FOREWORD

DNV GL rules for classification contain procedural and technical requirements related to obtaining and retaining a class certificate. The rules represent all requirements adopted by the Society as basis for classification.

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CURRENT – CHANGES

This is a new document.
The rules enter into force 1 July 2016.
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SECTION 1 GENERAL

1 Introduction

1.1 Application

1.1.1 The following rules apply to the general aspects of electrical systems which are needed to operate underwater systems.

1.1.2 The requirements of this chapter shall be regarded as supplementary to those given for main class in SHIP Pt.4 Ch.8 and the individual chapters for underwater systems in Pt.5, where applicable.

1.2 The electrical equipment and installations, including power supply arrangements, shall be constructed and installed to operate satisfactorily under all environmental conditions for which the underwater system is designed. Reference is given to Pt.3 Ch.3 Sec.2.

2 References

The documents to be submitted to the Society for approval and the initial tests and trials are stated in Pt.5 Ch.1 to Ch.9.

The necessary markings also for electrical components are summarized in Pt.4 Ch.1 Sec.2.

Recognised production standards include those provided by the International Electrotechnical Commission (IEC).

The following codes and standards are applicable:

— RU SHIP Pt.4 Ch.8
— relevant IEC equipment construction and design standards referred to
— IMCA D 045, R015 Code of practice for the safe use of electricity underwater.

3 Procedural requirements

3.1 Certification requirements

Products shall be certified as per Table 1

Table 1 Certification requirements

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard*</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical penetrations</td>
<td>TA(^{1})</td>
<td>Society</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underwater plug connections</td>
<td>TA(^{1})</td>
<td>Society</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical penetrations</td>
<td>W(^{2})</td>
<td>Manufacturer</td>
<td></td>
<td>Routine test after manufacturing</td>
</tr>
<tr>
<td>Underwater plug connections</td>
<td>W(^{2})</td>
<td>Manufacturer</td>
<td></td>
<td>Routine test after manufacturing</td>
</tr>
</tbody>
</table>
Electrical installations

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard*</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical equipment</td>
<td>$W^2$</td>
<td>Manufacturer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside pressure hull</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battery system incl.</td>
<td>$W^2$</td>
<td>Society</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charging and BMS system</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment for monitoring the H$_2$ -</td>
<td>$T^A$</td>
<td>Society</td>
<td></td>
<td></td>
</tr>
<tr>
<td>concentration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Unless otherwise specified the certification standard is the rules.

1) Type Approval Certificate
2) Works certificate

The details of type approvals and routine tests are defined in Sec.4.

3.2 Documentation

For documents for approval of submersibles and other vehicles see Pt.5 Ch.6 to Ch.9. The documentation for manned hyperbaric systems is summarised in Pt.5 Ch.1 Sec.2.

Documentation related to the system design shall be submitted as stated in RU SHIP Pt.4 Ch.8 Sec.1 [2.2.1] as far as applicable. Additional documentation will be required if deemed necessary.

3.3 Survey and testing requirements during and after manufacture

A test for insulation resistance shall be applied to every circuit between all insulated poles and earth, and between individual insulated poles. A minimum value of 1 MΩ shall be attainable, measured with 500 V DC; for lower rated voltages reference is made to IEC 60902-504 – Special features-control and instrumentation. Main and emergency power supplies shall be tested.

3.4 Survey and testing requirements during and after assembly

Components and groups of components shall be tested before installation into an underwater system.

3.5 Survey and testing requirements during and after installation

Functional tests shall be performed together with the overall commissioning of the underwater system.
SECTION 2 DESIGN PRINCIPLES

1 General principles

1.1
All electrical systems and equipment shall be constructed and installed in such a way that they are serviceable and perform satisfactorily under the design conditions specified for the underwater system to minimize the risk of fire, explosion, electric shock and emissions of toxic gases. The operating parameters of electrical equipment are to conform to the requirements stated in RU SHIP Pt.4 Ch.8.

Electrical circuits and equipment used in water shall be considered in each separate case and in accordance with IMCA D 045, R015 Code of practice for the safe use of electricity underwater. Provisions shall be made to reduce the possible fault currents, to which a person e.g. a diver can be exposed, to a harmless level.

1.2
Besides the essential consumers listed in SHIP Pt.4 Ch.8, the following items of electrical equipment also count as essential consumers:
— battery charging equipment for autonomous and independent submersibles with own charging device, e.g. generator
— battery room ventilators
— acid circulation and cooling system
— H₂ measuring device
— essential equipment for monitoring and treating breathing air
— bilge and emergency bilge system
— electrical installations for diving and buoyancy tanks, e.g. magnetic valves.

1.3 Cables
Cables for use in the outer area shall comply with RU SHIP Pt.4 Ch.8. All cables shall have an earthed braiding or screen around the conductors and be equipped with an insulating outer sheet.
The submerged cables shall be able to withstand an external hydrostatic pressure of 1.3 times the actual external pressure.
Unless installed in pipes, electrical cables shall be readily accessible for visual inspection.
Tensile loads shall not be transferred to the electrical cables.

2 Materials and insulation

2.1
The materials used in the construction of electrical machines, cables and apparatus shall be resistant to moist and salty sea air, seawater and oil vapours. They shall not be hygroscopic and shall be flame-retardant and self-extinguishing.
In addition, materials installed inside decompression chambers and diving bells shall be approved for operation in hyperbaric atmospheres and shall not liberate toxic gases or fumes under these conditions.

2.2
Materials with high tracking resistance shall be used for the supports of live parts.
2.3
The creepage and clearance distances shall be dimensioned as appropriate for the appliance in accordance with IEC. Generator circuit-breakers, pressure hull wall penetrations, under water plug connectors and appliances directly connected to the bus-bars shall be designed for the next higher nominal insulation rating.

2.4
Materials and insulations for electrical equipment used in water shall be agreed with the Society in each single case.

2.5
All materials of submerged systems shall be such that their electrical and mechanical properties are not influenced by water absorption.

3 Supply systems
Details of the main and emergency power supply systems of the different underwater systems are described in the individual chapters of Pt. 5.

3.1 Approved supply systems for underwater application
Direct current and single-phase alternating current:
— 2 conductors insulated from the submersible's/vessel's hull.
Three-phase alternating current:
— 3 conductors insulated from the submersible's/vessel's hull.

3.2
Systems earthing is not permitted.

Guidance note:
Exceptions may be allowed in the case of subsystems using isolating transformers and high resistance earthing

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---
Exceptions may be allowed in the case of subsystems using isolating transformers and high resistance earthing.

4 Voltaages and frequencies

4.1
The maximum permissible voltages are the following, but deviating voltages for propulsion drives may be agreed with the Society:
500 V:
— for permanently installed power systems
— for power systems connected by socket outlets
— for heating and galley equipment
— for battery charging system
— for external power supply.

250 V:
— for lighting systems and sockets for direct current and single-phase alternating current
— mobile appliances with protective insulation and/or protective isolating transformers
— machinery control and monitoring systems, vehicle control systems and vehicle safety systems
— for battery charging system
— for external power supply.

50 V (protective low voltage):
— for mobile appliances used in confined space conditions and in damp spaces, where appropriate using protective isolating transformers.

30 V:
— for all electrical equipment in diving bells and wet bells.

Guidance note:
The use of standard voltages and frequencies is recommended.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

4.2

The emergency source of power and the emergency power distribution shall be capable of handling peak loads.

5 Protective measures

5.1

All electrical equipment shall be protected in accordance with SHIP Pt.4 unless otherwise stated in the following.

5.2

The minimum classes of protection stated in Table 1 shall be applied in manned underwater systems. The class of protection shall be maintained for the equipment as installed, even when in operation (heeling position). In this context, the provision of shielding at the point of installation is deemed to be a protective measure.

5.3

To protect divers against excessive contact voltages and electric shock, additional safety measures shall be taken to avoid or restrict dangerous fault currents. These measures shall be agreed with the Society in each single case.
Table 1 Minimum degree of protection against foreign bodies and water (in conformity with IEC 60529)

<table>
<thead>
<tr>
<th>Where installed</th>
<th>Safety and measuring equipment</th>
<th>Generators, motors, transformers</th>
<th>Switchgear, electronic units, recording equipment</th>
<th>Telecommunications equipment, input units, signalling equipment, switches, sockets, junction boxes, actuators</th>
<th>Heating equipment, heaters, cooking equipment</th>
<th>Light fittings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control rooms and accommodation</td>
<td>IP 23</td>
<td>IP 23</td>
<td>IP 23</td>
<td>IP 44</td>
<td>IP 23</td>
<td>IP 23</td>
</tr>
<tr>
<td>Machinery spaces and sanitary spaces</td>
<td>IP 55</td>
<td>IP 44</td>
<td>IP 44</td>
<td>IP 55</td>
<td>IP 44</td>
<td>IP 44</td>
</tr>
<tr>
<td>Pipe tunnels, bilges</td>
<td>IP 56</td>
<td>–</td>
<td>–</td>
<td>IP 56</td>
<td>–</td>
<td>IP 56</td>
</tr>
<tr>
<td>Outside pressure hull</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Watertightness under pressure in accordance with the submersible’s design criteria</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

5.4
Each insulated supply system, including the secondary side of step-down or isolating transformers (or converters) shall be provided with an automatic insulation monitoring device, actuating switch-off and alarm by insulation faults. Alarm only may be used if a sudden switch-off of the equipment may cause danger for the divers. This insulation monitoring shall be continuous.

The indicator shall be located at the control stand.

Guidance note:
Protection against insulation failures may be achieved by double insulated apparatus or earth fault circuit breakers.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

5.5 Protective conductors
For the use of protective conductors the following shall be observed:

a) The protective conductors shall have the form of an additional cable, additional conductor or additional core in the connecting cable. The use of cable shields or sheaths as protective conductors shall be checked in every single case and shall be approved by the Society.

b) The cross-section of the protective conductor shall be at least half that of the principal conductors/outer conductors. However, with cross-sections up to 16 mm², its cross-section shall be equal to that of the principal conductors/outer conductors. The minimum cross-section of separately laid protective conductors is 4 mm². The cross-section of the protective conductor shall at least comply with the factors shown in Table 2.
Table 2 Cross-sections for protective conductors

<table>
<thead>
<tr>
<th>Cross-section of outer conductor [mm²]</th>
<th>Minimum cross-section of earthing conductor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in insulated cables [mm²]</td>
</tr>
<tr>
<td>0.5 to 4</td>
<td>equal to cross-section of outer conductor</td>
</tr>
<tr>
<td>&gt; 4 to 16</td>
<td>equal to cross-section of outer conductor</td>
</tr>
<tr>
<td>&gt; 16 to 35</td>
<td>16</td>
</tr>
<tr>
<td>&gt; 35 to &lt; 120</td>
<td>equal to half the cross-section of the outer conductor</td>
</tr>
<tr>
<td>≥ 120</td>
<td>70</td>
</tr>
</tbody>
</table>

a) In the submersible’s propulsion network, the dimensional design of the protective conductors shall be based on the maximum possible short-circuit currents of the equipment concerned, the maximum break times of the relevant protective elements and a maximum temperature rise of the protective conductor of 90°C.

b) The protective conductor shall be connected to the hull of the support vessel in a position where it can easily be checked.

c) The connections of the protective conductors to the submersible shall be installed at locations which are easily to check.

5.6 Special earthing requirements for manned hyperbaric systems

For earthing the following shall be considered:

a) Manned hyperbaric systems shall be equipped with an earthing and potential equalizing system. Connections for external earthing shall be provided at all pressure chambers. Also in gas storage and filling station, etc.

b) All metal parts of electrical installations – with the exception of live components – shall be earthed. The casings of electrical equipment mounted directly against the inside wall of pressure chambers are considered to be effectively earthed only if the contact surfaces are permanently free from rust, scale and paint and the casings are fastened with at least two corrosion resistant screws secured to prevent accidental loosening. If these conditions are not met, earthing shall be effected by separate earthing conductors.

c) The connections of the potential equalization at the diving bell/wet bell shall be installed where it can be checked easily. In an easily accessible position of the superstructure of the support vessel and on the diving bell/wet bell a connection point in the form of a connecting plate with preferably M 12 stud bolts shall be provided to which protective conductors can be connected without tools. This connection serves for the compensation of the potential between the manned hyperbaric system and the platform mounted to.

d) The casings of electrical equipment in water are always to be earthed by an earthing conductor included in the supply cable. Where this is not possible, casings mounted on the outside of the diving bell may also be provided with a separate external earth. In this case, however, the entire earth connection (connecting screws and earthing conductor) shall be provided corrosion-resistant.

e) The connections between the earthing conductor and the chamber and to the vessel’s earth shall be made with corrosion-resistant screw connections effectively safeguarded against accidental loosening. The dimensions of the screw connections shall be dimensioned according to the requisite cross-sections of the earth conductor to be connected and may not be used for other purposes.
f) Machines and devices which are mounted on insulating vibration dampers shall be earthed by flexible cables, wires or stranded copper straps.

g) Earth connections shall be accessible for maintenance and inspection. Wherever possible, they shall be marked. Earthing conductors in multi-core cables shall be marked green and yellow, at least at the terminals.

h) Earthing conductors shall be provided with corrosion protection compatible with their place of installation.

i) Copper earthing conductors are subject to the following minimum cross-sections:
   - external connections on support ship and water: 10 mm²
   - external connections inside chambers and living compartments: 6 mm²
   - separate earthing conductors inside switchgear and casings: 4 mm²
   - Earthing conductors in multi-core cables up to a conductor cross-section of 16 mm² shall correspond to the cross-section of the main conductor, subject to a minimum of 1 mm²
   - earthing conductors in multi-core cables with a conductor cross-section of more than 16 mm² equal to at least half that of the main conductor

   If other materials are used, the minimum cross-section shall be determined by the ratio of the electrical conductivity of these materials to the electrical conductivity of copper.

j) Cable sheaths and armouring are not to be used as earthing conductors.

   In the water, all metal enclosures shall be earthed by means of a copper earth conductor incorporated in the supply cable, with cross-section at least of the same size as the supply conductors and not less than 1 mm². For cables having metal wire braid or armour this may alternatively be used as earth conductor, provided that the braiding cross section is sufficient.

5.7 Special earthing requirements for submersible

a) Machines and appliances mounted on insulated vibration dampers shall be earthed with mobile cables, conductors or braided copper leads.

b) The connections of the protective conductors to the submersible shall be installed at locations which are easily to check.

c) At the superstructure resp. at the hull of the submersible a possibility for connection in the form of a connecting plate with stud bolt, preferably M 12, to which protective conductors can be connected without the use of tools shall be provided at an easily accessible position.

   This connection shall serve as compensation of potential between the recovered submersible and the support vessel.

6 Storage batteries and battery chargers

6.1

Storage batteries shall be rated such as to be capable of supplying the consumers during the period specified in accordance with the power balance, when charged to 80% of their rated capacity.

6.2

At the end of the supply period the voltage in the storage battery resp. in the consumers shall at least reach the values quoted in RU SHIP Pt.4 Ch.8 Sec.2 [9.4].
6.3
Approved storage batteries are lead-acid storage batteries with diluted sulphuric acid as electrolyte and steel storage batteries with nickel-cadmium cells and diluted potassium hydroxide as electrolyte.

6.4
Further types of batteries may be approved under consideration and test of the following points:
— resistance to short circuits
— fuse elements at occurring short circuits
— electrical monitoring elements
— fire risk/fire behaviour including consequences on adjacent cells or components
— special requirements for the installation location
— suitability of the used belonging electrical components
— integration in the electrical plant including switch gears
— charging devices and automation system for charging
— Release of flammable and/or toxic vapour and gas.

An risk analysis shall be provided.
Final installation requirements to be agreed with the Society.
If no special measures are taken only lithium iron phosphate type batteries up to 50 Wh in total may be installed within an atmospheric manned compartment. (see also [8])
Final acceptance to be agreed with the Society.

6.5
Storage batteries shall be designed such as to retain their undisturbed function at inclinations of up to 22.5° and such that for inclinations of up to 45° electrolyte will not leak. Cells without covers are not admissible.

6.6
The casing shall be resistant to electrolytes, mineral oils and cleaning agents, as well as to corrosion due to saline mist. Glass and readily flammable materials are not approved as materials for casings.

6.7
In the case of storage batteries containing liquid electrolyte it shall be possible to check the electrolyte level. The maximum admissible electrolyte level shall be marked.

6.8
Lead and alkaline storage batteries shall not be accommodated in the same space or be placed in direct proximity to each other.

6.9
Where the installed batteries contain an energy greater than 50 kWh or more, the battery shall be divided into smaller battery units so that at least safe operation of the submersible is still possible in the event of a fault.
Special attention has to be paid to lithium based batteries.
6.10
It shall be possible to bridge damaged cells with measures on board if they are located within the pressure hull. The use of rigid interconnection links between batteries shall be avoided.

6.11
The weight of the biggest transportable unit shall not exceed 100 kg.

6.12
The rating data of the storage batteries shall be indicated on rating plates. Storage batteries shall be serviced and operated in accordance with manufacturers' instructions.

6.13
Storage batteries providing a power source for electric propeller drives and/or the submersible's power network shall be accommodated in special battery spaces or containers. It is necessary to ensure that the storage batteries are accessible for cell replacement, repairs and maintenance.

6.14
Measures shall be taken to ensure that neither the crew nor the operational equipment can be endangered by emissions of electrolyte fumes.

6.15
A sign shall be mounted at the entrance of battery spaces pointing out that only insulated tools shall be used inside and conductive objects like keys, ballpoint pens, watches with conductive watch straps shall be taken off. Explosion hazard shall be pointed out.

6.16
Storage batteries shall be installed in such a way that mechanical damage is as far as possible excluded. Safe operation under the environmental conditions stated in Pt.3 Ch.3 Sec.2 shall be ensured and the discharge of electrolyte shall be prevented.
Suitable measures, e.g. provision of plastic trays or flexible rubber bags, shall be taken to prevent electrolyte from entering the battery space bilges in the event of mechanical damage to individual battery cells.

6.17
Battery housings shall be provided with adequate and unobstructed ventilation to open air in accordance with RU SHIP Pt.4 Ch.8 Sec.2 [9.4], so that an accumulation of generated flammable gases is avoided. The ventilation intake shall be fed into the lower parts and the outlet arranged in the uppermost part of the housing.
The location of rechargeable battery installations are considered as potentially hazardous area and shall be carefully considered during the conceptual design of the underwater system lay-out early in the project, in compliance with RU SHIP Pt.4 Ch.8 Sec.2 [9.4].
7 Special requirements for lead batteries

7.1 Battery spaces shall be arranged and ventilated to prevent the accumulation of ignitable gas mixtures.

7.2 The quantity of air to be aspirated and exhausted during charging shall be so calculated, that the lower explosion limit for a hydrogen air mixture will not be exceeded. H₂-monitors permanently mounted at suitable points shall measure the gas concentration in the battery space, the exhaust system and, where necessary, in other spaces within the submersible.

If the H₂ concentration reaches and exceeds a level equivalent to 35 % of the lower explosion limit (LEL), this shall automatically release a visual and audible alarm at a central monitoring station. Equipment for monitoring the H₂ - concentration shall be type approved.

7.3 Battery spaces shall contain no other electrical appliances apart from the storage batteries themselves. Lights, fuses (single voltage measuring device) and measuring devices for H₂ concentration may be installed if they are in accordance with the requirements for an atmosphere containing H₂ (see publication IEC 60079).

8 Special requirements for lithium based (e.g. lithium ion) batteries

8.1 All hazards shall be described in a safety description. Safety precautions mitigating the identified risks shall be included.

The safety description shall cover all potential hazards represented by the type (chemistry) of battery and at least cover:
— potential gas development (toxic, flammable, corrosive)
— fire risk
— explosion risk
— necessary detection and alarm systems (gas detection, fire detection etc.) and ventilation for the battery space
— a suitable fire extinguish method
— internal cell failure/thermal runaway
— internal and external short circuit
— external heating/fire.

8.2 The battery system shall have an integrated battery management system (BMS)

8.3 For following parameters shall be monitored in minimum, i.e. protections functions shall be provided:
— single cell voltage
8.4
A risk assessment shall be carried out in any case.

8.5
Compliance with UN 38.3 shall be proven by an international recognised laboratory.

8.6
Reference is made to the following standards:
— IEC 62620 (performance test)
— IEC 62619 and 62133 (safety functions)
— UN 38.3
— IEC 61508.

9 Battery chargers

9.1
Battery chargers shall be rated such that the maximum admissible charging currents cannot be exceeded.

9.2
The power demand of the consumers shall be taken into account when selecting the battery chargers.

9.3
The battery chargers shall be rated such that the tolerances of the limited characteristics and constant characteristics respectively are adhered to irrespective of external disturbance effects.

9.4
Battery chargers shall cut out automatically in case of:
— failure of the battery space ventilation (if an ignitable gas mixture may be created)
— excessive temperature of charging generator/battery charger
— overtemperature of the electrolyte (if a temperature control of the single cells is provided).
9.5

For lead batteries the following shall additionally be considered:

— If during charging simultaneously consumers are fed, the maximum charging voltage shall not exceed 120% of the rated voltage.
— Preferably chargers with IU or IUI resp. IUW characteristics shall be employed.
— Charging devices have to cut off automatically, if the H₂ concentration is too high, e.g. 60% LEL.
SECTION 3 ELECTRICAL PENETRATIONS IN PRESSURE HULL WALLS AND UNDERWATER PLUG CONNECTIONS

1 Design
For the design the following shall be considered:
— the design shall be done for 1.1 times the collapse diving pressure CDP
— pressure hull penetrations shall be gas and watertight. Their tightness shall be guaranteed even if the connected cables have been damaged or shorn off
— electrical penetrations are not to be used for the passage of other systems
— the positive and the negative conductors from a power source are not to pass through the same penetrating device at the pressure hull wall
— electrical conductors within the penetrating device shall be of solid material.

2 Type approval program for electrical pressure hull penetrations and plug connections

2.1 Test requirements

2.1.1 General
Type-testing is performed, on application, at the manufacturer’s works and comprises at least the following individual tests:
— hydraulic pressure test
— gas tightness test
— high voltage test
— measurement of insulation resistance
— visual check

2.1.2 Hydraulic pressure test
A test in which the test pressure shall be equal to twice the nominal pressure PN. The test shall be conducted in accordance with the test pressure/time curve shown in Figure 1, the changes in pressure shall be applied as quickly as possible.

![Figure 1 Test pressure/time curve for type approval](image-url)
2.1.3 Gas tightness test
For penetrations pressurized with gas a gas tightness test shall be performed.
A test with shorn, open cable ends. This test may be performed under air or alternatively under helium. The test pressure shall be 2 times the nominal pressure of the component PN for air and 1.5 times the nominal pressure of the component PN for helium. The leakage rate shall be specified by the manufacturer and to be approved by the Society.
In all pressure and tightness tests on pressure hull wall penetrations, the pressure shall be applied in each case from the pressure side of the wall penetration.
During the pressure and tightness test, the penetration shall be loaded with the rated current in all conductors.

2.1.4 High voltage test
A test at an AC voltage of 1000 V plus twice the rated voltage. This test is performed at the rated frequency and shall be carried out for 1 minute in each case between all the conductors mutually and between the conductors and the casing. The test is performed in the disconnected state. The sealing of the connector shells and the like is permitted to the degree stipulated by the manufacturer in the relevant data sheet.

2.1.5 Measurement of insulation resistance
The minimum value of the insulation resistance between the conductors mutually and between the conductors and the casing shall be 5 MΩ for the type test, for periodic classification surveys the minimum value shall be 2 MΩ.
The insulation resistance shall be measured with an instrument using 500 V DC. For lower rated voltage application reference is made to IEC 60902-504 – Special features-control and instrumentation.
With wet plug connections, the minimum insulation resistance is also to be measured after the connection has been made once in saltwater.

2.1.6 Visual check
Check against manufacturer's documentation.

2.2 Individual test after the manufacturing (routine test)
Each manufactured electrical pressure hull wall penetration and each plug connection shall be subjected to routine inspection after manufacturing by the manufacturer, see also Sec.1 [3].
This inspection comprises the following tests:
— hydraulic pressure test at the manufacturer in accordance with Figure 2 at 1.5 times the nominal pressure of the component PN and at the overall test with test diving pressure TDP, if applicable.
— high-voltage test
— measurement of insulation resistance
A works certificate (W) shall be issued covering the inspection.
Figure 2 Test pressure/time curve for routine tests
SECTION 4 ELECTRICAL MACHINES

1 Requirements

1.1 Electrical machines

1.1.1 Electrical machines shall conform to RU SHIP Pt.4 Ch.8.

1.1.2 All electrical penetrations in pressure containing structures shall be purpose designed, certified and shall be arranged with separate fittings.

1.1.3 Penetrations in pressure vessels shall be gas and water-tight, as applicable, even in the event of damage to the connecting cables. (see Sec.3 [2])

1.1.4 For the windings of electrical machines in submersibles at least isolation class F shall be provided.

1.1.5 In addition to the tests stipulated in RU SHIP Pt.4 Ch.8 Sec.5 [3] the following electrical machines shall be tested in the presence of a surveyor:
   — generators and motors for electric propeller drives
   — motors for steering gear drives and windlasses
   — all other motors driving machines and equipment necessary to the safety and manoeuvrability of the submersible.

1.2 Generators and electric propeller motors

1.2.1 Generators and all electric propeller motors shall to be equipped with a standstill heating system.

1.2.2 An automatic limitation of the performance of the driving motors has to secure that the board main is not overloaded.

1.2.3 The reverse power for reversing, reduction and shut-off shall be considered and shall be limited to permissible maximum values.

1.3 Electric propeller drives

1.3.1 Machines for electric propeller drives rated at more than 100 kW shall be equipped with monitoring devices in accordance with SHIP Pt.4 Ch.8.

1.3.2 If direct current motors are used, energizing current circuits where the failure may endanger the operation shall be protected against short circuit.
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