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**Submersibles — Hydrostatic pressure  
test — Pressure hull and buoyancy  
materials**

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## Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

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This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 13, *Marine technology*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

The document provides a unified specification for the hydrostatic pressure test method applicable to the pressure hull and buoyancy materials of submersibles to confirm that their pressure resistance performance is normal prior to assembly.

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# Submersibles — Hydrostatic pressure test — Pressure hull and buoyancy materials

## 1 Scope

This document specifies a test method for the hydrostatic pressure test for pressure hull and buoyancy materials of submersibles. The test sequence comprises a tightness test and the hydrostatic pressure test itself. It can also include continuous pressurization and depressurization tests, long-term static load and cycling external pressure tests.

This document is applicable to the pressure structure of manned submersibles and unmanned submersibles, including the pressure hull, its accessories (such as viewports, hatches and connectors) and buoyancy materials. The long-term static load and cycling external pressure tests are only applicable to buoyancy material.

This document is not applicable to submarines and other submersibles parking or operating underwater for more than one week.

## 2 Normative references

There are no normative references in this document.

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

### 3.1

#### **submersible**

vehicle operating underwater

### 3.2

#### **manned submersible**

*submersible* (3.1) occupied by persons

### 3.3

#### **unmanned submersible**

*submersible* (3.1) not occupied by persons

### 3.4

#### **maximum working depth**

maximum operating depth at which a *submersible* (3.1) can operate safely

Note 1 to entry: It is expressed in meters (m).

### 3.5

#### **maximum working pressure**

*p*

maximum pressure in which a system (pressure vessel, supporting controls and instrumentation) can be operated

**3.6**  
**test pressure**

$p_t$   
water pressure endured by the pressure structure during the pressurization test or tightness test

Note 1 to entry: It is expressed in megapascals (MPa).

**3.7**  
**pressure hull**

shell capable of withstanding the internal and/or an external pressure, in which occupants and the required equipment are housed

**3.8**  
**viewport**

penetration in the pressure vessel including a window, flange, retaining rings and seals

**3.9**  
**buoyancy material**

material for a *submersible* (3.1), whose density is lower than that of the ambient medium

**3.10**  
**structural change**

position which has a change in cross sectional area, structural configuration or other physical characteristic

**3.11**  
**stress raiser**

area where, due to the characteristics of the hull such as *structural change* (3.10), internal mounting, reduced thickness due to constructional tolerances, additional loads, etc., a change in stress is likely to occur

**3.12**  
**continuous pressurization and depressurization test**

test in which the pressurization rate and depressurization rate keep the same values without any pause for strain measurement

## **4 General**

### **4.1 Test program**

Prior to the test, the test program shall be prepared, including the test organization, test objective, test equipment, inspection content, loading and unloading procedures, support conditions and test result processing.

### **4.2 Manufacturing requirements**

Tests shall be carried out on completion of assembly, welding of components and accessories, and completion of heat treatment/post weld heat treatment, if applicable. The components and accessories shall be assembled in place, provided with quality certificates for materials, manufacturing and assembly.

### **4.3 Test equipment and instruments**

- a) The test equipment shall pass the certification, obtaining the qualifications of carrying out hydrostatic pressure test within the validity period.
- b) The test equipment and instruments shall pass the verification, which evaluates the metrological performance of measuring instruments and determines whether they are certified or not. The

equipment and instruments shall be within the specified period of validity and be checked and calibrated, and then remain in good condition before the test.

- c) The test equipment and instruments shall be installed in the appropriate positions according to the requirements of the test and to the relevant operating instructions, to prevent the test results from being affected by the external environment during the test.
- d) Two thirds of the range of the test pressure gauge shall not be less than the maximum test pressure.

#### 4.4 Requirements for the test environment:

- a) During the hydrostatic pressure test, the pressure medium temperature may be set as the room temperature (10 °C to 30 °C). For viewports, the temperature of the pressurizing medium during the test shall be the design temperature for which the viewport is rated, with a tolerance of +0/-2,5 °C (+0/-5 °F). Brief deviations from these temperature tolerances are allowed, provided that the deviation does not exceed 5,5 °C (10 °F) and lasts less than 10 min.
- b) Atmospheric pressure: 0,084 MPa to 0,106 MPa.
- c) Relative humidity: 30 % to 95 %.
- d) Pressure medium: fresh water or seawater.

#### 4.5 Test sequence

The hydrostatic pressure test of the submersible pressure structure consists of at least the following:

- a) a prior tightness test;
- b) the hydrostatic pressure test itself.

Optional testing includes strain measurement tests, and continuous pressurization and depressurization tests.

#### 4.6 Test record

All test checks shall be recorded, and relevant reports shall be filled in.

#### 4.7 Specification

The factors and terms in this document should be used when the design is not specific. When a design specifies other factors and terms, these should be considered, and the final decisions agreed with the designer and the recorded for use.

### 5 Detailed requirements

#### 5.1 Preparation before the tests

Prior to testing, the integrity and appearance of the pressure structure shall be checked, and parameters such as dimensions and weights of the pressure structure shall be measured.

#### 5.2 Hydrostatic pressure test

##### 5.2.1 General

The test shall be carried out by steps and in two stages, namely a prior tightness test and the hydrostatic pressure test itself. The test pressure during the hydrostatic pressure test may exceed the maximum working pressure within a short period of time; the pressure test shall be carried out repeatedly to

check the consistency and stability of the test. For the selection of the test pressure, since manned submersibles with occupants are concerned with personnel safety, the test pressure requirements for pressure hull and buoyancy materials of manned submersibles are higher than those for pressure hull and buoyancy materials of unmanned submersibles. For the sake of safety, the maximum test pressure during the hydrostatic pressure test shall be higher than the maximum working pressure of submersibles, with the specific settings and test processes as given in 5.2.2 to 5.2.4. Prior to conducting the hydrostatic pressure test, the user shall verify that the testing object has adequate design safety margins.

## 5.2.2 Test pressurization and depressurization rates and holding time

The process of the hydrostatic pressure test is to simulate the hydrostatic external pressure applied to the pressure structure during diving, operating at the maximum working depth, and surfacing of the submersible. The test pressurization rate shall not be less than the pressure change rate caused by the diving speed of the submersible. The holding time at the maximum working pressure shall not be less than the design operation time at the maximum working pressure. The depressurization rate shall not be less than the pressure change rate caused by the surfacing speed of the submersible. The holding time at a pressure higher than the maximum working pressure during the test may be adjusted according to actual conditions.

## 5.2.3 Hydrostatic pressure test of the pressure hull and its accessories including viewports, hatches and connectors

### 5.2.3.1 Test pressure of the pressure hull and its accessories

#### 5.2.3.1.1 Test pressure of the pressure hull of a manned submersible and its accessories.

- 1) For manned submersibles whose maximum working depth is not more than 6 000 m, the test pressure is set as 1,25 times the maximum working pressure.
- 2) For manned submersibles whose maximum working depth is more than 6 000 m, the test pressure is set as 1,1 times to 1,25 times the maximum working pressure.

#### 5.2.3.1.2 Test pressure of the pressure structure of an unmanned submersible and its accessories.

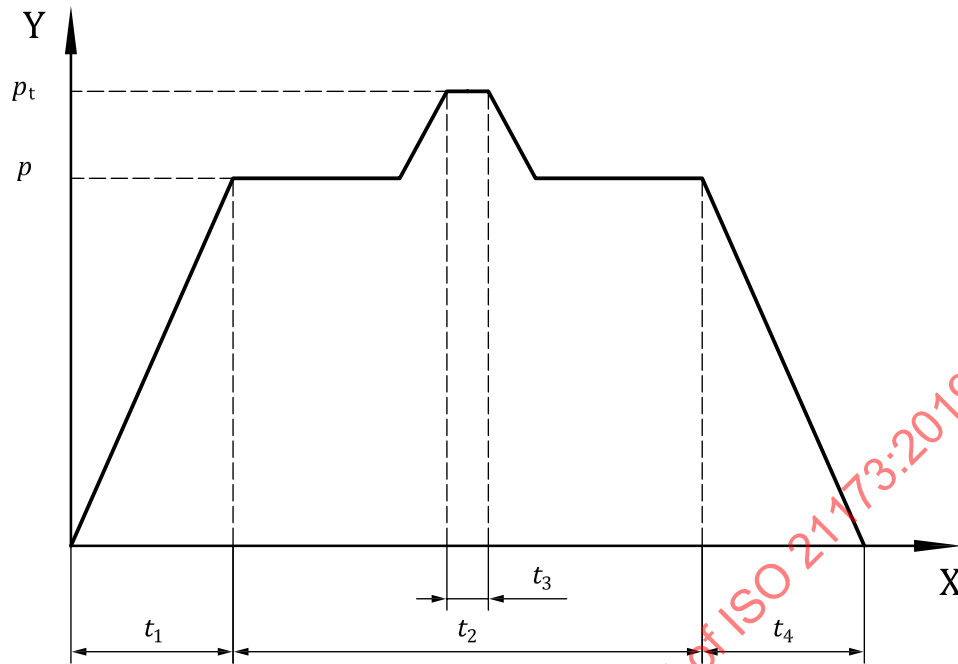
For the pressure hull and buoyancy materials of unmanned submersibles, the test pressure is set as 1,1 times to 1,25 times the maximum working pressure.

### 5.2.3.2 Test procedure for the pressure hull and its accessories

Prior to the hydrostatic pressure test, the maximum working pressure is applied to the pressure structure to check for leakage. Only by passing the tightness test, can the next hydrostatic pressure test proceed.

For a newly built pressure hull, it is generally recommended to conduct a pre-test before the formal hydrostatic pressure test. The pre-test procedure consists in pressurizing the pressure hull to the maximum working pressure and then releasing to zero, so as to eliminate the welding residual stress, machining stress and assembly stress, making the pressure hull to tend to a stable state.

The requirements for the hydrostatic pressure test are shown in [Figure 1](#).

**Key**

- X time, in h  
Y test pressure, in MPa  
 $p$  maximum working pressure of the submersible  
 $p_t$  test pressure  
 $t_1$  pressurization time  
 $t_2$  holding time at the maximum working pressure  
 $t_3$  holding time at the maximum test pressure  
 $t_4$  depressurization time

**Figure 1 — Pressure-time diagram of pressure hull and its accessories test**

- a) For manned submersibles, when the maximum working depth is not more than 6 000 m,  $p_t = 1,25p$ ; when the maximum working depth is more than 6 000 m,  $1,1p \leq p_t \leq 1,25p$ .
- b) For unmanned submersibles,  $1,1p \leq p_t \leq 1,25p$ .
- c)  $t_1$  shall not be more than the minimum diving time of the submersible;  $t_2$  shall not be less than the maximum working time at the maximum working pressure of the submersible;  $t_3$  means holding for a short time, such as 15 min;  $t_4$  shall not be more than the minimum surfacing time of the submersible; test pressurization and depressurization rates and holding requirements are shown in [Table 1](#).
- d) In general terms, the holding time at the maximum working pressure is longer than the holding time at the maximum test pressure.
- e) After testing, the pressure structure shall be capable of normal operation during the full test process and of maintaining satisfactory sealing, pressure resistance and working performance.
- f) Non-destructive examination shall be carried out before and after the test, the acceptance criteria shall be consistent. Suitable methods of examination, including visual and non-destructive (surface and volumetric), shall be used to evaluate the structure after testing, against the standard specified by the designer.
- g) In case the pressure structure should be more fully verified, the test may be carried out repeatedly.

- h) Before the test, the pressure hull's diameter, thickness and out-of-roundness should be measured. After the test, the pressure hull's diameter and out-of-roundness should be measured.
- i) The hydrostatic test procedure of viewports given by ASMEPVHO-1:2016 is also accepted.

**Table 1 — Requirements for hydrostatic pressure test of the pressure hull and its accessories**

| Test stage                | Pressurization and depressurization rates                                                                 | Holding time at the maximum working pressure                           |
|---------------------------|-----------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Hydrostatic pressure test | Not less than the pressure change rate caused by the maximum diving or surfacing speed of the submersible | Not less than the maximum working time at the maximum working pressure |

## 5.2.4 Hydrostatic pressure test of buoyancy materials

### 5.2.4.1 Test pressure of buoyancy materials

#### 5.2.4.1.1 Test pressure of buoyancy materials of manned submersibles.

- 1) For manned submersibles whose maximum working depth is not more than 6 000 m, the test pressure of buoyancy material blanks shall not be less than 1,25 times the maximum working pressure; the test pressure of buoyancy materials after being moulded into blocks shall not be less than 1,1 times the maximum working pressure.
- 2) For manned submersibles whose maximum working depth is more than 6 000 m, the test pressure of buoyancy material blanks and buoyancy materials after being moulded into blocks shall not be less than 1,1 times the maximum working pressure.

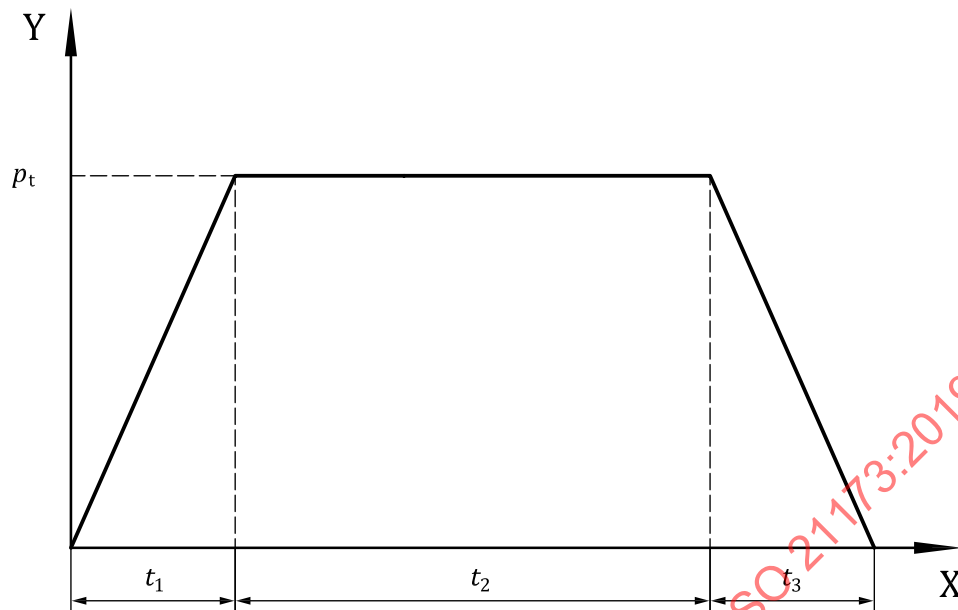
#### 5.2.4.1.2 Test pressure of buoyancy materials of unmanned submersibles.

The test pressure of buoyancy material blanks and buoyancy materials after being moulded into blocks shall not be less than 1,1 times the maximum working pressure.

### 5.2.4.2 Test procedure for buoyancy materials

Prior to the hydrostatic pressure test, the test objects shall be cleared of the dirt on its surface, weighed and the mass recorded. On completion of the test, the structural parts shall be taken out of the pressure equipment as soon as possible, then water stains on the surface of the structural parts shall be cleaned, and the test objects shall be visually checked and weighed.

- 1) The requirements for the hydrostatic pressure test of buoyancy material before formed are shown in [Figure 2](#).

**Key**

|       |                                              |
|-------|----------------------------------------------|
| X     | time, in h                                   |
| Y     | test pressure, in MPa                        |
| $p_t$ | test pressure                                |
| $t_1$ | pressurization time                          |
| $t_2$ | holding time at the maximum testing pressure |
| $t_3$ | depressurization time                        |

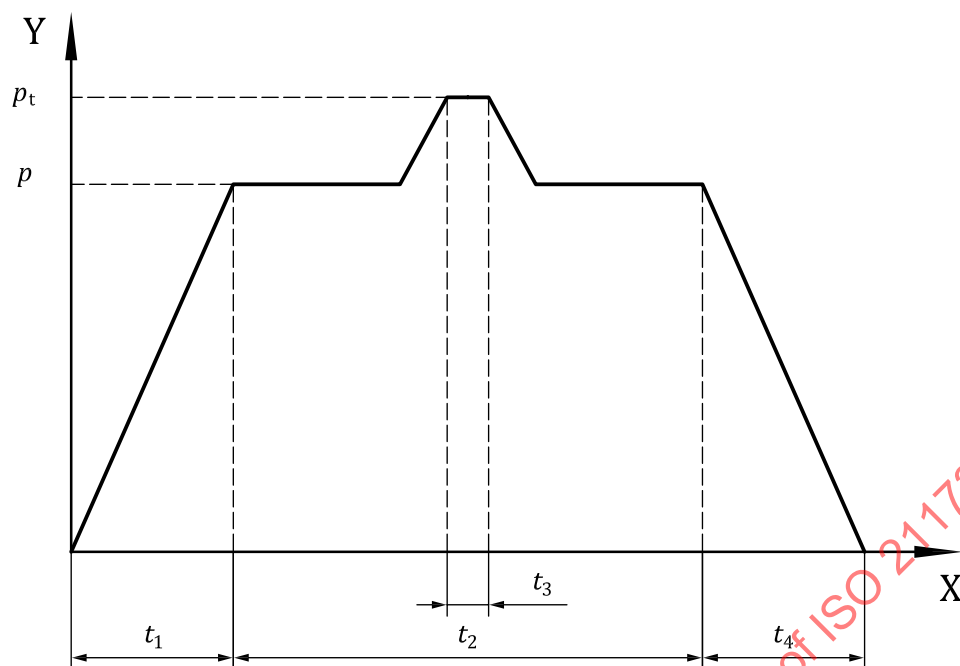
**Figure 2 — Pressure-time diagram of buoyancy material before formed test**

For manned submersibles, when the maximum working depth is not more than 6 000 m,  $p_t \geq 1,25p$ ; when the maximum working depth is more than 6 000 m,  $p_t \geq 1,1p$ ;  $t_1$  shall not be more than the design required diving time of the submersible;  $t_2$  shall not be less than the design working time of the submersible at the maximum working pressure;  $t_3$  shall not be more than required surfacing time of the submersible, test pressurization and depressurization rates and holding requirements are shown in Table 2. The materials after test shall show no deformation, water absorption shall not be more than one percent of its weight. Non-destructive examination shall be carried out before and after the test, the acceptance criteria shall be consistent.

**Table 2 — Requirements for hydrostatic pressure test of buoyancy material before formed**

| Test stage                        | Pressurization and depressurization rates                                                                 | Holding time at the maximum testing pressure                                             |
|-----------------------------------|-----------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| Maximum hydrostatic pressure test | Not less than the pressure change rate caused by the maximum diving or surfacing speed of the submersible | Not less than the design working time of the submersible at the maximum working pressure |

2) The requirements for the hydrostatic pressure test of formed buoyancy blocks is shown in Figure 3.

**Key**

- X time, in h  
 Y test pressure, in MPa  
 p maximum working pressure  
 $p_t$  test pressure  
 $t_1$  pressurization time  
 $t_2$  holding time at the maximum working pressure  
 $t_3$  holding time at the maximum test pressure  
 $t_4$  depressurization time

**Figure 3 — Pressure-time diagram of formed buoyancy block test**

$p_t \geq 1,1p$ ;  $t_1$  shall not be more than the minimum diving time of the submersible;  $t_2$  shall not be less than the maximum working time of the submersible at the maximum working pressure;  $t_3$  means holding for a short time, such as 15 min. In general terms, holding time at the maximum working pressure is longer than at the maximum test pressure;  $t_4$  shall not be more than the minimum surfacing time of the submersible; the pressure structure after testing shall be capable of normal operation during the full test process, and maintaining its satisfactory pressure resistance and working performances. In case of any special requirement, the test may be carried out repeatedly. Test pressurization and depressurization rates and holding requirements are shown in Table 3. The materials after test shall show no deformation, water absorption shall not be more than one percent of its weight. Non-destructive examination shall be carried out before and after the test, the acceptance criteria shall be consistent.

**Table 3 — Requirements for hydrostatic pressure test of formed buoyancy blocks**

| Test stage                | Pressurization and depressurization rates                                                                 | Holding time at the maximum working pressure                                              |
|---------------------------|-----------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| Hydrostatic pressure test | Not less than the pressure change rate caused by the maximum diving or surfacing speed of the submersible | Not less than the maximum working time of the submersible at the maximum working pressure |

### 5.2.5 Qualification testing of buoyancy material

Prior to the test, the test objects shall be cleared of the dirt on its surface, weighed and the mass recorded. The requirements for the test pressure, pressurization and depressurization rates as well as holding time are the same as those of the hydrostatic external pressure test. The test objects shall be pressurized slowly to the test pressure, with the holding time determined according to different test objectives. At the end of pressure holding, the pressure shall be relieved to the ambient pressure. On completion of the test, the structural parts shall be taken out of the pressure equipment as soon as possible, then water stains on the surface of the structural parts shall be cleaned, and the test objects shall be visually checked and weighed. The buoyancy material tested should not be re-used after completion of the tests. The pressurization and depressurization rates and holding times of qualification testing of buoyancy material are shown in [Table 4](#).

**Table 4 — Requirements for qualification testing of buoyancy material**

| Test sequence                              |                                                                     | Pressurization and depressurization rates                                                                 | Holding time at the maximum working pressure |
|--------------------------------------------|---------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|----------------------------------------------|
| Qualification testing of buoyancy material | One-week test<br>(Long-term static load test)                       | Not less than the pressure change rate caused by the maximum diving or surfacing speed of the submersible | 168 h                                        |
|                                            | Hydrostatic pressure immersion test<br>(Long-term static load test) | Not less than the pressure change rate caused by the maximum diving or surfacing speed of the submersible | 84 h                                         |
|                                            | Fatigue test<br>(cycling external pressure test)                    | Not less than the pressure change rate caused by the maximum diving or surfacing speed of the submersible | —                                            |

## 5.3 Optional tests

### 5.3.1 General

Optional tests include a strain test, and continuous pressurization and depressurization tests.

### 5.3.2 Strain test

If the strain measurement is required, strain measuring points shall be determined according to the test objective prior to the test, working and temperature compensation strain gauges shall be numbered, and the implementation scheme of measuring points of strain gauges shall be prepared as a part of the test program. Gauges shall be applied at typical positions of structure, structural changes of the structure, points around the main weld position, high-stress regions according to the finite element calculation, and stress raiser according to the measurement after construction. If necessary, temperature compensation plate shall be arranged on the inner and outer surface. Prior to the test, the maximum working pressure shall be applied to the pressure structure to check for leakage. Only by passing the tightness test, can the next test proceed. The requirements for pressurization, depressurization and holding tests are shown in [Table 5](#). The deviation between the stress value according to the strain measurement data and the calculated value should not exceed 10 %, but the measured value may be influenced by the material properties, the processing and construction, the position of the test point and so on. It should be judged according to the actual situation of the test.

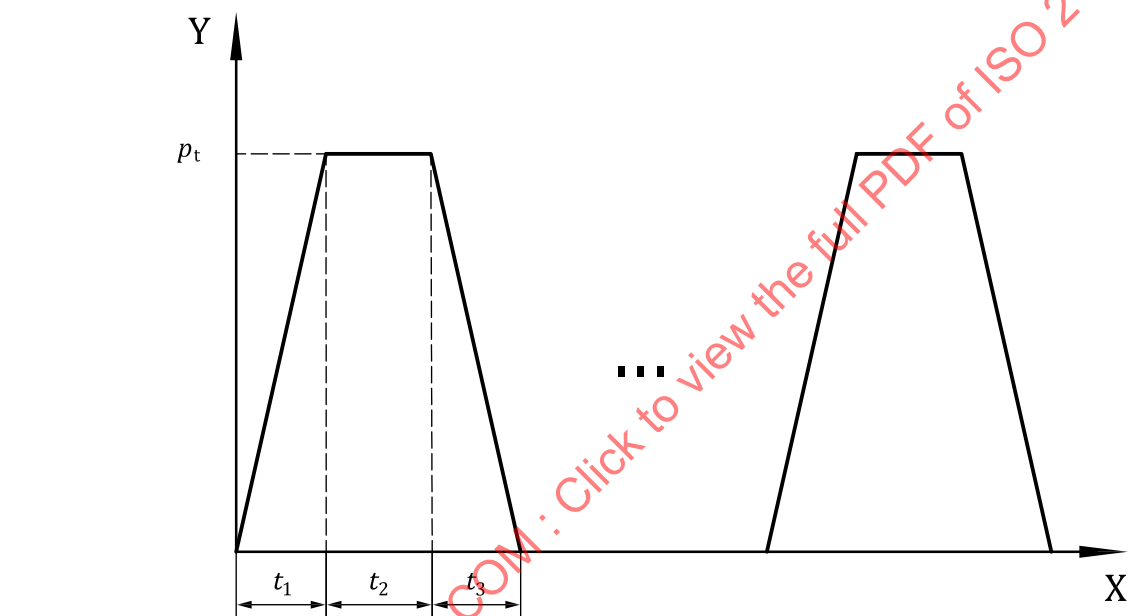
Table 5 — Strain test requirements

| Test stage         | Pressurization and depressurization rates                                                                                                                                          | Holding time at the testing pressure                                   |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Strain measurement | Not less than the pressure change rate caused by the maximum diving or surfacing speed of the submersible, the strain measurement may be made after pressure stabilizing for 3 min | Not less than the maximum working time at the maximum working pressure |

5.3.3 Continuous pressurization and depressurization test

Prior to the continuous pressurization and depressurization test, the maximum working pressure is applied to the pressure structure to check for leakage. Only by passing this tightness test, can the next test proceed.

The requirements for the continuous pressurization and depressurization test are shown in [Figure 4](#).



Key

- X time, in h
- Y test pressure, in MPa
- $p_t$  test pressure
- $t_1$  pressurization time
- $t_2$  holding time at the maximum test pressure
- $t_3$  depressurization time

Figure 4 — Pressure-time diagram of continuous pressurization and depressurization test

$t_1$  shall be less than the minimum diving time of the submersible;  $t_3$  shall not be more than the minimum surfacing time of the submersible; pressurization and depressurization rates and holding time requirements are shown in [Table 6](#).