Ministry of Defence
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Design Policy, Principles, Testing and Acceptance Requirements for Watertight Integrity of Submarines

Category 1

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Foreword

AMENDMENT RECORD

Amd No	Date	Text Affected	Signature and Date

REVISION NOTE

This standard is raised to Issue 3 to update its content.

HISTORICAL RECORD

This standard supersedes the following:

Def Stan 02-136 Issue 2 *08 Mar 2004*

Def Stan 02-136 Issue 1 *01 Apr 2000*

NES 136 Issue 1 *01 Jul 1988*

SSCI 133/87

Sponsorship

1. This Defence Standard (Def Stan) is sponsored by the Defence Equipment & Support, Safety and Engineering, Sea Systems, Ministry of Defence (MOD).

2. The complete Def Stan Issue comprises:

   Procedures for Design Policy, Principles, Testing and Acceptance Requirements for Watertight Integrity of Submarines

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Corporate experience and knowledge.
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Related Documents

16. In the tender and procurement processes the related documents in Clause 3 can be obtained as follows:

a)	British Standards	British Standards Institution, 389 Chiswick High Road, London, W4 4AL
b)	Defence Standards	Defence Equipment and Support UK Defence Standardization, Kentigern House 65 Brown Street, Glasgow, G2 8EX
c)	Other documents	Tender or Contract Sponsor to advise.

17. All applications to Ministry Establishments for related documents are to quote the relevant MOD Invitation to Tender or Contract Number and date, together with the sponsoring Directorate and the Tender or Contract Sponsor.

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20. This Defence Standard has been written and is to be used taking into account the policy stipulated in JSP430: MOD Ship Safety Management System Handbook.

Additional Information

(There is no relevant information)

0 Introduction

0.1 The overall responsibility for the safety of all vessels and associated equipment owned or operated by the MOD lies with the Secretary of State for Defence. He issued a Health and Safety policy statement in 1996, and again in 2007, which states that health and safety standards and arrangements within the MOD will be, so far as reasonably practicable, at least as good as those required by statute. To assure the safety of MOD shipping activities the Ship Safety Management System was introduced. The policy and guidelines for the management system are laid down in JSP 430. This identified watertight integrity as one of the key hazards to submarines which would require safety certification by a designated Naval Authority. The requirements for certification will be promulgated as Naval Authority Regulations.

0.2 This document is based largely on current practice. Projects seeking to adopt different approaches to Watertight Integrity are recommended to contact DES SE SEA-SM-SAF very early in the design process. New approaches will require careful justification in the appropriate safety case.

Design, Testing and Acceptance Requirements for Watertight Integrity of Submarines

1 Scope

1.1 This document defines the design policy for Watertight Integrity for submarines. It is applicable to both new design and existing classes of submarine.

1.2 This document seeks to discuss watertight integrity for submarines and the consequences of its loss, define the watertight envelope and hazards and consequent modes of failure, and the design principles to minimise the likelihood and consequences of failure of watertight integrity. Finally specific design, through life testing and inspection requirements are covered.

1.3 Design responsibilities are considered in the light of the implications of MOD's policy on Ship Safety Management and JSP 430.

1.4 This document does not consider collapse of the pressure hull as a watertight integrity issue; hull design is covered by MAP 01-074 and Def Stan 09-50.

1.5 This document is compatible with the consensus achieved on submarine survivability policy after an extended debate resulting in a paper reference DGSM/DNA&FP/109/1/1/1 dated May 1997.

1.6 Comments or proposals for amendments to this document should be referred to DES SE Sea-SM-SAF, Sea Systems Group, DE&S, MOD Abbey Wood, Bristol BS34 8JH.

2 Warning

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3 Normative References

3.1 The publications shown below are referred to in the text of this standard. Publications are grouped and listed in alpha-numeric order.

BR 8470	Shock and Vibration Manual
BS 1580	Unified Screw Threads Part 1 Screw Threads with Diameters ¼ inch and larger – Requirements Part 3 Screw Threads with Diameters below ¼ inch - Requirements
BS 2693-2	Screw Studs Part 2 Recommendations for High Grade Studs (Obsolescent)
BS 3643-2	ISO Metric Screw Threads Part 2 Specification for Selected Limits of Size

BS 949-1	Screwing Taps Part 1 Specification of General Dimensions
BS EN ISO 9001: 2000	Quality Management Systems - Requirements
Def Stan 00-101	Design Standards for Explosives Safety in MOD Ships and Submarines Part 2 Submarines
Def Stan 02-304	Shafting Systems & Propulsors Part 2 Design Requirements for Main Propulsion Shafting Auxiliaries
Def Stan 02-375	Valve Design and Manufacture
Def Stan 02-524	Guide to the Selection of Cable Glands in Submarines Part 3 Bulkhead Penetrators and Gland Tubes (Obsolescent)
Def Stan 02-706	Welding and Fabrication of Ship’s Structure
Def Stan 02-797	Pipework Engineering Part 1 General
Def Stan 02-862	Fasteners Part 4 Ferrous (Submarine First Level Quality Assured) Part 5 Non-Ferrous (Submarine First Level Quality Assured)
Def Stan 08-102	Requirements and Acceptance Criteria for Submarine Hydromechanics
Def Stan 08-137	Requirements for the Design & Test of Submarine Masts and Periscopes (Except Snort and Ventilation Masts) (Obsolescent)
Def Stan 08-171	Guide to the Selection of Cable Glands in HM Submarines
Def Stan 09-50	Design Standards for Submarine Structure.
DGSM/DNA&FP/109/1/1/1 dated May 1997	Submarine Survivability Policy Discussion Paper
JSP 430	MOD Ship Safety Manual
MAP 01-070	Surface Ship and Submarine Margins Guidance Part 3 - Submarines
MAP 01-073	Submarine Hydromechanics
MAP 01-074	Design of Submarine Structures
NCRE R548	Hull Valves Shock Requirements
PTS 14299	Production Test and Type Approval Specification for Polythene Moulded Cable Glands.
SSP 25	Quality Assurance for Safety in Submarines

3.2 Reference in this Standard to any normative references means in any Invitation to Tender or contract the edition and all amendments current at the date of such tender or contract unless a specific edition is indicated.

3.3 In consideration of clause **3.2** above, users shall be fully aware of the issue and amendment status of all normative references, particularly when forming part of an Invitation to Tender or contract. Responsibility for the correct application of standards rests with users.

3.4 DStan can advise regarding where normative references documents are obtained from. Requests for such information can be made to the DStan Helpdesk. How to contact the helpdesk is shown on the outside rear cover of Def Stans.

4 Definitions

For the purpose of this standard the following definitions apply:

4.1
Acceptance Authority
The competent organisation which monitors and certifies that the tests have been undertaken to the approved test forms, and that satisfactory results were observed by the certifying officers.

4.2
Bobbin/sleeve
A manufactured item(s) of a non–corrosive material that is welded into a drilled hole in the pressure hull insert. The wall thickness of the bobbin is determined by the edge preparation required for welding the inboard and outboard edges to the insert. The bore is determined by the spigot and 'O' seal of the fitted valve and its depth into the insert. Monel sleeves are generally used with hydraulic system valves.

4.3
Breach
A failure of the pressure retaining boundary. Unless otherwise stated, in this document the size of a breach is referred to by the diameter of a single circular hole having the same cross sectional area as the total area through which sea water can flow as a result of the breach. It is to be noted that the diameter of the pressure hull opening is that which remains after any restrictor has been fitted to the pressure hull plating and which has been permanently attached to the structure. See Fig 1.

4.4
Critical Hole Size (CHS)
The diameter of the hypothetical largest single unsecured hole in the pressure hull from which the submarine could recover successfully if operating within the Manoeuvring Limitation Diagram (MLD) at the time the breach is made. Each main watertight compartment can have a different (CHS).

4.5
Deep Diving Depth (DDD)
The maximum depth to which a submarine may be taken intentionally.

4.6
Deep Diving Depth Pressure (DDDP)
The sea water pressure at DDD.

4.7
Depth Dependent System Test Pressure (DDSTP)
The pressure to which Depth Dependent Sea Water Systems are tested. This pressure is decided during the design process and for existing classes is specified in FPN 019 FLAGO(SM) 8007. It is normally the same as, or slightly greater than, sea pressure at Minimum Collapse Depth (MCD).

4.8
Design Authority
The competent organisation responsible for and with authority to specify technical design requirements, undertake design tasks and approve design changes. The Design Authority may formally delegate all or part of the design task to a suitably competent organisation, but retains design responsibility.

4.9
First Level Systems
Are defined in SSP 25 and are quality assured for safety from failure leading to uncontrollable flooding which would hazard the submarine or result in a release of fission products.

4.10
In–Situ Out–to–In Pressure Test
Hydrostatic pressure test that simulates sea water loading.

4.11
Maximum Securable Hole (MSH)
The largest diameter hole capable of closure by remotely operated hull and or back up valve.

4.12
Minimum Collapse Depth (MCD)
The depth at which the pressure hull as built has an acceptably low probability of collapse, assuming that all possible (but allowable by specification) departures from standards are adverse.

4.13
Quality Assurance
With respect to the Quality Assurance of Submarines there are two levels of Quality Assurance requirements, standard BS EN ISO 9001:2000 requirements and extra requirements defined as First Level Quality Assurance. For the majority of items the confidence given by the general approach outlined in BS EN ISO 9001:2000 is sufficient. Where additional materiel assurance is required for reasons of submarine safety or prevention of fission product release, First level Quality Assurance is to be applied. See SSP 25

4.14
Specified Hole Size (SHS)
The diameter of the smallest hole in the pressure hull for which Quality Assurance to first level standards as defined in SSP 25 is to apply on associated pipes, valves and fittings.

5 Abbreviations

ALARP	As Low As Reasonably Practicable
BS	British Standard
CHS	Critical Hole Size
CNC	Customer Non-Conformance document
DDSTP	Depth Dependent System Test Pressure
Def Stan	Defence Standard
HP	High Pressure
MLD	Manoeuvring Limitation Diagram
ROB	Reserve of Buoyancy
SHS	Specified Hole Size
SSP	Sea Systems Publication
WTI	Water Tight Integrity

6 Watertight Integrity and Consequences of Loss

6.1 Introduction

6.1.1 The loss of watertight integrity is a major threat to submarine safety which may lead to a flood and possible loss of the vessel. It may be initiated by weapon attack, collision, system or structural fault or human error.

6.1.2 A submarine is exposed to risks resulting from the loss of watertight integrity (WTI) qualitatively different from a surface ship and with potential consequences which are not only much more severe but which can take effect with much greater rapidity; whereas options to recover from flooding are much more tightly constrained. It is not possible to reduce the risk of a flood occurring to zero purely by applying appropriate design standards. The Whole Ship Safety Case must show that the probability of a flood, and failure successfully to implement recovery action, leading to the loss of the submarine is incredible. This aspect is required to be covered as part of the Safety Case for the submarine required by JSP 430 and formal Naval Authority safety certification is required for Submarine Watertight Integrity. This requires a Safety Assessment of systems which control the watertight integrity of the submarine, whether pressure hull openings or systems which are subject to diving pressure at depth. Suitable mitigating features and emergency/contingency arrangements are to be included in the design.

6.2 Reserve of Buoyancy

6.2.1 Unlike a surface ship, which typically has a very large reserve of buoyancy (ROB), typically 200%, a submarine has a low ROB which limits the amount of flooding that can be sustained before the submarine sinks. Additionally should the flooding initiate with the submarine submerged then the ROB at the start of the incident is zero and immediate action must be taken by the crew to establish a buoyant condition. For most RN submarines the flooding of one compartment would cause complete loss of ROB, and hence sinking. It is often not practical to reduce compartment size to the extent necessary to change that fact. Current RN submarines do not, therefore, rely on damaged buoyancy and stability assessments, but rely totally on the prevention and control of flooding.

6.2.2 The low reserve of buoyancy of a submarine, traditionally around 10% of surfaced displacement but zero submerged, limits the amount of excess water which can be tolerated on board. The deeper the submarine, the greater the flooding rate. If the submarine is to recover, i.e. re-establish a buoyant condition, detection and reaction times are critical. For floods through an isolable leak path the time to shut hull valves is critical in limiting the amount of negative buoyancy that must be overcome. For unisolable floods the critical time is that taken to reduce depth so the leak rate decreases to a manageable level and deballasting systems take effect.

6.3 Depth Dependent Pressure

Because of the depth at which the submarine operates, a flood from a depth dependent system can enter the submarine highly pressurised: apart from increasing the flow rate through a given leak, the force of a high pressure jet or spray may have damaging effects on safety critical systems (over and above the simple presence of sea water), may render a compartment untenable for ship’s staff or prevent the actions necessary to recover from the flood.

6.4 Availability of Propulsion

For a large proportion of its operating envelope a submarine’s ability to increase buoyancy to counteract flooding is small - in these conditions recovery depends on the continual availability of propulsion for a long enough time to enable the submarine to drive up to a depth at which the leak rate is reduced and the deballasting systems become effective.

6.5 Manoeuvring Limitation Diagrams/Safe Manoeuvring Envelope

To avoid subjecting the submarine and crew to unnecessary risks, advisory constraints are placed on submarine peacetime operations. To allow the submarine to operate safely over the majority of its speed and depth range advice is provided to the Command in the form of Manoeuvring Limitation Diagrams (MLDs). These present manoeuvring advice in graphical form showing combined speed, depth, pitch and plane angle restrictions defining a safe manoeuvring envelope within which the submarine should be able to recover safely in the event of a maximum specified flood or hydroplane jam accident. The calculations make assumptions about the execution of Emergency Procedures, reaction times, availability of propulsion power and allowable submarine pitch limits as explained in Def Stan 08-102 and MAP 01-073. The Safe Manoeuvring Envelope (SME) is the ASTUTE equivalent of the MLD and was developed to take account of the failure modes of the ASTUTE manoeuvring and control system and split aft hydroplanes. It shows manoeuvring limits in terms of speed, depth and submarine pitch (as opposed to after plane angle).

6.6 Critical Hole Size

A Critical Hole Size (CHS) for each compartment is derived from the MLD calculations. It is defined as the diameter of the largest hypothetical single unsecured hole in the watertight envelope from which the submarine could recover successfully if operating within the MLD at the time the breach occurs. Each main watertight compartment can have a different CHS, see MAP 01-073 for further details and assumed reaction times.

6.7 Limited use of Blowing at Depth

To counter a secured flood and restore the submarine’s buoyancy the excess water must be discharged to sea or an equivalent quantity of ballast blown. If the flood is unsecured it will be necessary to blow the main ballast tanks and drive to the surface using the main propulsion. The deeper the submarine the less the initial effect of the high pressure air blow. For a large part of the operating envelope the HP Blow will be relatively ineffective.

6.8 Comparison of ingress at depth/pumping capacity

Pumping rates are generally low compared to flooding rates at depth. For example the SSN HP Bilge and Ballast pumps are individually capable of discharging $22m^3$/hour at DDD whilst a single ended failure of critical hole size would admit $1368m^3$/hr - a ratio of approximately 1:62 or 1:30 if both pumps can be run in parallel.

6.9 Collateral Damage

The effects of a leak from a depth dependent system of a relatively minor bore could have catastrophic consequences when the submarine is at depth. For example a jet of high pressure water from a small burst in a depth dependant system could incapacitate adjacent control systems vital to submarine propulsion and control. This needs to be considered by the use of Failure Mode Effect and Criticality Analyses during the design of system and compartment layouts.

7 The Watertight Envelope

7.1 Watertight Envelope

The watertight integrity of the submarine is provided by the envelope of the pressure hull, the penetrations through the pressure hull and the boundaries of the fluid systems within the pressure hull subject to ambient sea water pressure.

7.2 Types of Penetration

The penetrations through the pressure hull fall into five types for watertight integrity considerations depending upon the nature of the design and operation of the pressure boundary:

a) **Type A**: penetrations for systems open to the sea. These include both those required to be open at specified depths only and those required to be open at all depths down to Deep Diving Depth or greater.

b) **Type B**: penetrating structures with an inner and outer boundary where the outer boundary is opened during normal operation of the equipment and ambient pressure is taken on the inner boundary (e.g. Garbage Ejector, Torpedo Tubes, SSEs, LILO).

c) **Type C**: penetrating structures with an inner and outer boundary where the outer boundary (which normally experiences ambient sea pressure) is not normally open at sea but may be accidentally breached and the inner boundary serves as a back-up (e.g. periscopes, shore supply connections, conning tower, Escape Towers and Logistic Escape Trunks (LETs)).

d) **Type D**: penetrating structures incorporating mechanical or electrical equipments that penetrate the hull (e.g. main shafting, operating shafts, cable glands).

e) **Type E**: penetrating structures with no inner boundary (e.g. accommodation hatch, Dutch breach, torpedo embarkation hatch).

7.3 Hard Systems

Systems subjected to ambient sea pressure at depths down to and including Deep Diving Depth are referred to as “Hard Systems”. The volume/length of “hard” systems is to be minimised, as are connections, joints, penetrations and other features which may introduce potential threats to system integrity. Connection types are to be chosen which minimise the risk of failure or leakage

8 Hazards to Watertight Integrity

a) The risks to the watertight integrity of a submarine are a function of both the engineering constraints within which it is designed and built and the regime under which it is operated. Broadly the hazard threatens the submarine through the risk and consequences of failure of the watertight envelope due to shock, wear and tear by erosion/corrosion or fatigue, collision, explosion and maloperation.

b) The design of the hull, systems and penetrations is normally to use appropriate validated design codes and is to include factors for shock, through life corrosion/erosion and fatigue cycles to diving depth. This will form part of the safety justification that the risk of failure of the watertight envelope has been reduced to Tolerable and ALARP.

8.1 Shock

8.1.1 Warships and their systems, whether surface ship or submarine, are to be designed to withstand degrees of shock defined by the operational scenarios within which they are required to operate. The shock regime mandated by the operational requirement is to be specified by the contract for the vessel.

8.1.2 The Design Authority is required to justify the whole design, including hull, hull penetrations, fasteners, systems, valves, and auxiliary fittings etc. against the contractual shock requirements as part of the design justification for the Whole Ship Safety Case. This may be done by use of recognised MOD design methods such as those contained in Def Stan 09-50, BR 8470 or NCRE R548 where appropriate, or by the use of alternative design codes specifically developed or modified for the particular application. Design codes which have been newly developed or modified are to be shown to have been validated and justified against the original design intent to MOD’s satisfaction. It should be noted that a statement of compliance with MOD standards alone does not justify the design.

8.2 Wear and Tear

8.2.1 In the extreme, wear and tear of the fabric of the watertight envelope could lead to loss of integrity as a result of failure due to corrosion, erosion, fatigue, or a combination of all three. Corrosion and erosion are dependent on the materials used, the operating environment and the time at risk. Fatigue is a function of the materials used, the operating environment and the number of operating cycles experienced.

8.2.2 Estimates of rates of wear can be made from historical or experimental data and appropriate allowances included in the design. This, with institution of rigorous inspection, maintenance and testing regimes in service, reduces the likelihood of the various components reaching a critical state. The Safety Case for the design must include justification of the design allowances assumed and the inspection, maintenance and testing regime.

8.3 Collision

8.3.1 Submarines are especially vulnerable to collision and the possible resultant loss of watertight integrity when coming to or operating at periscope depth or during surface running. Their relative lack of manoeuvrability at low speeds and innate lack of visibility to other vessels renders them more vulnerable to collision than surface ships. Generally this coincides with being in confined waters, such as pilotage waters, channel approaches, constrained navigational channels and during littoral operations.

8.3.2 It is not practicable to design the submarine pressure hull to avoid a direct breach due to collision or some other impact, although the design factors of safety of the hull and the rigorous quality control standards applied during construction will reduce the risk.

8.3.3 Loss of watertight integrity through breach of the pressure hull is unlikely, but breach of, or damage to, masts and periscopes, conning tower hatches or diver lock-out facilities as a result of a collision may be more likely. All these, and any other scenarios peculiar to the proposed operational deployment of the submarine class must be considered as part of the Whole Ship Safety Case.

8.3.4 A collision on the surface will probably result in the rupture of one or more main ballast tanks. In order to be able to survive this the submarine design must have sufficient reserve of buoyancy as required by Def Stan 08-102. It is also necessary to subdivide the ballast tanks both to lessen the free surface effect when surfaced and to improve damaged survivability.

8.3.5 The principles concerning internal submarine watertight subdivision are mainly governed by consideration of structural strength, the requirement for, escape bulkheads, stipulated by Submarine Escape and Rescue Policy, and, in nuclear submarines, the requirements for Reactor Compartment bulkheads. The greater the watertight subdivision, the greater the chances of surviving the flooding incident but the higher the cost. The trade-offs between current design standards, risk reduction, costs, weight penalties, and construction, maintenance, access and layout constraints must be assessed for any new design.

8.4 Explosion

8.4.1 Explosion, either of the submarine’s own weapons or by enemy action is likely to lead to loss of the vessel. Design to reduce the likelihood of explosion of the submarine’s own weapons is well understood. Rigorous well documented certification procedures exist for weapon design and handling during embarkation, stowage, and discharge. JSP 430 Part 3 Chapter 8 requires Explosive safety certification which includes Weapon Stowage Compartment design and construction. Def Stan 00-101 Part 2 contains design standards for explosive safety in submarines.

8.4.2 Design against breach of watertight integrity due to direct explosion of enemy weapons must be subject to cost effectiveness considerations and has not been considered practicable to date. Design for shock, see above, covers the effects of stand-off explosions.

8.5 Human Factors

Deliberate maloperation of systems leading to loss of watertight integrity is not considered credible on the grounds that self preservation is a strong human instinct and submarine crews are selected and highly trained. Notwithstanding this, the risk of inadvertent operation of systems leading to a loss of watertight integrity must be considered during design and shown to have been reduced to an acceptable level of risk which is Tolerable and ALARP.

9 Degrees of Loss of Watertight Integrity

9.1 General

9.1.1 Loss of watertight integrity can vary from insignificant weeps to a catastrophic failure leading to loss of the submarine. The design of the Pressure Hull, penetrating structures and internal sea water systems, which during normal operation experience ambient sea pressure, must include appropriate safety margins to reduce the likelihood of failure to incredible or Tolerable and ALARP.

9.1.2 Loss of watertight integrity can be addressed as degrees of leakage through the watertight envelope. These fall into four broad categories of seriousness, which are significant for different reasons but do not all have safety implications:

a) Gross leakage,

b) Intermediate leakage,

c) Nuisance leakage, and

d) Marginal leakage.

9.2 Gross Leakage

9.2.1 This is a safety issue: it relates to flow rates the same as, or greater than that generated by a critical hole sized (CHS) leak; which is to say for current RN Submarines of the order of tons per second. Breach of the pressure hull on this scale is considered incredible and catastrophic. Breach of a depth dependent sea water system giving an effective double-ended leak (from both inlet and outlet) until isolated is considered to be the worst possible theoretical scenario.

9.2.2 To approach these sort of flow rates requires a very large scale failure of a depth dependent system and that the valves isolating it fail to shut in a major way: either by jamming fully or nearly fully open, or by detaching from the pressure hull, or by the valve body breaking, or by the control circuit or actuating mechanism completely failing to respond: backups likewise.

9.2.3 These flow rates have significance because of the rate at which they add mass to the submarine. The only recovery action, if submerged, is to surface immediately. Failure to recover means the submarine will sink: if beyond the continental shelf inevitably killing all the crew in the process. As the ultimate submarine catastrophe a lot of attention has been given to preventing the worst case outcome by design, quality assurance and testing; and by provision of advice on limitations on the operation of the submarine embodied in Manoeuvring Limitation Diagrams (MLDs) and associated Emergency Operating Procedures (EOPs).

9.2.4 Gross leakage is likely to occur when surfaced only when a major hull opening is breached by loss of freeboard alongside or inadvertent maloperation of a major opening e.g. Garbage Ejector or Torpedo Tube. Even then the rate of ingress will be less severe than at depth since the ambient pressure head is reduced.

9.2.5 The Safety Case must consider these possibilities and appropriate mitigation measures be included in the design.

9.3 Intermediate Leakage

9.3.1 This is also a safety issue and is the least clear-cut in definition of the four categories of leakage. By definition it lies between Gross and Nuisance leak rates. The breach of the watertight envelope is insufficient on its own to exceed the assumptions made in the MLDs (reaction times, pumping capacities and blowing rates etc.) and so does not necessarily lead to loss of the submarine. The leakage, however, may be sufficient to cause collateral damage leading to loss of the submarine through loss of propulsion, control systems, communications, vital power supplies, or tenure of control positions, etc.

9.3.2 A sunken submarine may be trapped on the bottom by lack of buoyancy but still have the pressure hull intact and all or part of her ship’s company alive. If initial emergency action has stemmed the leak but isolation is not perfect there will be a continuing inflow of water. This will reduce the breathable volume of air remaining, increasing the overpressure. This will cause distress to the survivors, progressively reducing their ability to help themselves, reduce the probability that they can be successfully rescued and beyond a certain point make survival unlikely.

9.4 Nuisance leakage

This category is defined as being that level of continued flow which can be tolerated - just - while essential maintenance is carried out on a system: implicitly that rules out damaging or dangerous rates of flow and hence cannot be regarded as having safety ramifications.

9.5 Marginal leakage

This can be defined as the range of leak rate being acceptable for a particular valve or penetration size under test conditions as illustrated below. Such low flow rates have no safety-critical effects on the submarine.

9.6 Acceptable Levels of Leakage

9.6.1 Ideally the watertight envelope of the submarine should be just that; in practice it is necessary to have various penetrating systems and equipments which breach the boundary. Whilst these penetrations will have seals of one sort or another which will be designed to maintain the watertight integrity initially, they will deteriorate in service due to ageing, cyclic operation, and general wear and tear thus producing breaches of the watertight envelope. Similarly valves for isolation of systems will be expected to be tight on initial assembly and test but may be expected to pass or leak progressively during service: this dictates different acceptance standards for Build or refit and In-Service testing.

9.6.2 The amount of leakage that is acceptable depends upon various factors such as the nature of the seal, whether or not there is a back-up provided, whether periodic testing is practicable, whether the leak can be rectified afloat, whether the system downstream is hard or soft, how much operational time is left before the next scheduled maintenance opportunity, whether deterioration rates can be predicted and so on.

9.6.3 The designer needs to consider the above when assessing the testing regime required for each penetration in the watertight envelope. In practice the various penetrations fall into distinct categories based on the nature of the type of watertight boundary and its mode of operation as described in Clause 6.

9.7 Orders of Magnitude of Leakage

An illustration of the orders of magnitude of the various degrees of leakage is provided by Figure 1. The values used in the figure relate to a “typical” SSBN and must be derived for each submarine class as part of the Safety Case.

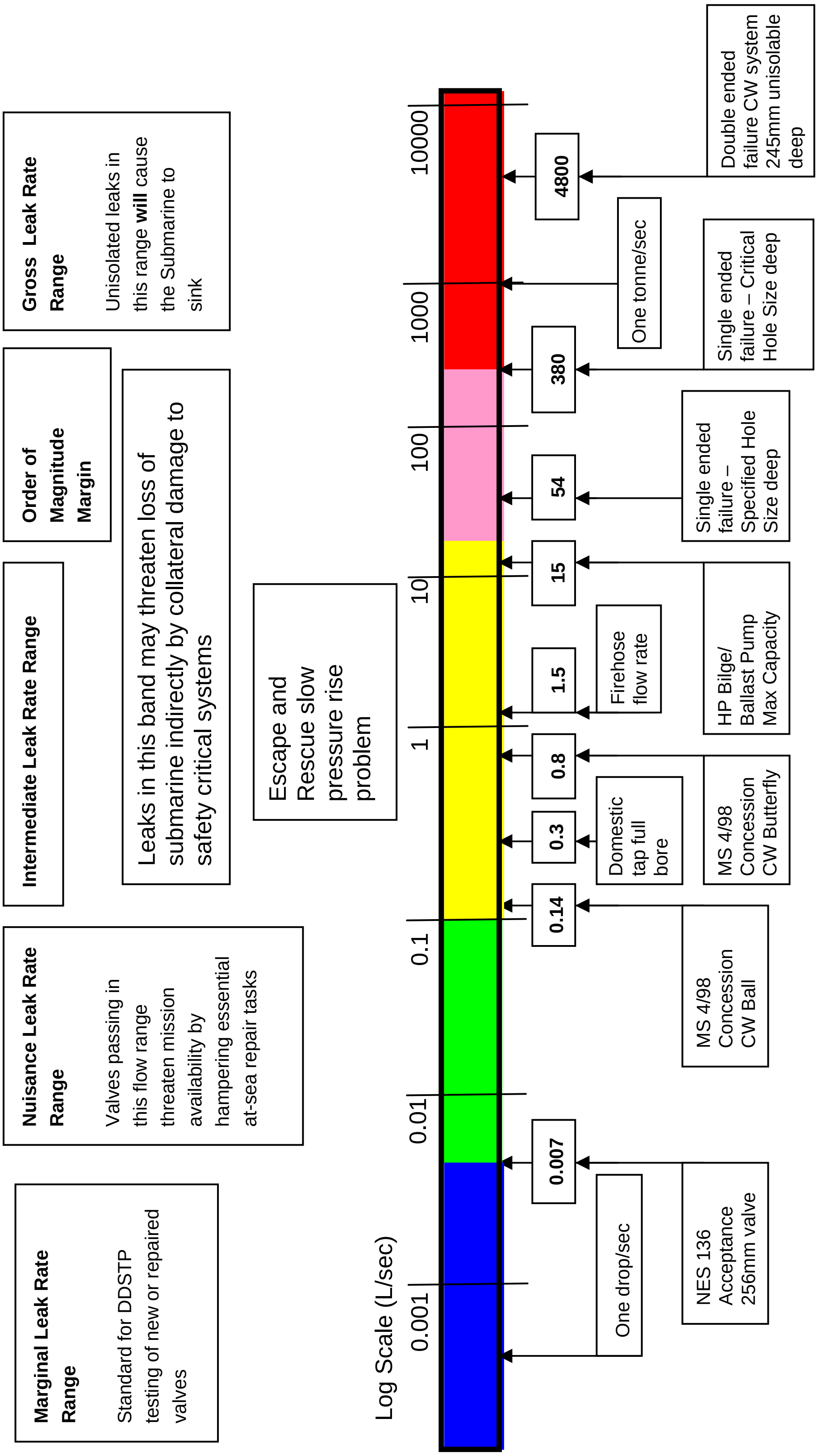

Figure 1 - Typical Orders of Magnitude of Leakage

10 Design Principles to Reduce the Risk and Consequences of Loss of Watertight Integrity

10.1 General

10.1.1 The requirement of JSP 430 for a Ship Safety Case includes Safety Certification for Watertight Integrity. Historically this has been covered by completion of a Safe to Dive Certificate prior to the first occasion on which the submarine is dived after build or refit. The Safety Case for new designs, or changes to existing designs affecting watertight integrity, must include assessment of the design to show that the risks to the submarine's watertight integrity have been reduced to Tolerable and ALARP.

10.1.2 Designers should seek to include redundancy and diversity in the design to reduce the risk of catastrophic failure and the amount of First Level Quality Assurance required.

10.1.3 When assessing the credibility of failure, account is to be taken of the following:

a) the characteristics of the materials used in the construction of the equipment and its components and the level of QA applied;

b) the thoroughness of any survey of the equipment;

c) the design characteristics of the equipment noting design margins and that, for example, fracture under compression loading is unlikely to occur remote from welds;

d) the time in service since a successful pressure test. It should be noted that the assurance against structural failure at operating pressures provided by the over pressurisation to DDSTP decreases with the time elapsed since the last successful test. Normally the practical DDSTP test interval is greatly in excess of the period of assurance provided by the test.

e) subject to satisfactory design and Non–Destructive Examination (NDE) of welds and thickness gauging; fracture of pressure hull hatches, Shore Supply Insert, Torpedo Tube Rear Door, Bow Cap and LET is considered to be as credible as, or less credible than, the failure of the pressure hull;

f) previous operational experience with the materials and design in-service:

g) the risk of collision causing a breach in the outer boundary of masts, periscopes and the Conning Tower is to be recognised

h) the back up valve on a soft or open ended system is to be considered as the inner boundary.

i) single mode, common mode and dependent failures should be considered when developing the design.

j) the proposed periodicity of survey and repair.

10.2 Watertight Integrity on the Surface and Alongside

10.2.1 The provision of adequate freeboard in way of pressure hull access hatches will reduce the risk of flooding when the submarine is on the surface. Design criteria for freeboard for pressure hull hatches are specified in Def Stan 08-102, to which reference must be made. The freeboard is maintained by controlling buoyancy by management of ballast tanks and internal variable ballast.

10.2.2 The need to pass services through a pressure hull hatch must be avoided. Pressure hull connections are to be provided for services known to be regularly required when in harbour i.e. shore power, fresh water, gas supplies, telephones, etc. If pressure hull hatches have to be used for passing services while in harbour the hatch providing the greatest freeboard is to be used and the ability to secure the pressure hull boundary must be maintained (e.g. using a `TOP HAT'). Passing services must be fitted with quick release couplings at the hatch to enable rapid disconnection and to allow the pressure hull boundary to be secured in an emergency.

10.2.3 For situations where an unsecurable flood is experienced but the submarine is at, or able to reach, the surface, each main watertight compartment is to be capable of being pressurized with air from each adjacent main watertight compartment. This system is of limited use depending upon the source of the flood. The system will not be effective against a breach high in the hull. In current nuclear submarines pressurisation of the reactor compartment and tunnel is not a requirement but facilities to pressurise compartments adjacent to the reactor compartment are to be provided in the tunnel. At major watertight bulkheads pressure gauges and control valves are to be fitted to register and control pressure on both sides of the bulkhead.

10.3 Watertight Doors

Access between main watertight compartments is to be by means of power operated watertight doors. The actuation systems are to be capable of operation at all angles of heel and trim up to 30 degrees in any direction, or to the limits specified in the design requirements for the submarine.

10.4 Flood Alarm Systems

10.4.1 A system is to be fitted to warn of rapid flooding and give indication at the ship control console and manoeuvring room control positions. It should include:

a) Compartment flood alarms initiated by float switches sited in all main watertight subdivisions; the switches should be positioned to function after a specified quantity of water has entered the compartment in all combinations of heel and trim required by the design specification.

b) Manual flood alarm switches fitted each side of the entrances/exits of each watertight section.

c) Alarms to warn of failure or gross leakage in sea-connected systems, eg Main Circ system.

10.4.2 Any system of automatic flood alarms must be designed to reduce spurious alarms to a minimum.

10.5 Human Factors

10.5.1 The risk of inadvertent operation of systems leading to a loss of watertight integrity must be considered during design and shown to have been reduced to an acceptable level which is Tolerable and ALARP.

10.5.2 As a defence against maloperation where it could be possible to open both the outer and inner boundaries of systems to the submarine simultaneously (e.g. Garbage Ejector, Torpedo Tubes etc.) the design should incorporate interlocks to add a further level of defence.

10.5.3 No system shall place excessive reliance on operator reliability, in particular no system should be designed so that a single inadvertent human error can lead to loss of the submarine.

10.6 Pressure Hull

The watertight integrity of the pressure hull is achieved by its design as a continuous envelope with the minimum number of penetrations required to enable successful operation of the submarine. The design codes used are to be justified against the contractual and operational requirements for the submarine and are to form part of the Ship Safety Case. The design is to be justified by reference to design standards, factors of safety, material specification, Quality Control on build, Non-Destructive Examination, trials results and historical and modelling evidence etc. to prove that the probability of failure is either not credible or reduced to Tolerable and ALARP.

10.7 Hull Penetrating Equipment/Systems

10.7.1 The design policy should ensure that pressure hull structural failure is likely to occur before the structural failure of the penetrations, systems and fittings.

10.7.2 Penetrations through the hull are to be minimised. Where penetrations are unavoidable the size is to be minimised. Where necessary, penetrations are to be provided with multiple layers of safety or barriers to flooding so that no single credible failure can lead to loss of the submarine. Where this is not possible (e.g. Dutch Breach, logistics trunk, Weapons Embarkation Hatch) the design is to be justified to a similar standard to that of the Pressure Hull and is to be demonstrated to be watertight at pressures equal to the Minimum Collapse Depth of the hull.

10.7.3 The design of hatches and seals should incorporate the intrinsically safe design principle of using ambient sea pressure to assist in achieving the seal. Hatches should open against the pressure where possible. Where this is not practicable the design is to prevent inadvertent opening when under pressure.

10.7.4 A complete record of ALL the penetrations in the pressure hull boundary is to be maintained including hatches, covers, glands (electrical and mechanical) and shaft seals, which form a seal at a pressure boundary when the submarine is operational. The lists are to be drawn up by the Shipbuilder and are for use and updating by the Support Contractor/Refitting Authority. They are to be approved and endorsed by the Design Authority. The lists are to cover:

a) ALL valves and penetrations above Specified Hole Size (SHS - see clauses 10.8.4 & 10.8.5 below) that are to be subjected to Depth Dependent Systems Test Pressure (DDSTP) testing and (If applicable) In Service Seat Leakage (ISSL) checks. Details to be included are Penetration Number, Fitting Number, Description, Test Frequency, Diameter of hole in hull, Type of Valve, Test Blank Drwg. No., Remarks, Size relative to CHS/SHS.

NOTE For the definition of DDSTP and testing procedures refer to clause 4.1.

b) ALL the remaining valves, fittings and openings above SHS (see clauses 10.8.4 & 10.8.5 below) that are impractical to test or cannot be tested at refit. To include identification as above with justification for not carrying out DDSTP test and alternative functional tests/inspections with frequency required.

c) ALL penetrations or openings of less than SHS (see clauses 10.8.4 & 10.8.5 below). Details to include identification and details of inspections/ functional tests at DDD.

10.8 Quality Assurance

10.8.1 Many components involved in watertight integrity are, by definition, amongst those where failure could lead to loss of the submarine. A high degree of assurance of their integrity is therefore essential.

10.8.2 In current submarines this is achieved by their designation as First Level as defined in SSP 25.

10.8.3 Pressure hull integrity at build is ensured by application of rigorous Quality Assurance of materials, fabrication procedures and non-destructive examination. Throughout the service life of the submarine the integrity is assured by periodic hull surveys and hull valve inspection, revalidation, refurbishment and testing.

10.8.4 First Level QA is required on all hull and back up valves or other components where failure would result in a breach equal to or greater than Specified Hole Size (SHS), which is defined as the smallest hole in the pressure hull for which QA standards are to apply. The size of the breach is the diameter of the hole that would be left in the pressure hull with the valve removed but with a bobbin or sleeve still secured to the plating; for welded-in valves it is the valve's bore, for bolted on valves it is the size of the hole in the pressure hull insert.

10.8.5 The SHS is normally to be smaller than or equal to the size of the smallest local CHS divided by √2. However, in the exceptional case of there not being any system in which a double ended breach could occur, the SHS may be of bore between CHS and CHS divided by √2. The SHS must never be larger than the CHS.

10.8.6 The Quality Assurance (QA) requirements for all hull fittings, systems, equipment and fasteners are to be decided by the Design Authority based on an assessment of risk to the submarine due to failure of the item, the requirements of the contract and the guidance of SSP 25.

11 Specific Design Requirements

11.1 General Requirements for Penetrations

11.1.1 In general the number and size of pressure hull penetrations is to be kept to a minimum, thus simplifying the task of maintaining watertight integrity. Where a pressure hull insert is used to reinforce a penetration, the insert is to be designed in accordance with Def Stan 09-50 and associated guidance in MAP 01-074. SSG should be consulted for applicability of other design codes or practices for the design of inserts.

11.1.2 Hull penetrations are to be sited clear of hull welds, in accordance with Def Stan 02-706, and are to conform to the requirements for separation from other penetrations and other major structural attachments to the pressure hull.

11.1.3 The risk of very small openings being clogged by dirt, paint, etc., is to be considered when designing small diameter open ended pressure hull penetrations.

11.2 Requirements for Types of Hull Penetration

11.2.1 Penetrations of the Pressure Hull can be divided into five generic types, each with its own design requirements:

a) **Type A -** Hull valves for systems open to sea.

   1) The concept of Critical Hole Size is discussed in clause 6.6 above. Hull valves whose bore is equal to or greater than the local Critical Hole Size (CHS) that are normally operated when dived are to be capable of being operated both locally and remotely. In addition, a back up valve, capable of being shut both locally and remotely, is to be fitted to all such hull valves in order to safeguard watertight integrity in the event of failure of the hull valve internals or actuator, and to allow downstream maintenance to be carried out in the event of a badly leaking valve. The foregoing are minimum mandatory requirements for submarine safety. It should not preclude fitting back-up valves to smaller hull valves where this is considered necessary to aid damage control, or for other operational reasons. Power operation of these valves should also be considered.

   2) The back up valve is to be fitted directly on to the hull valve wherever practical. If this is not possible, the back up valve may be fitted with an intermediate length of piping. The intermediate length of pipe is to be kept as short as possible and is not to exceed 2m in length. No connections are to be made to the intermediate pipe between the valves except for measurement probes and air connections, when fitted to clear choked inlets.

3) Hull and back up valves fitted in accordance with the above are to have both locally and remotely controlled power operation if they are designed to be normally open throughout the full depth range of the submarine. Where practicable the facility for manual operation is also to be provided.

4) To ensure shutting is achieved within the time required to recover the submarine, and to ensure that closing can be carried out under pressurised flooding conditions, both hull and back-up valves in systems of diameter greater than CHS opened throughout the depth range of the submarine must have remote power operation to shut to provide rapid closure in case of a leak, as required by the MLD/SME. Design of the operating systems for both hull and back-up valves must take account of the possibility of power supply failure by the provision of alternative or secure supplies, or energy storage devices such as battery back-up and hydraulic accumulators. Valves between SHS & CHS may have back-up valves and/or remote operation at the discretion of the design authority, the choice to be justified in the safety case.

5) Hull valves (not including back up valves) whose bore is equal to or greater than the local CHS that are not designed to be open throughout the full operating depth of the submarine, or are not opened when dived, are to be provided with a means of being locked in the shut position. Remote power operation of such valves is not mandatory, but may be considered for the rapid shutting of large or inaccessible valves. The locking device is to be strong enough to hold shut against power operation.

6) Power operated hull and back up valves are to be capable of both remote and local actuation. Remote indication of valve position is to be provided, for example, directly from the valve spindle. Indication is not to be derived from the valve control signal. Where practicable the facility for manual operation is to be provided. A mechanical valve position indicator on the valve spindle is required for all hull valves. A local accumulator is to be provided for each group of power operated valves with sufficient capacity to cycle all of the valves in the group at least once.

7) Emergency shutting of all remotely operated power actuated hull and back up valves is to be effected from the Control Room and/or the Manoeuvring Room, as appropriate by a system ergonomically designed to reduce errors by use of mimic displays, for example. Emergency shutting of a hull valve is also to shut its back up valve, if fitted. Control is to be by a high integrity supply with an independent energy source, e.g. battery backed 24 volt DC grade 1 supply; on the loss of this supply all remotely powered hull and back up valves are to fail shut, except those specified to fail “as is”, e.g. for Main Circ Hull Valves in order to maintain propulsion, or to fail open, e.g. HPDHR/Emergency Cooling Sea Water Systems.

8) The pipework connecting hull and backup valve is to be designed in accordance with Def Stan 02-797 Part 1. Where the facility to dismantle intermediate pipework is required, a welded taper neck flange coupling is to be used. Pipework is to be jointed by fusion butt welds.

b) **Type B** - Inner and outer boundary. Normal operation includes periods with outer open, diving pressure on inner e.g. SSE, Torpedo Tubes.

1) Subject to satisfactory design to an equivalent standard as the hull and application of similar Quality Assurance, test and inspection regimes during build, the catastrophic failure of the outer boundary, including welds, joints, coamings etc., will not be considered credible at depths less than that of the hull. External hydrostatic testing may not be required, if it is impractical. Operational testing and inspection during deep dive will be required. Testing of the inner boundary to DDSTP will be required where practicable.

2) Should the inner boundary be subject to diving pressure throughout the depth range of the submarine, or a collision could cause a breach greater than or equal to SHS, then the inner boundary is to be designed, constructed, inspected and assured to the same standards as the outer boundary.

3) In cases where the inner boundary is not open throughout the operating depth range of the submarine and cannot present a credible breach of greater than or equal to SHS, the inner boundary is to be designed against a hydrostatic pressure appropriate to its operating requirement.

4) Valves which control a watertight boundary when flooding, venting, equalising or draining type B penetrations are to be designed to be fit for purpose appropriate to the role of that watertight boundary.

5) Type B openings of less than CHS are not expected to be required. Should the need arise their design will need to be justified as part of the safety case.

6) Frangible covers fitted inboard of missile tube muzzle hatches are not considered as part of either inner or outer watertight boundaries.

c) **Type C** - Outer boundary normally shut, inner back-up e.g. conning tower Single Escape Tower and Logistics Escape Trunk (LET).

1) Subject to satisfactory design to an equivalent standard to the hull and application of similar Quality, test and inspection regimes during build, the catastrophic failure of the outer boundary, including welds, joints, coamings etc., will not be considered credible at depths less than that of the hull and hydrostatic testing will not be required, if it is impracticable.

2) If there is a credible risk of failure in the outer boundary resulting in a breach equal to or greater than the SHS, then an inner boundary is to be provided. If there is a credible risk of a breach in the inner boundary greater than or equal to SHS then the inner boundary is to be designed, constructed, inspected assured and tested to the same standards as the outer boundary.

3) In circumstances other than those above, the outer and inner boundaries are to be demonstrated to be watertight at MCD.

d) **Type D** - penetrations incorporating mechanical or electrical equipment e.g., periscopes, masts, shafts, operating rods, cable glands etc.

1) This requirement covers hull penetrating masts, periscopes and main shafting.

2) The outer boundary is to have a pressure bearing capability as that of the pressure hull and is to be demonstrated by hydrostatic shop test.

3) An inner boundary is to be provided with the same capability as the outer boundary if there is a risk of credible failure in the outer boundary resulting in a breach equal to or greater than SHS for example due to collision, and a credible failure of the inner boundary would result in a breach equal to or greater than SHS. In such circumstances the inner boundary capability must be demonstrated by a hydrostatic shop test.

4) General design requirements for hull penetrating masts can be found in Def Stan 08-137 (for legacy equipment only).

5) All main propulsion shafting, and systems including the stern gland sealing arrangements are to be designed and installed in accordance with the requirements of Def Stan 02-304 Pt 2.

6) Cable glands are to be selected from Def Stan 02-524 Pt 3 (for legacy equipment only).

e) **Type E** - no inner boundary.

1) This category covers accommodation hatches, service hatches, logistic trunks, Dutch Breaches, Torpedo Embarkation Hatches, etc. with no inner hatch.

2) Subject to satisfactory design to equivalent strength and standards to the hull, application of similar Quality and inspection regimes during build and strength testing, the catastrophic failure of the boundary (including welds, joints, coamings etc.,) will not be considered credible at depths less than that of the hull.

3) In circumstances other than these the watertight integrity at MCD is to be demonstrated by a hydrostatic shop test.

11.3 Design Records

11.3.1 A complete record of ALL the penetrations in the pressure hull boundary is to be maintained under the categories below. The lists are to be drawn up by the shipbuilder and updated by the refit contractor. They are to be endorsed by the Design Authority.

11.3.2 The information on the lists is to include:

a) Penetration No.

b) Fitting Number

c) Description

d) Position

e) Drawing No.

f) Type of valve/fitting

g) DDSTP Test Yes/No

h) Maintenance Schedule reference

i) Test Frequency (130 wks, refit etc)

j) Diameter of hole in hull

k) Size relative to CHS

l) Size relative to SHS

m) Test blank/bonnet details

n) In-service inspection and seat leakage test requirements

o) Comments (including justification for not testing to DDSTP and alternative requirements with test form reference and deep dive inspection requirements)

11.4 Hull Valves

11.4.1 All hull valves are to be designed in accordance with Def Stan 02-375 unless otherwise specified.

11.4.2 Wherever practicable, hull valves are to be designed to be welded into the pressure hull plating. Steel valve bodies are to be fitted with corrosion resistant linings.

11.4.3 Non–welded valves are to be of the flanged and spigot type, attached to the hull pad or insert with fasteners as specified below. They are to be designed to limit leakage in the event of the securing studs stretching under shock loading, for example, incorporating a flange joint and a secondary ‘O’ seal on the circumference of the spigot.

11.4.4 If an air connection facility is to be provided to enable blocked inlets to be blown clear, ideally it must be fitted outboard of the hull valve, i.e. in the sea chest zone and before the grating. Where this is impractical the connection is to be made between the hull and back up valves.

11.5 Electrical/ Fibre Optic Glands

All cable Pressure Hull Glands are to be designed in accordance to the requirements of Def Stan 08-171 (or PTS 14299 if designed before December 2004) and demonstrated to be watertight integrity to MCD. They should preferably be sited in low fire risk areas.

11.6 Depth Dependent Systems

11.6.1 The design should aim to avoid systems liable to cause a flood being sited adjacent to systems necessary for recovery.

11.6.2 It is to be a principal design aim that the extent of depth dependent sea water systems within the pressure hull are to be minimised and that the number of pressure hull penetrations is to be kept to an absolute minimum.

11.6.3 The integrity of the depth dependent sea water systems is a major factor contributing to the safety of the submarine. It is therefore necessary to have an extremely high level of confidence in the integrity of the systems and of the corrective measures available if a system breach occurs.

11.7 Penetration Blanks

11.7.1 To maintain the highest standards of watertight integrity, redundant system penetrations are to have their valves removed and the penetration blanked. A blank is inherently safer than a hull and back-up valve under shock due to its reduced mass.

11.7.2 Safety considerations lead to a hierarchy of methods of blanking the penetration. Ideally the redundant insert should be cut out and a blank welded in of similar thickness and material to the surrounding pressure hull. This has the advantage that it needs no in-service access for survey or testing subsequent to initial proof of successful fitting.

11.7.3 Where this is not considered practicable or cost effective, bolted blanks should be fitted with the order of preference being:

a) Fit external and internal blanks

b) Fit a single external blank,

c) Fit a single internal blank with the outside faired with filler.

11.7.4 For penetrations with hole diameter equal to or greater than Critical Hole Size double blanking is required.

11.7.5 External blanks would normally be impractical to test, but are considered inherently safer than internal blanks since diving pressure tends to reinforce the seal.

11.7.6 External with internal blanks will need the interspace surveying periodically for weeping and possible corrosion.

11.7.7 Internal inspection of an external blank is relatively easy, and it has the advantage that a temporary repair can be effected by fitting an internal blank.

11.7.8 Internal blanks will require periodic DDSTP testing and inspection for corrosion. If the blank starts to weep at sea it will not be possible to do anything other than monitor the situation and renew the arrangements once alongside, or in dock.

11.7.9 The choice of materials to be used for blanks and fillers should take into account the possibility of galvanic corrosion and where possible should seek to eliminate it.

11.7.10 Incorporation of a spigot in a blank reduces the likelihood of leaking under shock and should be used on external blanks where retightening of bolts is obviously impractical.

11.7.11 All material, plate and fasteners are to be quality assured in accordance with SSP 25. For blanks and hull fasteners on penetrations with less than Specified Hole Size, Certificates of Conformity are required in lieu of full QA documentation for material composition, mechanical properties and heat treatment records. Fasteners are to be in accordance with Def Stan 02-862 Part 4 or 5 as appropriate.

11.8 Hull/First Level Fasteners

Hull fasteners of First Level systems are to be designated First Level in accordance with SSP 25, from the hull opening up to and including the sea side of the back-up valve and are to be of the appropriate type and size and are to comply with the requirements of the latest issue of Def Stan 02-862 Part 4. Permissible grades are Submarine Grade 1 - Metric (SM1-M) and Submarine Grade 1 - Unified (SM1-U), and each fastener is to be marked with the appropriate identification, SM1-M or SM1-U.

11.8.1 Obsolete Specifications

First Level Fasteners currently in use or in stock may have been supplied to obsolete specifications DG Ships 300 or NES 730 Part 7 (Metric), or DG Ships 8064 or NES 730 Part 11 (Imperial). The material for these fasteners will be BS PD 970 Grade 605M36 (En16) or BS PD 970 Grade 709M40 (En19) with mechanical properties of condition R for nuts and T for other fasteners. These fasteners will be marked NS/M and not as specified in Def Stan 02-862 Part 4. Provided these fasteners are zinc plated, correctly marked and are otherwise to specification they are acceptable for use.

11.8.2 Fastener Inspection and Replacement

11.8.2.1 The requirements for inspection and replacement of hull fasteners are under review by the Design Authority. Maintenance Authorities should follow the DA requirements for each maintenance period and obtain DA advice when carrying out repairs. In-service inspection requirements are covered by relevant Planned Maintenance Schedule and Hull Survey Requirements.

11.8.2.2 In principle, any first level fastener that is removed or disturbed at any time during maintenance for example by the removal of a nut, is to be fully replaced (nut and stud or bolt). Any first level fasteners which are not removed and replaced during maintenance periods are to be inspected visually. If there is any evidence of deterioration, for example corrosion or distortion, the fastener in question is to be fully replaced with a new fastener as specified in clause 11.8.1.

11.8.2.3 Should difficulty be experienced in obtaining a new fastening to the correct specification, a previously used fastener may be reused provided that it is zinc plated, correctly marked NS/M or as required by Def Stan 02-862 Part 4, and that it successfully passes the dimensional and visual inspections specified in Def Stan 02-862 Part 4. In particular GO/NO GO gauges are to be used to check the acceptability of the thread, and the unthreaded length is to be checked to ensure that it is within tolerance and that no stretching has taken place. Bolts and studs are also to be checked for straightness. Where the zinc plating is damaged but the fastener is otherwise acceptable, re-plating may be allowed to bring the fastener back to specification, however chemical stripping and re-plating of fasteners is only to be carried out to a procedure agreed by the Design Authority.

11.8.2.4 When it is intended to reuse a fastener, approval for reuse is to be sought through the Design Authority by Customer Non-Compliance (CNC) procedure and the Pressure Hull Fastener Register is to be annotated accordingly. A Quality Record Card is to be completed including the results of the checks and inspections required above.

11.8.2.5 Fasteners renewed initially and removed later for some purpose during the same refit or other maintenance period may be reused provided that they are undamaged and comply with the dimensional and visual checks specified in Def Stan 02-862 Part 4. In this particular case CNC procedure is not required.

11.8.2.6 Any fastener found on inspection not to be marked NS/M or as required by Def Stan 02-862 Part 4, or with a marking which is suspect, is to be destroyed and replaced with a correctly marked fastener.

11.8.2.7 All stud holes are to be cleaned and made free of debris before studs are fitted. The clean metal engagement thread of the stud is to be coated with a Medium Strength Threadlock (NATO Stock No. 8030-99-224-8992/8261, Loctite Grade 241 or equivalent) before fitting and torque loading. When a nut is fitted to a stud the thread again is to be clean and free of debris. The stud thread is to be coated with a Medium Strength Threadlock before the nut is fitted and tightened. Threadlock is not to be used with nylon insert type nuts.

11.8.2.8 There may be a limited number of non-standard fasteners fitted in a submarine. These will have been procured to individual drawing references rather than to the above mentioned standards. For non-standard fasteners inspection and replacement is to be in accordance with the above requirements. The stud register is to be endorsed with the appropriate drawing number and/or concession number.

11.8.2.9 If the removal and replacement of a fastener causes a disturbance to the fitting, a system or in-situ pressure test to the appropriate test level is required before the system can be accepted into service.

11.8.3 Thread Protrusion

11.8.3.1 For Hull and First Level Fasteners the shortest standard fastener that gives a minimum protrusion of a half thread is to be used. The upper limit on protrusion is constrained by the need to ensure that no fouling occurs under service conditions and that the specified shock clearance to adjacent fittings and equipment is provided; and the desire to minimise unfastening difficulties over corroded or painted threads. In practice the range of fastener lengths available is such that protrusion will never exceed five threads and will generally be in the range one half to three threads.

11.8.3.2 For self locking nuts where the locking feature is on the top of the nut (for example, nylon insert ring type) the minimum thread protrusion is to be one thread. The maximum thread protrusion is to be as defined above.

11.8.3.3 Fasteners are not to be cut to length as this will damage the zinc plating and may remove the identification.

11.9 Stud Hole Requirements

11.9.1 For in-service submarines the depth and form of existing stud holes is dependent on the Class and is to be in accordance with the relevant approved drawings.

11.9.2 For new holes the bottom of the hole is to taper as for a standard drill, that is 118^{o}, and the hole must be tapped as deep as practicable using a bottoming tap to BS 949-1 with an angle of 23^{o}. In no case is the last full thread to be more than 1½ pitch from the start of the taper.

11.9.3 The thread tolerance of the tapped hole is to conform to tolerance 6H of BS 3643-2 for metric threads and tolerance 2B of BS 1580 for unified threads.

11.9.4 All stud holes are to be examined as defined in BS 2693-2 (for legacy equipment only). GO plain gauges and GO screw plug gauges are to be inserted to full depth in order to detect the effect of excessive drill or tap wear. A NO GO screw plug gauge is to enter not more than 1½ threads. Holes are to be cleaned of solid waste, oil and other extraneous material prior to gauging. Details of stud holes failing the examination are to be referred to the Design Authority for advice on concession or remedial action.

11.10 Stud Requirements

11.10.1 Replacements for existing studs are to be procured to the dimensions specified on the relevant approved drawings and as referenced in the Stud Register. Where details are insufficiently defined then the requirements for new studs below are to be followed.

11.10.2 For new hull studs the metal end is to have a screwed thread to the tolerance fit defined in Def Stan 02-862 Part 4 to ensure that the stud will lock at the run-out of the thread at the bottom of the tapped hole (in addition to the use of a threadlock compound). Thread at each end of the stud is to extend into the flange of the fitting by whichever is the greater of 3mm or 1/8th of stud diameter. For spigotted fittings this requirement may be relaxed subject to approval by the Design Authority.

11.10.3 Hull studs are to have a stretching length the diameter of which is to be not more than 98% and not less than 95% of the core diameter and is to be merged into the threaded parts of the stud. Its length is to be not less than 50% of the core diameter.

11.10.4 The surface finish of the stretching length is not to be more than an average roughness of 3.2µm.

11.10.5 The stud is to be inserted by hand until a resistance is felt. It is then to be torque loaded by one half turn for M24 (or 1.0") studs and smaller and by one quarter turn for larger sizes.

11.11 Pressure Hull Fastener Register

11.11.1 A Pressure Hull Fastener Register is to be kept to provide a complete record of all the fasteners in the pressure hull boundary. The Register is to be provided by the Prime Contractor (or maintenance contractor if appropriate) and updated by the maintenance authority. Registers are to be approved by the Design Authority.

11.11.2 The Pressure Hull Fastener Register is to be based on the lists of hull penetrations and is to reflect the inner and outer boundaries.

11.11.3 The Register is to contain details of fasteners which are used in all pressure hull penetrations including hatch coamings, hull valve to back-up valve (sea side) connections, and the inner boundaries of torpedo tubes, garbage ejector, and submerged signal ejectors together with hatch coaming fasteners. Fasteners whose failure would not cause loss of watertight integrity are not to be included even when associated with a fitting that does contribute to watertight integrity.

11.11.4 The Register is to be updated to the "as fitted" condition at the end of build or maintenance periods as appropriate and is to be produced at the preliminary reading of the D448 (or the equivalent refit meeting) as a final and complete document.

11.11.5 The Master Copy of the Register is to be held on board the submarine and is to be kept up to date by Ship Staff.

12 Testing and Acceptance

12.1 Pressure Testing

12.1.1 The reason for testing of the watertight integrity of the submarine and its appropriate systems at a pressure equivalent to the maximum it is expected to see in service may appear obvious. However, there is more than one reason for undertaking what is usually an expensive and time consuming process.

12.1.2 Systems subject to Deep Diving Depth Pressure (DDDP) in normal operation and hull and back-up valves which may be required to hold against DDDP, are tested to a pressure equivalent to, or slightly greater than, that at the Minimum Collapse Depth of the submarine's hull. This is referred to as Depth Dependent Systems Test Pressure (DDSTP). The relation of DDD to MCD is defined in Def Stan 09-50 Design Standards for Submarine Structures. If DDSTP is designed to be slightly higher than MCD, the probability of system failure under pressure is equal to or less than the probability of failure of the pressure hull at that pressure.

12.1.3 Testing is required, at various stages through the submarine or system's life, to provide:

a) demonstration of structural strength of the structure (valve body, garbage ejector body etc.), and its associated fastenings and fittings

b) assurance of watertight integrity at the time of testing

c) evidence of correct assembly and standard of workmanship

d) demonstration of correct functioning/operation and performance and thus

e) evidence for acceptance from the shipbuilder or refit authority

f) a basis for estimation of further acceptable service life

12.1.4 Where practicable hull valves should be given full functional test (i.e. testing against operational performance requirements). The functional test should incorporate, where practicable, realistic operation of the control and indication systems, power supplies, actuators and valve mechanisms against the flow rates, differential pressures etc. which would be experienced in service. If it is not practical to carry this out with the hull valve installed, the operational testing should be performed at the manufacturers as part of type testing.

12.1.5 The evidence provided by testing acts as a guard against incorrect assembly, incorrect use of materials, and gross deterioration of materials in service; and thereby provides assurance of submarine safety and fitness for use throughout the operational period until the next due test. The test results will form part of the evidence supporting the design justification for the Ship Safety Case.

12.1.6 Regular testing to a pressure representing the expected maximum operational depth also engenders faith in the operators that the systems will operate as required, when required.

12.1.7 Testing alone does not prove necessarily that the design is correct. It does not show that the degree or rate of in-service corrosion is likely to be acceptable, or that fatigue cracking exists or is likely to have a particular growth rate. Thus testing will not prove that the service life can be guaranteed for a particular period.

12.1.8 It may be wholly impracticable to test some portions of the watertight boundary in assorted items in service. This does not negate the safety benefit obtained from the assurance of watertight integrity gained from testing those parts for which it is practicable.

12.1.9 In-situ DDSTP testing of hull valves is onerous, time-consuming and costly, since to test all the hull valves a docking is required. To enhance operational availability an In Service Seat Leakage (ISSL) monitoring policy has been developed for T and V Classes that provides evidence for either the need for overhaul or the justification for further service and extension of DDSTP testing intervals. This condition based monitoring activity assesses hull valve performance during each running period by completion of an ISSL test form and annually by completion of a Deep Dive Test Form (DDTF). Fundamental to ISSL and its validity for extending docked hull valve testing intervals, is the completion of planned DDSTP tests as required by the Design Authority and supporting evidence of acceptable material state and corrosion rates. The results of this initiative allow development of a knowledge base from which engineering judgement can be applied to determine the requirement for maintenance and DDSTP testing and reduce the need for docking with confidence that safety is not being compromised.

12.1.10 ISSL monitoring takes cognisance of the fact that a sea water wetted hull valve's sealing face will invariably degrade over time although functionality and configuration of the valve remains acceptable in terms of system availability and platform safety. Seat leakage is assessed against nuisance limits, as explained in Clause 9 and the impact on escape and rescue timelines is considered. Other leakage rates within the compartment will also be considered, to form a picture of the overall material state of the submarine.

12.2 Test Pressure

12.2.1 All items that are designed to withstand ambient sea pressure are to be given a representative test and a shop test when new and after refurbishment agreed with the Design Authority for Watertight Integrity and the equipment Design Authority.

12.2.2 In the case of equipment and systems designed to operate at Deep Diving Depth Pressure (DDDP) the test pressure is to be Depth Dependent Systems Test Pressure (DDSTP) which is normally equal to, or slightly greater than, the sea pressure at Minimum Collapse Depth as defined in MAP 01-070 Part 3. For equipments and systems designed to operate at a pressure other than DDDP the test pressure is not to be less than 1.35 times the maximum operating pressure. For items needing in-situ DDSTP testing, the record and date of the in-situ DDSTP test and the times and dates of the in-situ Performance or Functional Test are required as part of the QA documentation.

12.2.3 It is to be noted that the Escape Tower Systems that are critical to the functioning of the DSRV/Submersible operations are to be tested to DDSTP + 10%.

12.3 Applicability

12.3.1 All Hull Valves and Backup Valves (and associated fasteners, joints and seals), fittings and equipment forming part of the pressure hull boundary and designed to operate at DDD are treated as part of the pressure hull structure and are functionally tested to DDDP during the Deep Dive following build and those carried out at regular intervals in service.

12.3.2 Hull valves and back-up valves (including associated fasteners, joints and seals), fittings and equipment forming part of the pressure hull boundary that are not designed to operate at DDD (e.g. Diesel Exhaust valve) are to be functionally tested at their respective maximum operating depth after build and refit.

12.3.3 Due to the high stresses imposed on the valves and the system when pressurised to DDSTP, the number of times the system is taken to this pressure is to be reduced to a minimum. During pressure testing the system is to be subjected to gradually increasing pressure, with leaks being rectified as found before proceeding to DDDP and DDSTP.

12.4 Method of DDSTP Testing

12.4.1 All DDSTP testing is to be conducted to a formalised test procedure developed during the building programme or upkeep period preparation and the test results are to be recorded in test forms and appropriate QA documentation. These records will be subject to routine audit by the Design Authorities as required by the contract. On completion of Build or upkeep period the record will be the completed test forms held by the build or refit yard, the Submarine and the Design Authority, or those nominated by the contract, as part of the Ship Safety Case.

12.4.2 Provision is to be made for in situ testing of fittings and valves as specified in Table 1 by means of a hydrostatic test applied externally. Out–to–In Hull Valve pressure tests are to be carried out using test blanks. Special arrangements may be necessary for hull valves connected to external pipework for sea tubes and hydraulic valves. Typical out–to–in test fittings are shown in Figures 2 to 6. A suitable gasket able to support a pressure of DDSTP is to be used. Following testing care is to be taken to re-install gasket, jointing compound, plugs etc., used for the protection of test blanks and fastener holes.

12.4.3 Tests are to be carried out using gauges calibrated within the previous three months and marked with the calibration error. Test gauges and relief valves are to be fitted between the pressure source and the item under test. Relief valves are to be sealed with tamper proof locking arrangements. The relief valve is to be set to lift at a maximum pressure of DDSTP + 5% and tested within the previous three months of the date of the test. Relief valve pressure for Escape Tower systems tested to DDSTP +10% is to be adjusted accordingly. A means of rapidly reducing the applied pressure is to be demonstrated prior to the test.

12.4.4 In the case of combined hull and back up valves the test pressure is to be applied to the hull and back up valve separately.

12.4.5 Test pressure is to be maintained for a minimum period of 15 minutes and for no longer than 1 hour. Maintaining DDSTP pressure is preferred over continual pressure cycling due to the potential for fatigue.

12.4.6 During out–to–in hull valve testing, leak rate past the valve is to be measured.

12.4.7 The frequency of application of DDSTP is to be kept to the minimum necessary to satisfy this Def Stan and the Design Authority requirements. The test pressure must be applied only after all known system defects have been rectified, as required by 12.3.3 above.

12.4.8 System DDD/DDSTP testing is to be undertaken against outboard blanks with hull and back up valves open where the facility to fit blanks exists.

12.4.9 For long periods of platform/system inactivity in a sea water wetted environment (for example between undocking and sea trials in refit),sea water systems are to be drained, dried and blanked, or filled with demineralised/fresh water to reduce deterioration of hull valve components and their subsequent ability to withstand DDDP/DDSTP pressure. During prolonged shutdown, periodic cycling of wetted hull valves will also reduce deterioration.

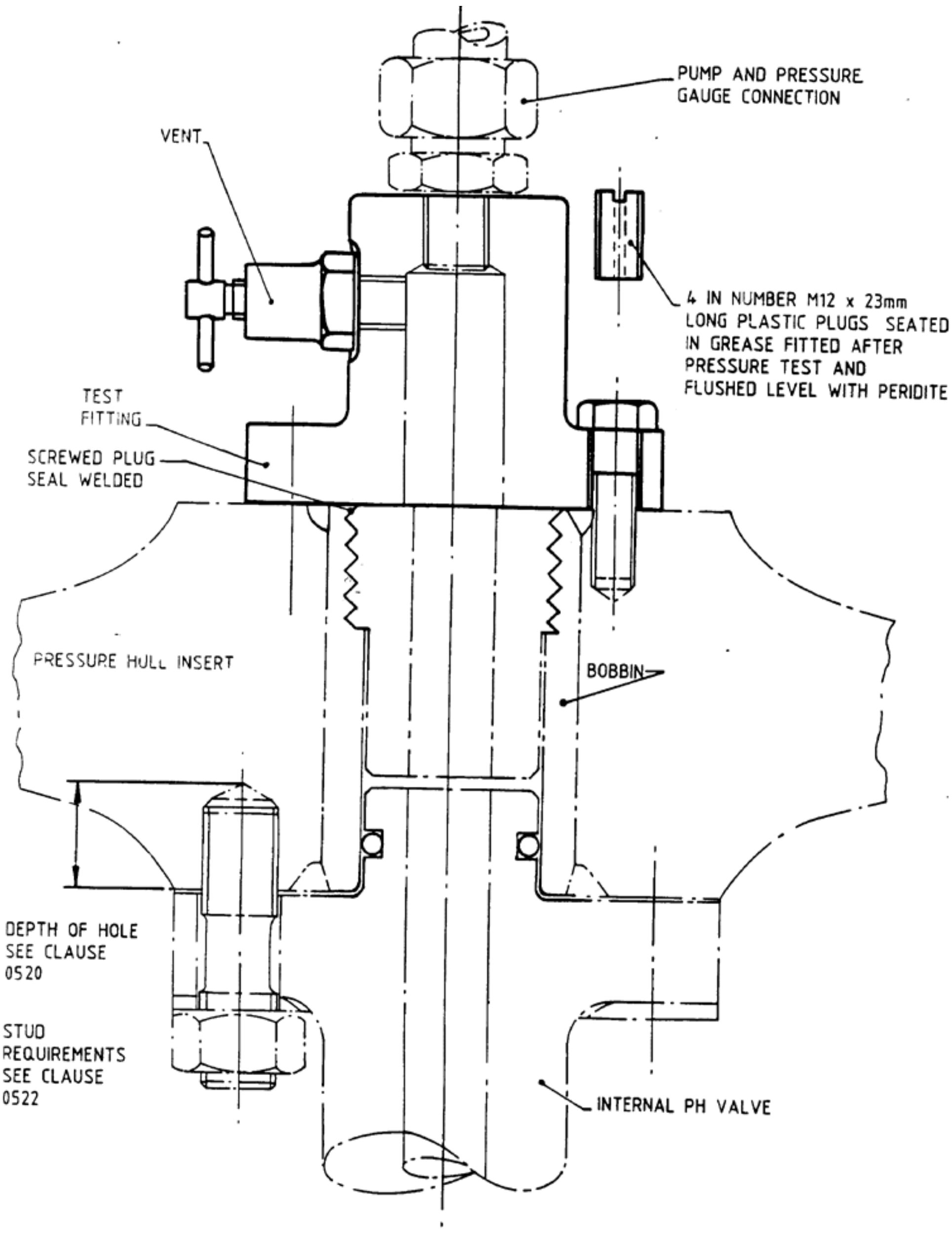

Figure 2 - In Situ Test Rig for Pressure Hull Insert

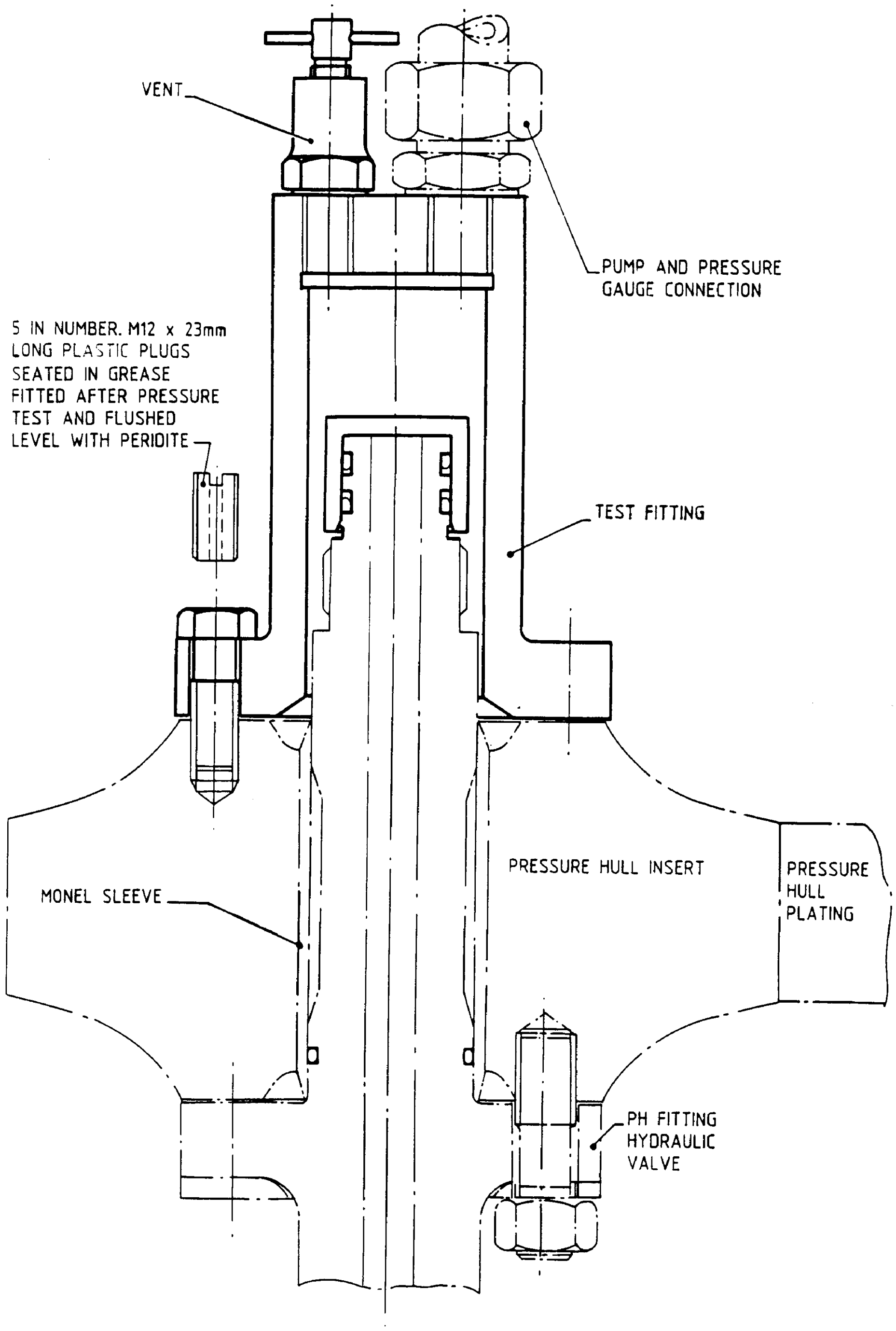

Figure 3 - In Situ Test Rig for Hydraulic Valve

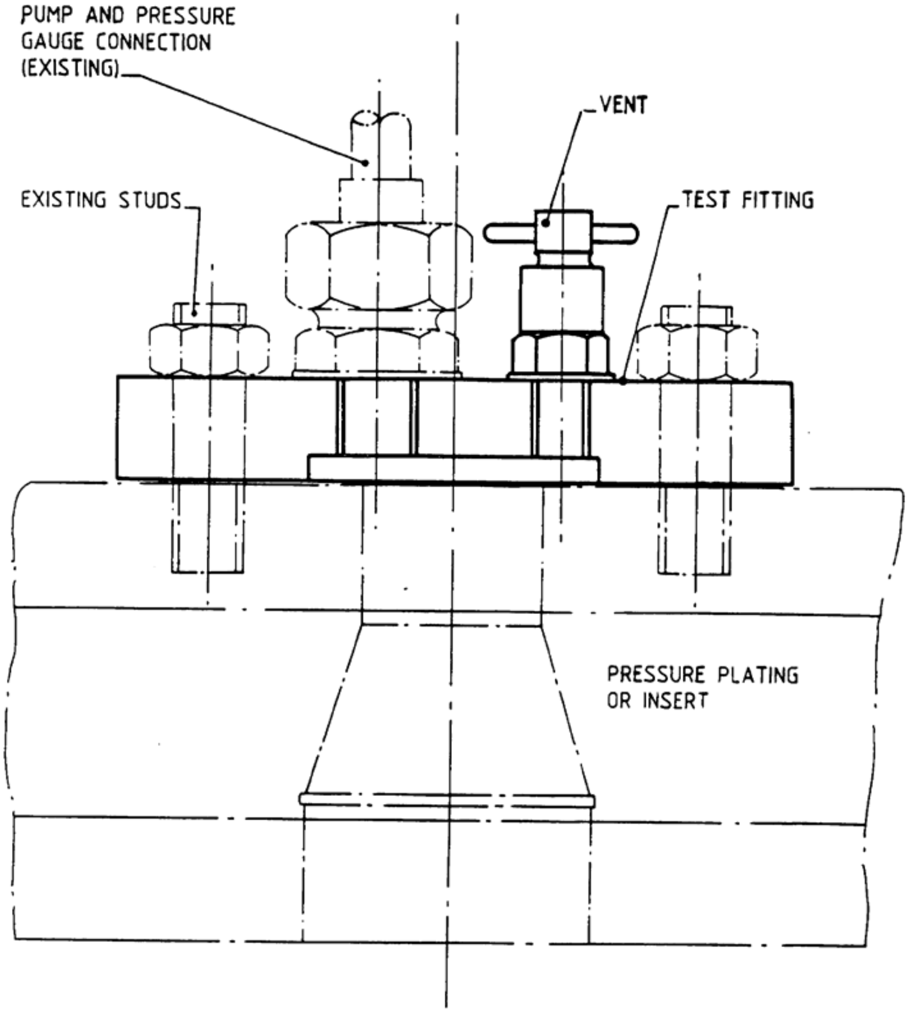

Figure 4 - In Situ Test Rig using Test Plate

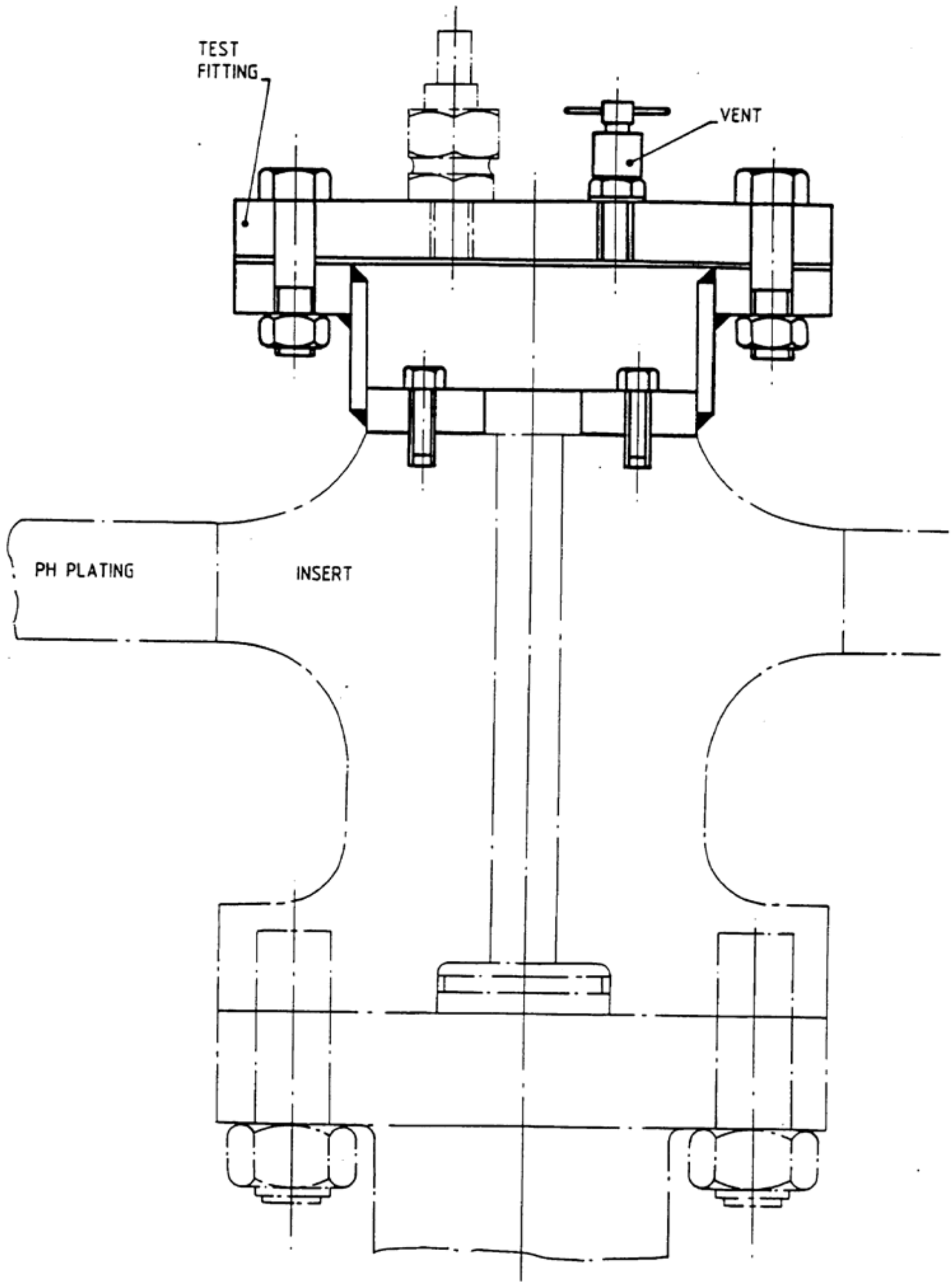

Figure 5 - In Situ Test Rig Showing Hat Box and Cover Plate

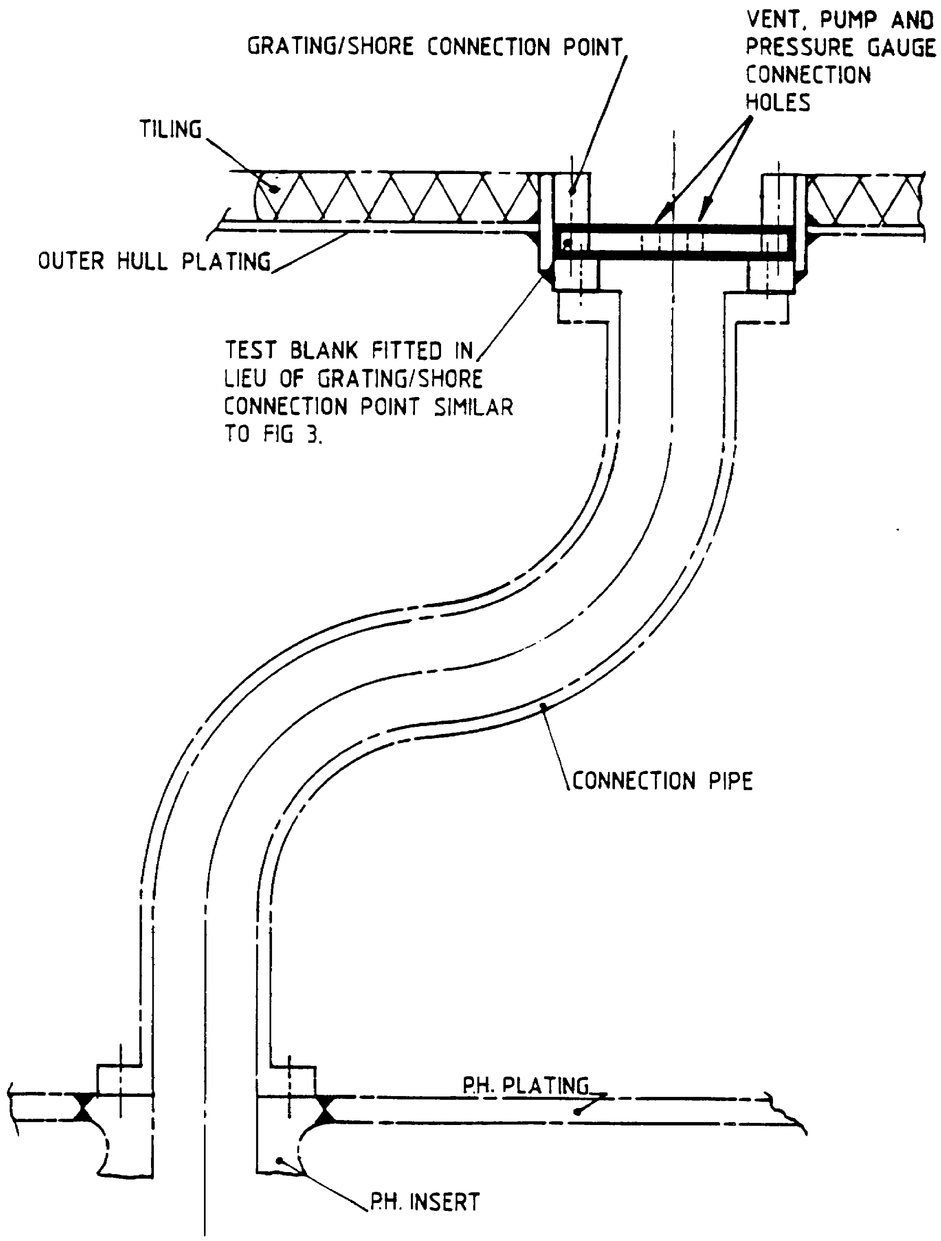

Figure 6 - In Situ Test Rig Fitted in way of Services with Piping between Pressure Hull and Outer Hull Casing

12.5 Scope and Occasions for Pressure Testing

All equipments, fittings and systems where a credible failure could result in breach(es) of total area greater than or equal to that of SHS are to be subjected to an in–situ pressure test on the following occasions, unless otherwise agreed by the Design Authority and MOD Sponsor and supported by a Safety Justification:

12.5.1 During Build and Major Upkeep periods within the period 12 months prior to the start of sea trials;

a) In–Service at intervals to be agreed by the Design Authority for Watertight Integrity and the equipment Design Authority.

b) For all equipment, fittings and systems where a credible failure could result in breach(es) of total area less than that of CHS and greater than or equal to that of SHS, the Design Authority may grant a concession on the 12 month period above.

12.5.2 Where systems that are isolated from ambient sea pressure continue outboard of the hull valve (e.g. external hydraulics), a system pressure test of the hull valve to DDSTP or greater may be taken as satisfying the requirements for testing the joints and fasteners in the valve body, but not the fastener fixing the valve to the hull, or the seal between the pressure hull or sleeve and the valve flange or spigot.

12.5.3 In the case of pressure hull equipments and fittings with outer and inner boundaries where the total cross sectional area of openings in the inner boundary designed to be opened in normal service is less than the area of the Critical Hole there is no requirement for in situ pressure testing of the outer boundary.

12.5.4 In the case of pressure hull equipments with outer and inner boundaries, the inner boundary must also be subject to a pressure test, by blanking the outer boundary if necessary, e.g. periscope mast upper section, unless the maximum credible breach of the outer boundary (by accident or design) is less than the Critical Hole Size and the inner boundary is not normally subjected to ambient sea pressure. Exceptionally it may be considered that such a pressure test after final assembly and installation of the equipment would have an unacceptably adverse effect on its subsequent performance. In such cases the requirement will be waived provided an assessment of the structural integrity is carried out, supported by appropriate tests during assembly, to satisfy the Design Authority and MOD Sponsor that the risk of a material failure causing an unacceptable breach in the inner boundary that could lead to the loss of the submarine is ALARP. Similar procedures are to be followed if the inner boundary is subsequently breached or slackened for any purpose.

12.5.5 For the design of certain types of penetrating equipments and fittings it may be considered by the Design Authority that an in–situ out–to–in pressure test is not feasible, for example electrical glands, main shaft seals, and hatches with no inner boundary. In such cases the following requirements are to apply:

a) where there is no requirement for an in–situ pressure test in accordance with clause 12.6.1, a representative out–to–in shop test is to be undertaken. This must be applied to the equipment in as near its final state of assembly as practicable using a specially manufactured testing rig if necessary;

b) if the watertight integrity of the pressure hull boundary depends on the strength of the pressure hull attachment, the fasteners used are to be proof tested to not less than 1.35 times the normal working load.

12.5.6 Where in–situ testing is not practicable full Quality Assurance documentation is to be provided including chemical composition, mechanical properties, heat treatment records where necessary, full non-destructive examination records and shop pressure test results.

12.6 Planned DDSTP Test Events during Maintenance Periods

12.6.1 Planned DDSTP test events are driven by the Design Authority requirement to undertake routine planned testing which allows a platform to have its relevant safety critical hull valves and systems re-certified for continued safe operational use.

12.6.2 Repeat inner boundary testing as a result of intrusive work post hull valve and system DDSTP test (and during the same maintenance period), need only be to system working pressure. Repeat testing of this nature should be kept to an absolute minimum.

12.7 Retesting

12.7.1 Retesting only relates to repeat testing of hull valves and hard systems which are within valid DDSTP certified dates (i.e. between planned DDSTP test intervals). This section does not apply to maintenance periods where DDSTP certification is being re-issued under planned test events, as outlined above.

12.7.2 If work is performed on the system, hull valve, fasteners and equipment or fittings either during build, refit or in service after a test, it will be necessary to retest in full or in part as indicated below.

12.8 Retesting to DDSTP

12.8.1 If joints forming part of the outer pressure hull boundary are broken or slackened then the appropriate test procedures are to be reapplied in full to that part of the outer boundary before the submarine proceeds to sea.

12.8.2 If components or joints of a hard sea water system are repaired by welding or brazing, then, irrespective of the amount of repair work, that part of the system including the repair is to be tested to DDSTP on completion of the work before the submarine proceeds to sea.

12.9 Retesting to Working Pressure

12.9.1 In the following cases a retest to working pressure is accepted because the outer boundary has been proved to DDSTP (or appropriate test pressure) and has not been disturbed:

a) If a joint in a sea water system covered by in–date DDSTP hull valve and system certification is breached or slackened inboard of the hull valve, that part of the system is to be retested to working pressure;

b) If any part of the inner boundary of a designated pressure hull penetration is broken or slackened while covered by hull valve and system DDSTP certification , then that equipment or fitting is to be retested to the specified working pressure;

c) If a hull or hard system valve is refitted without removal from the hull or breaking or slackening of a system joint, the refitted item is to be retested to the specified working pressure. Repacking of valve glands which does not involve opening up of the valve body or removal of the valve from the system is not regarded as a breach of the system and a retest is not necessary;

d) If new or refitted components, shop tested to DDSTP and certified by correct Quality Assurance documentation, are installed in an equipment, fitting or system covered by in–date DDSTP certification, then that equipment or fitting or that part of the system into which they are fitted is to be tested to the specified working pressure immediately. (If there is any doubt whether a component has been shop tested to DDSTP then this pressure must be successfully applied before installation in the submarine.)

12.10 Summary of Testing—Periodicity and QA Requirements

The testing of valves and fittings is as shown in the following table:

Table 1 - Summary of Testing

Size of opening	QA Requirements				DDSTP (in situ) Testing Requirement
	Valve	Back Up valve	Remote Control	Fittings	
Greater than or equal to CHS	Full 1st level iaw SSP25 & record of functional /performance & DDSTP tests		Record of performance/functional test	Full 1st level as for valves	Build, upkeep and in service maintenance planned by the DA. (see Art 8.27a)
Less than CHS, greater than or equal to SHS,	Full 1st level iaw SSP25 & record of functional /performance & DDSTP tests		Record of performance/functional test	Full 1st level as for valves	Build and upkeep periods or when worked upon (see Arts 8.27b)
Less than SHS	Partial 1st level iaw SSP25	N/A	N/A	N/A	N/A

NOTE For items greater than SHS the replacement of any hull fastening or systems fastening in accordance with Clause 7 will necessitate a revalidation of the system or hull valve/fitting in situ test.

12.11 Effective Dates for Testing

12.11.1 The effective date for all tests undertaken during Build is the date of commencement of Contractor's Sea Trials.

12.11.2 The effective date for all tests undertaken during upkeep is the start of the sea trials.

12.11.3 For tests undertaken outside an upkeep period the effective date is the date of the test.

12.12 Acceptance Standards for DDSTP Testing

12.12.1 Degrees of loss of watertight integrity and acceptable levels of leakage are discussed in clause 9, which should be referred to.

12.12.2 Visible distortion of valves, pipes, pipe flanges, flexible hoses or other components must not occur during any pressure test covered by this Def Stan.

12.13 Build and Refit

12.13.1 At build and refit all system joints and seals must be completely watertight at DDDP. Minor weeps and beading from mechanical joints and seals may be accepted at DDSTP at the discretion of the Design Authority for Upkeep Periods and the Technical Authority (TA) and Approving Authority (AA) for new build subject to fasteners not being over tightened. This acceptance must take account of the type, importance and position of the component and is to be recorded on the appropriate Test Form and subsequent QA Audit procedures.

12.13.2 As the testing of hull valves to DDSTP in general acts as a guard against incorrect assembly, incorrect use of materials, and gross deterioration of materials in service, the acceptance standards for the initial test at build or re-assembly and installation during refit, should be, for contractual reasons:

a) Mechanical joints and seals are to be completely watertight at DDDP and at DDSTP;

b) Hull valve seats are to be leak tight at DDDP but minor weeps at DDSTP are acceptable at the discretion of the Design Authority for Upkeep Periods, and the Technical Authority (TA) and Approving Authority (AA) for new builds;

12.14 In-Service

12.14.1 Acceptable leakage rates for hull and back-up valves in-service will be determined by the Design or Acceptance authority and will need to take account of whether the leak rate can be considered to be of marginal level, or whether it may develop, or has developed into the nuisance category which may be tolerable, or to the intermediate category which has distinct safety implications. (see clause 9 for definitions of leakage rates).

12.14.2 The decision on what level of leakage in-service will depend upon consideration of such thing as:

a) Whether the system into which the leakage passes is soft or hard. If soft, whether reliefs are fitted and of sufficient size to prevent damage to either the system or other equipment which could compromise operations or safety.

b) ability to drain the leakage to water collection and disposal systems whilst allowing in-situ maintenance afloat, including contribution of other leaks in the same compartment to an overall compartment leakage figure, relative to available pump capacity

c) the ability to monitor the system in service for increased leakage,

d) availability of history of development of leakage rates for similar valves.

e) time to next scheduled testing and maintenance.

12.14.3 At the discretion of the Design Authority and noting the factors outlined above, the following acceptance rates should act as guidance for acceptance of build, refit and in service hull valves that have undergone refurbishment.

a) In hull and backup valves (where fitted) connected to hard or soft systems some leakage may be accepted into the system at DDDP and DDSTP. All leak rates are to be measured and recorded on the appropriate Test Form. All acceptable leak rates are at the discretion of the Design Authority but are not to exceed 0.1 litres per hour per mm of hull valve bore without concession approval.

12.14.4 For in service wetted hull valves that have not undergone refurbishment but have been subjected to DDSTP test, then the Design Authority is to be consulted on acceptable leakage rates. The Design Authority should take cognisance of the factors governing acceptance, outlined in clause 12.14.2 above.

12.14.5 Hull Valves whose PH pen dia >CHS that have undergone overhaul will also require breakout pressures and timings (in both directions) to be recorded and reported to the Design Authority. This information can be incorporated into the final maintenance period DDSTP deliverable, as detailed in clause 12.16.2 below.

12.14.6 For information, recent previous practice used the following acceptance rates for DDSTP tests:

a) In hull and backup valves connected to hard systems some leakage into the system may be accepted at DDDP and at DDSTP. Leakage rates are to be measured and recorded on the Test Form. Acceptable leakage rates are at the discretion of the Acceptance Authority but are not to exceed 0.1 litre per hour per mm (5 pints per hour per inch) of hull valve bore;

b) Hull valves and backup valves, where fitted, on soft or open ended systems are to be leak tight at DDDP but minor weeps at DDSTP are acceptable at the discretion of the Acceptance Authority up to a maximum of 0.1 litres per hour per mm of hull valve bore.

12.14.7 For DDSTP pressure tests carried out In–Service:

a) the outer boundary of each equipment or fitting is to be completely watertight at DDDP. Minor weeps and beading from mechanical joints and seals may be accepted at DDSTP at the discretion of the Acceptance Authority subject to fasteners not being over tightened;

b) minor weeps and beading from mechanical joints and seals in the inner boundary may be accepted at DDDP (or the specified working pressure) at the discretion of the Acceptance Authority subject to fasteners not being over tightened.

12.15 Concessions

Formal concession procedure is to be applied when the design intent or the periodicity for in–situ pressure testing cannot be met or acceptance standards cannot be achieved. Diving depth restrictions may be applied as a condition of acceptance of a concession.

12.16 Reporting

12.16.1 Completion of the tests defined in this Def Stan is to be recorded on the appropriate test forms and reported to the Design Authority (Build) and Acceptance Authority (Upkeep periods).

12.16.2 Reports are to be available as follows:

a) Fastener Register :

  1) At build—preliminary D448 meeting;

  2) At maintenance and overhaul periods—preliminary D237a meeting or LSCAM.

b) DDSTP Deliverable:

  1) At build—prior to CSTs;

  2) At maintenance and overhaul periods —before the Pre- Sea Trials Inspection;

  3) In–service, and for retesting when (1) or (2) cannot be met—as soon as practicable following the test.

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