INTERNATIONAL STANDARD

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# Determination of the resistance to cryogenic spill of insulation materials —

## Part 2: Vapour exposure

*Détermination de la résistance des matériaux d'isolation thermique suite à un refroidissement cryogénique —*

*Partie 2: Phase vapeur*



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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).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 9, *Liquefied natural gas installations and equipment*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 282, *Installation and equipment for LNG*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

A list of all parts in the ISO 20088 series can be found on the ISO website.

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.



# Introduction

The test is intended to be, as far as practicable, representative of a potential accidental pressurised release of cryogenic LNG material manufactured in industrial plants. The test includes

a) release from of cryogenic liquid under pressure, and

b) scenarios where the conditions in the jet characterized predominantly by gaseous exposure.

Liquid jet release may be formed upon release of Liquified Natural Gas (LNG) from process equipment operating at pressure, e.g., some liquefaction processes utilise 40 - 60 bar operating pressure. However, at specific distances from the release point, it is expected that the liquid fraction will diminish such that there is practically no effect from liquid cooling in the stream.

This test is designed to give an indication of how cryogenic spill protection materials will perform in a sudden exposure to cryogenic jet where it is expected that little or no liquid fraction is present.

The dimensions of the test specimen might be smaller than typical items of structure and plant. The liquid cryogenic jet mass flow rates can be substantially less than that which might occur in a credible event. However, individual thermal loads imparted to the cryogenic spill protection materials, from the cryogenic release defined in the procedure described in this document, have been shown to be representative of areas exposed to a cryogenic LNG accidental release where little or no liquid is present.

# Determination of the resistance to cryogenic spill of insulation materials —

# Part 2:
# Vapour exposure

**CAUTION — The attention of all persons concerned with managing and carrying out cryogenic spill testing is drawn to the fact that liquid nitrogen testing can be hazardous and that there is a danger of oxygen condensation (risk of explosion), receiving a 'cold burn' and/or the possibility that harmful gases (risk of anoxia) can be evolved during the test. Mechanical and operational hazards can also arise during the construction of the test elements or structures, their testing and disposal of test residues.**

**An assessment of all potential hazards and risks to health shall be made, and safety precautions shall be identified and provided. Appropriate training and Personal Protection Equipment (PPE) shall be given to relevant personnel.**

**The test laboratory is responsible for conducting an appropriate risk assessment in order to consider the impact of liquid and gaseous nitrogen exposure to equipment, personnel and the environment.**



## 1 Scope

This document describes a method for determining the resistance of Cryogenic Spill Protection (CSP) systems to vapour generated from a cryogenic liquid release where the liquid content is practically zero. It is applicable where CSP systems are installed on carbon steel.

The test provided in this document is not applicable to high pressure cryogenic liquid releases that can be found in refrigeration circuits and in LNG streams immediately post-liquefaction.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 22899-1, *Determination of the resistance to jet fires of passive fire protection materials — Part 1: General requirements*

## 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**
**cryogenic spill protection**
**CSP**
coating or cladding arrangement, or free-standing system which, in the event of a cryogenic jet release, provides insulation to restrict the heat transfer rate from the substrate

**3.2**
**limiting temperature**
minimum temperature that the equipment, assembly or structure that is protected can reach

**3.3**
**nozzle**
assembly from which the cryogenic liquid is released as a jet

**3.4**
**sponsor**
person or organization who/which requests a test

**3.5**
**specimen owner**
person or company that holds or produces a material to test

**3.6**
**cooling power**
amount of heat transferred per unit area per unit time from a surface (W/m$^2$)

## 4 Test configurations

The test is conducted with the plate specimen placed vertically. The material to be tested is exposed to a liquid nitrogen release under pressure where the liquid fraction is practically zero (i.e. gaseous exposure). Due to safety concerns, the test should only be performed outside unless there are sufficient safeguards implemented to mitigate the confined space and $LN_2$ (liquid nitrogen) safety risks.

## 5 Construction of the test apparatus and substrates

### 5.1 Apparatus

The key items required for the test are the following.

**5.1.1 Nozzle and cryogenic liquid feed assembly**, where the temperature and pressure of the liquid can be measured at the point the liquid enters the nozzle.

**5.1.2 Environmental chamber**, (3-sided plastic tunnel) up to a length of 6 m.

**5.1.3 Liquid nitrogen**, of sufficient volume for the test duration supplied from a tanker capable of offload via a pump to generate the required stable pressure at the nozzle.

**5.1.4 Carbon steel specimen**, protected with CSP.

**5.1.5 Thermocouples**, to determine the temperature as a function of time in the steel specimen and the atmosphere immediately in front of the test specimen.



### 5.2 Materials and tolerances

The steel grade used for the test shall be recorded. Where welded, construction shall be representative or the as-built structure. All dimensions are in millimetres and, unless otherwise stated, the following tolerances shall be used.

— whole number ±1,0 mm;

— decimal to point ,0 ±0,4 mm;

— decimal to point ,00 ±0,2 mm;

— angles ±0’ 30”;

— radius ±0,4 mm.

Test specimen shall be a structural steelwork test specimen as described in ISO 22899-1.

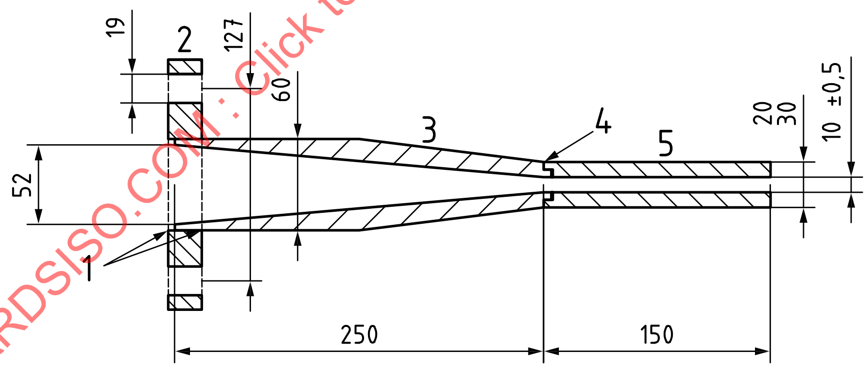


### 5.3 Release nozzle

#### 5.3.1 Nozzle construction

Liquid nitrogen is released towards the specimen from a nozzle. An example of a suitable nozzle has the following characteristics. The nozzle of length 150 mm, constructed from a stainless-steel pipe of nominal diameter 10 mm ± 0,5 mm and of outside diameter 20 mm to 30 mm, giving a wall thickness between 5 mm and 10 mm. The nozzle shall not be tapered and the end shall be clean cut, with no chamfering of pipe walls. The nozzle is fed with liquid nitrogen from a DN50 diameter schedule 40S stainless steel pipe, with a machined section reducing in internal diameter to 10 mm over a 250 mm length as shown in Figure 1.

Dimensions in millimetres




**Key**

1 welds

2 slip-on flange

3 reducing section

4 butt weld

5 straight-sided nozzle

**Figure 1 — Feed pipe and nozzle construction**

### 5.3.2 Nozzle position

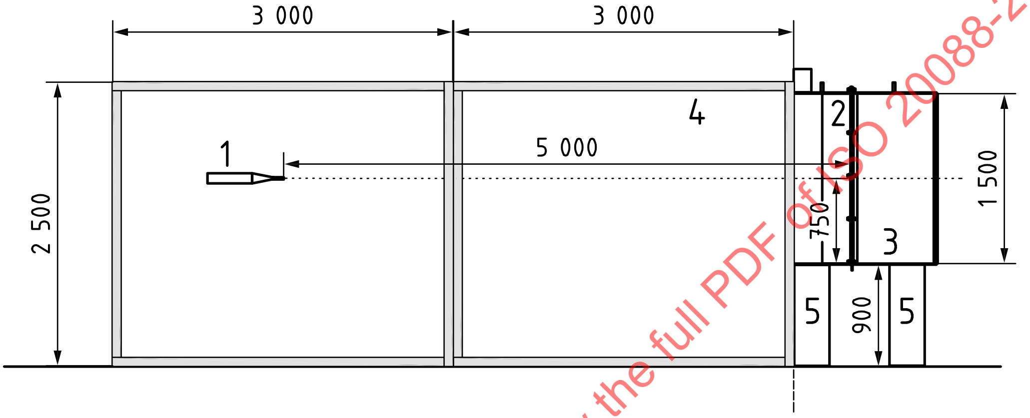
The nozzle shall be positioned horizontally in front of the test specimen, aligned with the centre point such that the cryogenic release impacts normal to the plate specimen as shown in Figure 2. The tip of the nozzle shall be located to give the required cooling power described in Clause 8.

EXAMPLE 5 000 mm ± 10 mm from the protected surface of the test specimen when the average outlet pressure is 8 barg (0,8 MPa) [standard deviation of 0,8 barg (0,08 MPa)] and liquid temperature lower than −170 °C (An example of specimen support and side view configuration is shown in Figure 2).

## 5.4 Test assembly supports

The test assembly shall be supported using material resistant to cryogenic temperatures.

Dimensions in millimetres




**Key**

1 release nozzle (piping omitted for clarity

2 recirculation chamber (insulated on back surface)

3 protective chamber

4 environmental chamber

5 recirculation chamber and protective chamber supports

**Figure 2 — Example of vapour test (side view)**

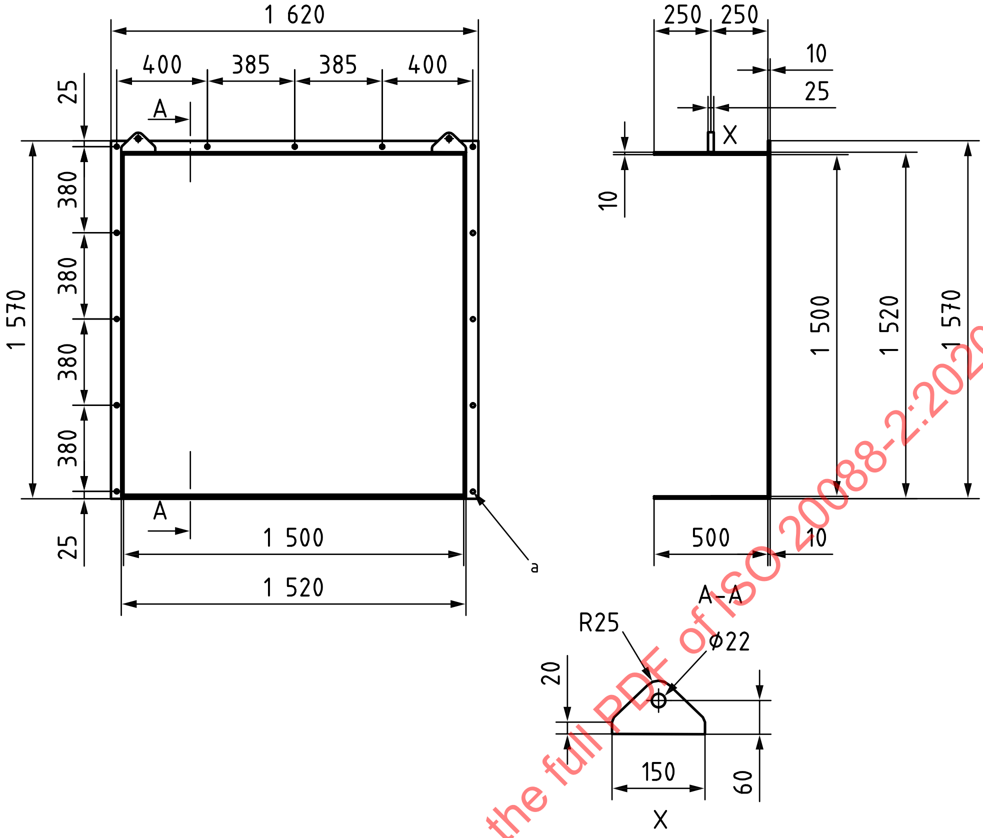
## 5.5 Test specimen and recirculation chamber

It shall be the primary test piece to which the CSP is applied to the internal surface of the box. Dimension shall be as described in ISO 22899-1. To provide extra support and stability, the protective chamber shall be attached to the rear of the recirculation chamber as shown in Figure 3. Insulation board (U Value maximum 1,25 W/m$^2$.K) shall be affixed to the rear of the recirculation chamber.



Dimensions in millimetres




a Thirteen holes drilled.

**Figure 3 — Recirculation chamber and test sample**



# 6 Cryogenic spill protection materials

## 6.1 General

CSP systems generally come in two forms; wet applied materials/coatings and preformed systems. Preformed systems include boards, tiles, blankets, sandwich panels, etc. and are characterized by systems that include joints and fixings. Preformed systems can be used in conjunction with wet applied materials.

The application/installation methodology, including any necessary surface preparation, reinforcement, thickness, top-coats, field joints, etc. shall be determined by the sponsor and/or specimen owner and details provided for inclusion within the test report.

The thickness shall be measured at the positions specified in Figure 4 for sprayed applied systems. The measurement positions indicated shall be regarded as approximate. For preformed systems, thickness shall be measured for the protective layer at locations proximal to those presented in Figure 4. If there are clear signs of thinning or thickening at positions away from those indicated for measurement, additional measurements should be taken.

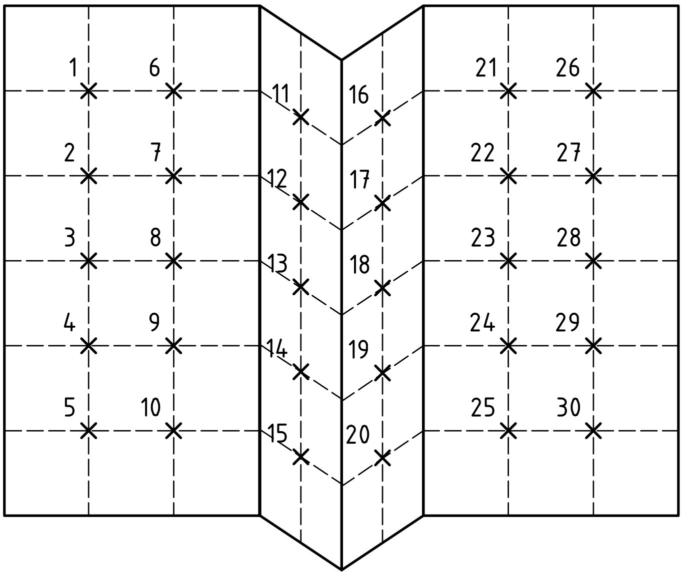



**Figure 4 — Thickness measurement points for test specimen**

### 6.2 Wet applied coating systems

For CSP systems/materials that are wet applied as coatings, the CSP systems/materials should be applied in the same manner as will be used in service.

### 6.3 Preformed system testing

For preformed systems, the system shall also be installed in the same manner as will be used in service.

The method of installing the system shall include representative joints, fixings and wet applied material interface details; a minimum of two joints should be included as follows.

a) One horizontal joint located over thermocouples: 3, 14 and 4 in Figure 5.

b) One vertical joint located over thermocouples 4, 7, 10 as shown in Figure 5.

Joints should be tested, either in a single test or separate tests, as determined by the sponsor and/or specimen owner, ensuring the details are representative in accordance with Clause 10.

## 7 Instrumentation for test specimens

### 7.1 General

Thermocouples shall be fastened to all test specimens. The type and fixing shall be in accordance with one of the methods described in Annex A.

Readings shall be recorded at intervals of not more than 1 second.

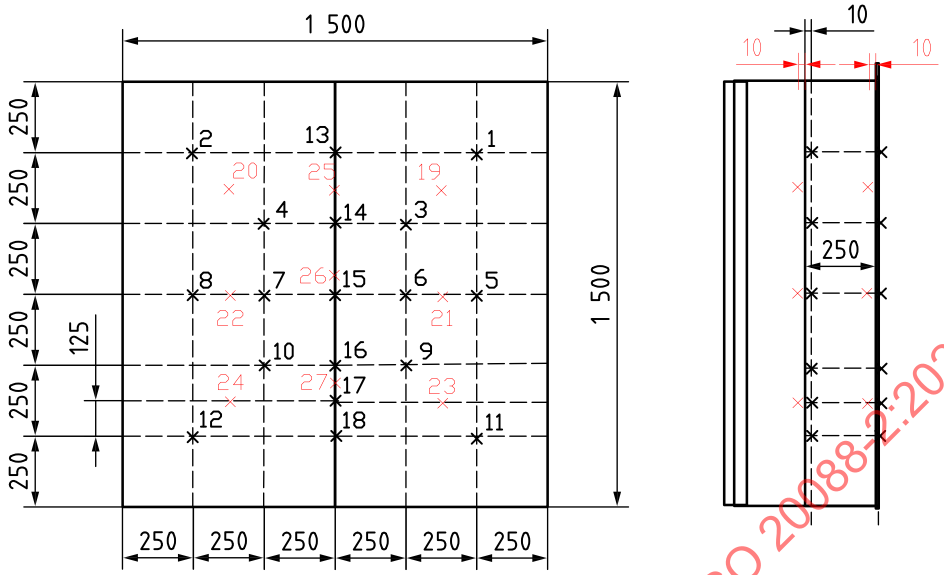
### 7.2 Thermocouple location

Thermocouples are positioned as shown in Figure 5. For thermocouple locations shown in red, these shall be positioned at a distance of 10 mm ± 2 mm away from the test samples (i.e. in the test atmosphere). Thermocouples shown in black shall be within the steel substrate, as described in Annex A.



Dimension in millimetres




**Key**

1 thermocouples 13 to 18

2 thermocouples 1 to 12

NOTE Thermocouple locations for specimen. Red thermocouples are in front of the box whereas the black marks are in relation to thermocouples in the steel.

**Figure 5 — Vapour test thermocouple configuration (front view)**



## 8 Test environment

The test shall be preferably operated outdoors. If curing and conditioning is conducted under different conditions, it shall be clearly stated in the test report.

The test shall be carried out in an environment in which the effects of the weather do not significantly affect the test and the following conditions shall apply.

— The distance of the nozzle from the test specimen and the pressure measured at the exit of the schedule 40 feed pipe prior to entry to the nozzle should be such that the thermocouples in front of an unprotected bare steel back face of the sample reads in the range −50 to −70 °C, generating a steel temperature between −40 to −60 °C after 15 minutes release. The test should only be performed using a validated test configuration.

— The average steel temperature of the steel that will be protected by the CSP material prior to testing shall be 23 ± 3 °C at the beginning of the test.

— An environmental chamber (3-sided plastic tunnel) up to a length of 6 m, attached to the recirculation box, see Annex B.

— No direct sunlight exposure.

## 9 Test procedure

The test laboratory should ensure test parameters are maintained throughout the duration of the test.

The test procedure shall include the following.

a) Pressure and temperature readings at the nozzle taken throughout the test. The temperature of the protected steel substrate shall be monitored throughout the test, taking note of the locations of any sudden drop in temperature. The measurements shall be taken at every 1-second interval.

b) The specimen owner shall provide the specimen for the test in a condition representative of its practical application. Specifically, the test should feature the proposed joint geometry for preformed systems as described in 6.3.

c) Photographs of the test specimen shall be taken before the test.

d) The thickness of the CSP as well as the outer dimensions of the CSP system/assembly shall be verified prior to commencement of the test.

e) Observations shall be recorded of significant details of the behaviour of the test specimen during the test and after the cryogenic liquid release impingement ceases. Information on deformation or partial removal of the surface or cracking shall be noted.

f) Photographs of the test specimen shall be taken as soon as is practicable after the end of the test to reflect the observations made in e). These pictures shall be included in the test report.

The test procedure should include the following.

— The test set-up should ensure that the intended vapour from the cryogenic liquid release impinges the steel specimen, protected with CSP, from the start of the test (e.g. provide a deflector plate or nozzle until the cryogenic liquid release stabilises with the required test parameters).

— Provision should be made that a sample can be inspected within 5 minutes after termination of the test. Sample access time should be recorded.

## 10 Repeatability and reproducibility

The test method described in this document is expected to be repeatable and reproducible between test laboratories. It is the responsibility of the specimen owner to demonstrate that the test results of the sample(s) are representative of their CSP system, including any joints and fixing details, as well as the applicability to the specific structures to be protected.

## 11 Uncertainty of measurement

The overall uncertainty of the measurements shall be within the limits listed below. This shall include the uncertainty of the measuring sensors and logging system. Calibration testing shall show a level of confidence of at least 95 % with respect to known reference points.

Temperature ±5 °C or ±2 %, whichever is greater.

Pressure ±0,1 barg or ±2 %, whichever is greater.

## 12 Test report

The test report shall include the following information.

a) the name of the testing laboratory, the date of the test, a unique test reference, a report identification and a reference to this document, i.e. ISO 20088-2:2020;

b) the name(s) of the sponsor, the manufacturer and the product;

c) documentation on how and when the test specimen was prepared, details of the application of the CSP material (e.g. environmental temperature and humidity during application), the name of the applying/installing company, if appropriate;



d) a complete description of the test specimen, including measurements of the thickness of cryogenic spill protection material and the hardness, if measured; the mean, standard deviation and range of measurements of thickness shall be given as well as details of any joint (if applicable) e.g., position, type, size of overlap and method of fixing;

e) construction drawings of the CSP system, wherever possible;

f) when appropriate, details of any deviations from the normal test configurations and the reasons for them;

g) a record of test details and post cryogenic exposure characterization including

   1) ambient conditions (for example - air temperature, relative humidity, wind speed and direction),

   2) temperature and pressure at nozzle,

   3) temperature of sample, and

   4) for assemblies, a full inspection following the test to validate construction details and assess CSP performance (the assembly should be dismantled so that all components of the system can be checked for cryogenic penetration, integrity and general condition and a visual record made),

   5) the test result, shall be given in the format;

h) the appearance of the test specimen before and after the test and photographs;

i) the behaviour of the test specimen in case of cracking and/or unusual sound;

j) loss of CSP thickness;

k) surface cracks;

l) temperature/time graphs and spreadsheets of temperatures at no less than 30 second intervals for each thermocouple;

m) temperature and pressure graphs at nozzle;

n) temperature/time for each individual thermocouples;

o) an optional classification in terms of the type of specimen tested, critical temperature drop and period of resistance see Annex B.



## 13 Practical applications of test results

### 13.1 General

The main purpose of the test is to determine the temperature drop in the steel substrate when subject to a pressurized cryogenic jet where there is practically no liquid content present. The test is also determined to be suitably conservative when considering vapour release from a pool of cryogenic liquid.

Although the procedure has been designed to simulate some of the conditions that occur in an actual cryogenic liquid release, it cannot produce all conditions exactly. The results of this test do not guarantee structural stability but can be used as an element of a cryogenic risk assessment for structures. Supplementary testing may also take into account other factors that are pertinent to an assessment of the cryogenic hazard for a particular end use such as chemical resistance towards LNG, weathering, ageing, torsional flexing, loading, impact or explosion resistance or smoke production, to name a few.

The relevance of the test set up and results with regards to

— cryogenic liquid release scenario, and

— location of the CSP on structures

shall be the responsibility of the end user. The acceptability of the test, in relation to the end use, can be subject to an independent verification authority [such as a class society (if part of their scope)] or remain at the discretion of the owner (or through delegation to the responsible design engineering company or consortium).

## 13.2 Performance criteria

### 13.2.1 General

The purpose of this test method is described in the scope. It is not the purpose of this test method to provide guidance on the acceptability of a particular thickness of CSP for items such as free-standing panels, or on the coating or method of assembly to be used.

A typical performance criterion for CSP is that the temperature of the protected structural element does not fall below a defined critical value (low temperature limit) within a specified cryogenic jet exposure time as specified by the sponsor.

Another criterion of performance provided by the test could be the minimum time required to reach the limiting temperature as specified by the sponsor.

### 13.2.2 Coatings and spray-applied materials — Substrate temperature

The temperature time profiles at each measurement position shall be used to determine the minimum temperature at each position reached during the test. The position and time of a sudden increase in the rate of temperature drop, if any, should be recorded as it can be indicative of possible failure of the cryogenic spill protection coating at that point. For the same reasons, the localized minimum temperature shall be reported in conjunction with the nearest cryogenic spill material thickness measurement.

### 13.2.3 Systems and assemblies

#### 13.2.3.1 Substrate temperature

The temperature time profiles at each measurement position shall be used to determine the temperature at each position reached during the test. The minimum substrate temperature shall be reported. The position and time of any sudden increase in the rate of temperature drop, if any, should be recorded as it is indicative of possible failure of the system/assembly at that point.

#### 13.2.3.2 Impairment of protection integrity

The penetration of liquid through any cracks, holes or breaches in joints shall be considered when assessing the integrity of a system. The amount of penetration and condition of the method of fixing can be evaluated in the following terms.

a) Evidence of passage of liquid through the system with the fixing system ineffective reflected by a localized fast drop in temperature.

b) Evidence of passage of cold vapour through the system with the fixing system effective.

c) No passage of vapour through the system and with the fixing system effective.

d) Evidence of material de-bonding

If the temperature criterion is met, then a specimen meeting criterion c) clearly provides a wider safety margin than a specimen meeting criterion a). A statement of the criterion that is most appropriate should be included in the report.

## 13.3 Factors affecting the validity of the test

### 13.3.1 General

During some tests there can be, for example, a failure of control, instrumentation or of a seal. These are failures of the test procedure and do not indicate a failure of the test specimen. The most common failures are considered in 13.3.2 and 13.3.3.

### 13.3.2 Failure at nozzle

It can happen that the cryogenic liquid release does not occur from the start of the test (e.g. failure of deflector arrangements). If visual confirmation of liquid release can be made from the temperature measurement as stated in Clause 9, including the time at which the liquid was present, the test may be considered valid.

### 13.3.3 Failure of thermocouples

Up to three thermocouples can fail (e.g. can be shown not to be measuring temperature with the required accuracy) during a test and the test still be considered valid provided that the thermocouple position(s) do not correspond to the area of greatest damage.

Failure of thermocouples directly underneath a joint as described in 6.3 will terminate the test if the largest temperature drop is shown along the line of the joint.