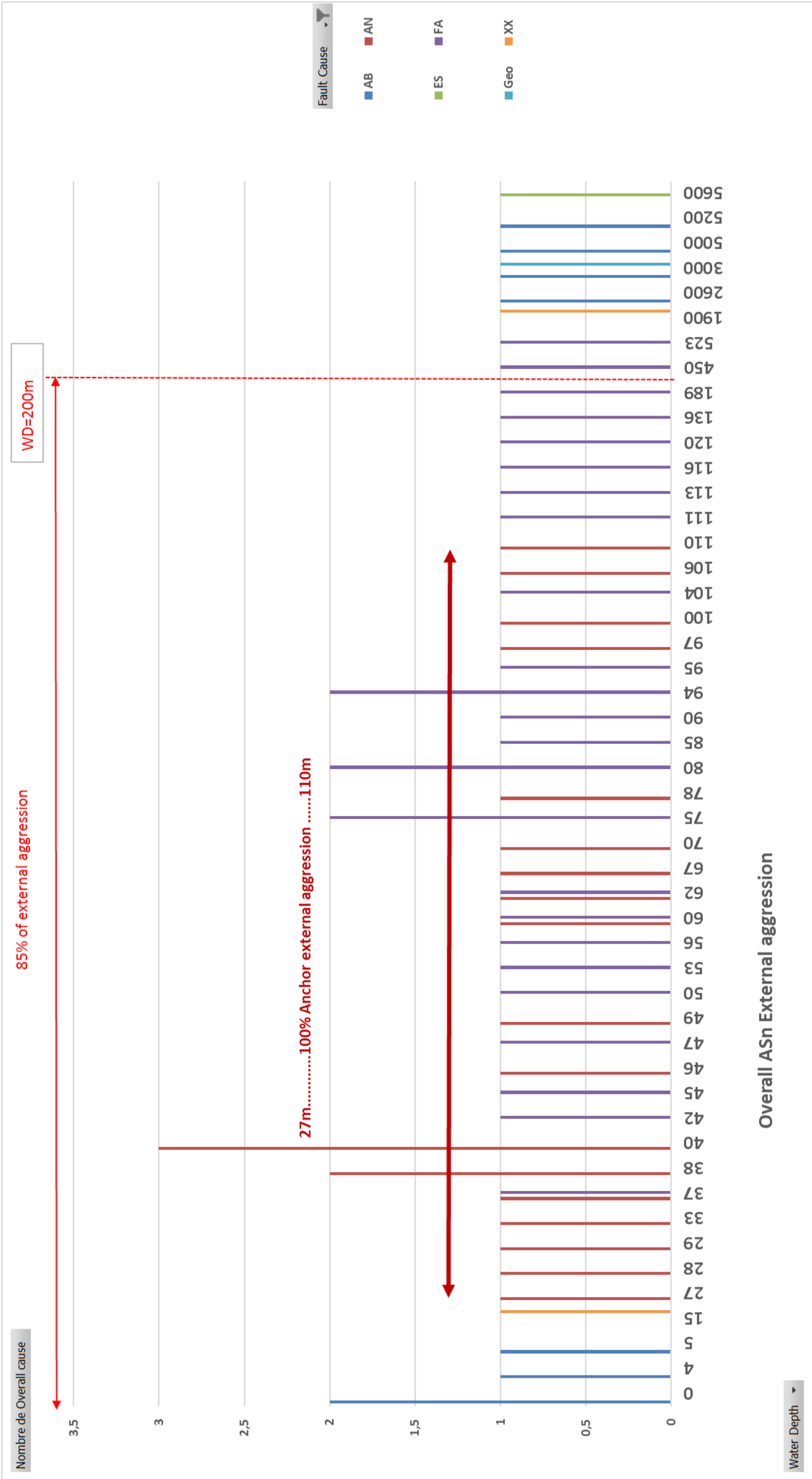
[1] P. Mole, J. Featherston & S. Winter, “Cable Protection –Solutions through new installation and burial approaches” Cable& Wireless Marine (England) SubOptic, 1997, San Francisco, USA.

[2] P.G. Allan, Selecting Appropriate Cable Burial Depths – A Methodology IBC Conference on Submarine Communications. The Future of Network Infrastructure, Cannes, November 1998

[3] P.G. Allan, R.J. Comrie, “The Selection of Appropriate Burial Tools and Burial Depths” SubOptic 2001 Kyoto, May 2001

[4] Ships, Newbuildings, Hull&equipment, Main Class part3 Chapter 3 DET NORSKE VERITAS Norway

7. APPENDIX


Fault Cause
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WD=200m
85% of external aggression
27m..........100% Anchor external aggression 110m
Overall ASn External aggression
Nombre de Overall cause
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