G3 Liquefied gas cargo and process piping

(1974) (Rev.1 1979) (Rev.2 1997) (Rev.3 Dec 2008 withdrawn) (Corr.1 Dec 2009 withdrawn) (Rev.4 Mar 2011) (Rev.5 Jan 2013) (Rev.6 Jan 2016) (Rev.7 Dec 2019) (Rev.8 Oct 2023)

G3.1 General

G3.1.1 The present texts give general principles for approval and survey of the relevant items of liquefied gas tankers for classification purposes. They do not intend to cover full details of such approval and survey procedures which are to be found in the rules of each Classification Society.

G3.1.2 Consideration of future technical advances may warrant modifications to the principles and details set forth in the text. IACS will accordingly review continuously these requirements.

G3.1.3 IGC Code means the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (as amended by IMO Resolutions MSC.370(93), MSC.411(97) and MSC.441(99)).

Note:

1. The requirements of G3.6 Rev.3 are to be uniformly implemented by IACS Societies for piping components and pumps:
   i) when an application for testing is dated on or after 1 July 2010; and
   ii) which are installed in new ships for which the date of contract for construction is on or after 1 July 2010.

2. The requirements of G3.6 Rev.4 are to be uniformly implemented by IACS Societies for piping components and pumps:
   i) when an application for testing is dated on or after 1 January 2012; and
   ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2012.

3. The requirements of G3.6 Rev.5 are to be uniformly implemented by IACS Societies for piping components and pumps:
   i) when an application for testing is dated on or after 1 January 2014; and
   ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2014.

4. The requirements of G3.6 Rev.6 are to be uniformly implemented by IACS Societies for piping components and pumps:
   i) when an application for testing is dated on or after 1 January 2017; and
   ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2017.

5. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.

6. Rev.7 of this UR is to be uniformly implemented by IACS Societies for piping components and pumps:
   i) when an application for testing is dated on or after 1 January 2021; or
   ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2021.

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7. Rev.8 of this UR is to be uniformly implemented by IACS Societies for piping components, cargo pumps and gas/reliquefication/refrigeration compressors:
i) when an application for prototype testing is dated on or after 1 January 2025; or
ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2025.

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G3.2 Scope

The requirements here below apply to liquefied gas cargo and process piping including cargo gas piping and exhaust lines of safety valves or similar piping.

G3.3 Scantlings for internal pressure

G3.3.1 Piping Scantlings

Piping systems are to be designed in accordance with recognized standards acceptable to the Classification Society.

G3.3.2 Design pressure

(a) The design pressure *P* in the formula in G3.3.4 (a) is the maximum pressure to which the system may be subjected in service.

(b) The greatest of the following design conditions is to be used for piping, piping systems and components, based on the cargoes being carried:

(i) for vapour piping systems or components which may be separated from their relief valves, and which may which contain some liquid, the saturated vapour pressure at 45°C, or higher or lower values, if agreed upon by the Classification Society, may be used (see 4.13.2.2 of the IGC Code).

(ii) for systems or components which may be separated from their relief valves and which contain only vapour at times, the superheated vapour pressure at 45°C or higher or lower values, if agreed upon by the Classification Society, may be used (see 4.13.2.2 of the IGC Code), assuming an initial condition of saturated vapour in the system operating pressure and temperature; or

(iii) design conditions defined in 5.4.2.3 to 5.4.2.5 of the IGC Code ~~(Resolution MSC.370(93))~~.

(c) The minimum design pressure is not to be less than the value defined in 5.4.1 of the IGC Code ~~(Resolution MSC.370(93))~~.

(d) The additional requirements regarding surge pressures defined in 5.4.3 of the IGC Code ~~(Resolution MSC.370(93))~~ are to be complied with.

(e) The design pressure of the outer pipe or duct of gas fuel systems are not to be less than the value defined in 5.4.4 of the IGC Code ~~(Resolution MSC.370(93))~~.

G3.3.3 Allowable stress

For pipes, the allowable stress K referred to in the formula in G3.3.4 (a) is the lower of the values defined in 5.11.3.1 of the IGC Code ~~(Resolution MSC.370(93))~~.

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G3.3.4 Minimum wall thickness

(a) The wall thickness of pipes is not to be less than that determined from the following formula:

$$t = (t_0 + b + c) \Big/ \left(1 - \frac{a}{100}\right)$$

where t = minimum thickness (mm)
t_0 = theoretical thickness (mm)
$t_0 = PD/(2Ke + P)$

P = design pressure (MPa)
D = outside diameter (mm)
K = allowable stress (N/mm^2) (see G3.3.3)
e = efficiency factor

(i) $e = 1$ for seamless pipes and for longitudinally or spirally welded pipes, delivered by manufactures approved for making welded pipes which are considered equivalent to seamless pipes when non-destructive testing on welds is carried out in accordance with the Rules of the Classification Society.

(ii) in other cases, an efficiency factor of less than 1.0 may be required by the Classification Society depending on the manufacturing process.

b = allowance for bending (mm). The value of b is to be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, b is to be determined from the following formula:

$$b = \frac{1}{2{,}5}\frac{D}{r}t_0$$

with r = mean radius of the bend (mm)

c = corrosion allowance (mm). When corrosion or erosion is expected, an increase in wall thickness of the piping is to be provided over that required by other design requirements.
This allowance is to be consistent with the expected life of the piping.

a = negative manufacturing tolerance for thickness (%).

(b) The minimum thickness is to be in accordance with recognized standards acceptable to the Classification Society.

(c) The additional requirements in 5.11.2.4 of the IGC Code ~~(Resolution MSC.370(93))~~ are to be complied with.

(d) In fuel gas piping systems of design pressure greater than the critical pressure, the tangential membrane stress of straight section of pipe or ducting shall be according to 5.11.4 of the IGC Code ~~(Resolution MSC.370(93))~~.

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G3.3.5 Flanges, valves, fittings etc.

(a) For selection of flanges, valves, fittings etc., a recognised Standard is to be used taking into account the design pressure defined under 5.4 of the IGC Code ~~(Resolution MSC.370(93))~~.

(b) For flanges not complying with a recognised standard, the dimension of flanges and relative bolts are to be to the satisfaction of the Classification Society.

(c) The design and installation of expansion bellows shall be in accordance with recognized standards acceptable to the Classification Society and to be fitted with means to prevent damage due to over-extension or compression.

G3.4 Stress analysis

G3.4.1 When design temperature is -110°C or lower, a complete stress analysis, taking into account all the stresses due to weight of pipes (including acceleration if significant), internal pressure, thermal contraction and loads induced by hog and sag of the ship for each branch of the piping system is to be submitted to the Classification Society. For temperatures above -110°C, stress analysis may be required in relation to design or stiffness of the piping system, choice of materials, etc; in any case, consideration is to be given by the designer to thermal stresses, even though calculations are not submitted.

G3.4.2 This analysis is to take into account the various loads such as pressure, weight of piping with insulation and internal medium, loads due to the contraction, for the various operating conditions. The analysis may be carried out according to the Rules of the Classification Society or to a recognised code of practice.

G3.5 Materials

G3.5.1 Choice and testing of materials used in piping systems are to comply with 5.12.1 and 5.12.2 of the IGC Code ~~(Resolution MSC.370(93), Corr.1)~~ and ~~with~~ W1 taking into account the minimum design temperature.

G3.5.2 For an outer pipe or duct equipped with mechanical exhaust ventilation having a capacity of at least 30 air changes per hour, the effects of both pressure and possible low temperature in the event of a high pressure line failure shall be taking into account

G3.5.3 Where the cargo piping system is of a material susceptible to stress corrosion cracking in the presence of a salt-laden atmosphere, requirements of 5.12.4 of the IGC Code ~~(Resolution MSC.370(93))~~ are to be complied with.

G3.6 Tests of piping components and pumps prior to installation on board

G3.6.1 Valves

G3.6.1.1 Prototype Testing

Each type of valve intended to be used at a working temperature below -55ºC shall be subject to the type tests defined in 5.13.1.1.1 to 5.13.1.1.3 of the IGC Code ~~(Resolution MSC.370(93))~~.

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For emergency shutdown valves, with materials having melting temperatures lower than 925°C, the type testing shall include a fire test to a standard acceptable to the Classification Society.

G3.6.1.2 Unit Production Testing

All valves are to be tested at the plant of manufacturer in the presence of the Society's representative. Testing is to include hydrostatic test of the valve body at a pressure equal to 1.5 times the design pressure for all valves, seat and stem leakage test at a pressure equal to 1.1 times the design pressure for valves other than safety valves. In addition, cryogenic testing consisting of valve operation and leakage verification for a minimum of 10% of each type and size of valve for valves other than safety valves intended to be used at a working temperature below -55°C. The set pressure of safety valves is to be tested at ambient temperature.

For valves used for isolation of instrumentation in piping not greater than 25mm, unit production testing need not be witnessed by the surveyor. Records of testing are to be available for review.

As an alternative to the above, if so requested by the relevant Manufacturer, the certification of a valve may be issued subject to the following:

- The valve has been approved as required by 3.6.1.1 for valves intended to be used at a working temperature below -55°C, and
- The manufacturer has a recognized quality system that has been assessed and certified by the Society subject to periodic audits, and
- The quality control plan contains a provision to subject each valve to a hydrostatic test of the valve body at a pressure equal to 1.5 times the design pressure for all valves and seat and stem leakage test at a pressure equal to 1.1 times the design pressure for valves other than safety valves. The set pressure of safety valves is to be tested at ambient temperature. The manufacturer is to maintain records of such tests, and
- Cryogenic testing consisting of valve operation and leakage verification for a minimum of 10% of each type and size of valve for valves other than safety valves intended to be used at a working temperature below -55°C in the presence of the Society's representative.

G3.6.2 Bellows

The prototype tests defined in 5.13.1.2.1 to 5.13.1.2.4 of the IGC Code ~~(Resolution MSC.370(93))~~ are to be performed on each type of expansion bellows intended for use on cargo piping outside the cargo tank and where required by the Administration or recognized organization acting on its behalf, on those installed within the cargo tanks.

G3.6.3 Cargo Pumps and Gas/Reliquefication/Refrigeration Compressors

Compressors and pumps are to be suitable for their intended purpose. All equipment and machinery are to be adequately designed to ensure suitability within a marine environment with due consideration to UR E10 and UR M46. Such items to be considered would include, but not be limited to:

(a) environmental;

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(b) shipboard vibrations and accelerations;

(c) effects of pitch, heave and roll motions, etc.; and

(d) physical and chemical properties of product

The manufacturer is to submit documentation indicating the equipment has been designed to comply with the above criteria.

G3.6.3.1 Cargo Pumps

Each size and type of pump is to be approved through design assessment and prototype testing. Prototype testing is to be witnessed in the presence of the Classification Society's representative.

For the design assessment of the pumps, ISO 13709:2009 and ISO 24490:2016, as applicable, can be used. Other applicable recognized standards acceptable to the Classification Society may be considered.

(a) Material Testing: Tests for pump materials need not be witnessed by the Classification Society's representative except for the boundary components, which are in direct contact with the medium and for a design temperature below – 55ºC in accordance with 6.2.2 of the IGC Code.

Note: The following pump components can, for example, be considered boundary components:

For centrifugal type pump: impeller, inducer, guide vane, casing, shaft and coupling.

For reciprocating type pump: cylinder cover, valve cover, cylinder liner, piston and piston rod, crankshaft, crank case.

(b) Prototype Testing: Prototype testing is to include hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. For submerged electric motor driven pumps, the capacity test is to be carried out with the design medium or with a medium below the minimum working temperature. For shaft driven deep well pumps, the capacity test may be carried out with water. In addition, for shaft driven deep well pumps, a spin test to demonstrate satisfactory operation of bearing clearances, wear rings and sealing arrangements is to be carried out at the minimum design temperature. The full length of shafting is not required for the spin test but must be of sufficient length to include at least one bearing and sealing arrangements. After completion of tests, the pump is to be opened out for examination.

The vibration criteria of machinery and equipment are to be provided by the pump manufacturer. These are to be compared against an applicable internationally recognised standard[1], as applied to the design, and are to be accepted by the Classification Society.

(c) Unit Production Testing

All pumps are to be tested at the plant of manufacturer in the presence of the Classification Society's representative. Testing is to include hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. For submerged electric

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motor driven pumps, the capacity test is to be carried out with the design medium or with a medium below the minimum working temperature. For shaft driven deep well pumps, the capacity test may be carried out with water.

As an alternative to the above, if so, requested by the relevant Manufacturer, the certification of a pump may be issued subject to the following:

- The pump has been approved as required by 3.6.3.1(a) and (b), and
- The manufacturer has a recognised quality system that has been assessed and certified by the Classification Society subject to periodic audits, and
- The quality control plan contains a provision to subject each pump to a hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. The manufacturer is to maintain records of such tests.

G3.6.3.2 Gas Cargo and Reliquefication/Refrigeration Compressors

Each size and type of compressor is to be approved through design assessment and prototype testing. Prototype testing is to be witnessed in the presence of the Classification Society's representative.

For the design assessment of the gas compressors, API standards. 617:2014 (w. Errata 1:2016), 618:2016 or 619:2010, as applicable, can be used. Other applicable recognized standards acceptable to the Classification Society may be considered.

(a) Material Testing: Tests for compressor materials need not be witnessed by the Classification Society's representative except for the boundary components, which are in direct contact with the medium and for a design temperature below – 55 ^{o}C in accordance with 6.2.2 of the IGC Code.

Note: The following compressor components can, for example, be considered boundary components:

For centrifugal type compressor: impeller, inducer, guide vane, casing, shaft and coupling.

For reciprocating type compressor: cylinder cover, valve cover, cylinder liner, piston and piston rod, crankshaft, crank case.

(b) Prototype Testing: Prototype testing is to be consistent with the applicable standard as applied for design assessment and is to include hydrostatic test of the compressor pressure boundary components, mechanical running test and a performance test. The hydrostatic test is to be carried out at a pressure equal to 1.5 times the design pressure (or 1.25 times the design pressure where the test fluid is compressible) and for, at least, 30 minutes. The mechanical running test and performance tests should include recording of the gas used, temperatures, pressures, testing of alarms and shut down, pressure relief devices and vibration measurements to ensure that the limits do not exceed those proposed by the manufacturer and that other features relating to the performance of the equipment are in accordance with the specification. Similarly, during the performance test, power consumption and the gas loads are to be recorded.

The vibration criteria of machinery and equipment are to be provided by manufacturers, consistent with the applicable recognized standard[1] as applied to the design. Otherwise,

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when the data on the vibration criteria are not available, justification is to be submitted for criteria used as reference in terms of overall Root Mean Square (RMS) vibrational velocity value for normal operation conditions.

Alternative limits, demonstrated by fatigue calculations, may be accepted by the Classification Society.

(c) Unit Production Testing: Each compressor is to be tested at the plant of manufacture in the presence of the Classification Society's representative. Testing is to include hydrostatic test of the compressor pressure boundary components. The hydrostatic test is to be carried out at a pressure equal to 1.5 times the design pressure (or 1.25 times the design pressure where the test fluid is compressible) and for, at least, 30 minutes.

As an alternative to the above, if so, requested by the relevant Manufacturer, the certification of a compressor may be issued subject to the following:

- The compressor has been approved as required by 3.6.3.2(a) and (b), and
- The manufacturer has a recognised quality system that has been assessed and certified by the Classification Society subject to periodic audits, and
- The quality control plan contains a provision to subject each compressor to the hydrostatic test of the compressor body equal to 1.5 times the design pressure (or 1.25 times the design pressure where the test fluid is compressible) for, at least, 30 minutes, and a mechanical running and performance test. The manufacturer is to maintain records of such tests.

(d) Installation: The complete compressor assembly connected to the vessel systems is to be subjected to a leak test using air or other suitable medium, to a pressure depending on the leak detection method applied. The test is to be performed in presence of the Classification Society's representative and considered satisfactory when no joint leaks are observed.

~~**G3.6.3.1 Prototype Testing**~~

~~Each size and type of pump is to be approved through design assessment and prototype testing. Prototype testing is to be witnessed in the presence of the Society's representative.~~

~~In lieu of prototype testing, satisfactory in-service experience, of an existing pump design approved by a Society submitted by the manufacturer may be considered.~~

~~Prototype testing is to include hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. For submerged electric motor driven pumps, the capacity test is to be carried out with the design medium or with a medium below the minimum working temperature. For shaft driven deep well pumps, the capacity test may be carried out with water. In addition, for shaft driven deep well pumps, a spin test to demonstrate satisfactory operation of bearing clearances, wear rings and sealing arrangements is to be carried out at the minimum design temperature. The full length of shafting is not required for the spin test, but must be of sufficient length to include at least one bearing and sealing arrangements. After completion of tests, the pump is to be opened out for examination.~~

~~**G3.6.3.2 Unit Production Testing**~~

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~~All pumps are to be tested at the plant of manufacturer in the presence of the Society's representative. Testing is to include hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. For submerged electric motor driven pumps, the capacity test is to be carried out with the design medium or with a medium below the minimum working temperature. For shaft driven deep well pumps, the capacity test may be carried out with water.~~

~~As an alternative to the above, if so requested by the relevant Manufacturer, the certification of a pump may be issued subject to the following:~~

- ~~The pump has been approved as required by 3.6.3.1, and~~
- ~~The manufacturer has a recognised quality system that has been assessed and certified by the Society subject to periodic audits, and~~
- ~~The quality control plan contains a provision to subject each pump to a hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. The manufacturer is to maintain records of such tests.~~

G3.7 Piping fabrication and joining details

G3.7.1 General

The requirements of this section apply to piping inside and outside the cargo tanks. However, the Classification Society may accept relaxations from these requirements for piping inside cargo tanks and open ended piping.

G3.7.2 Direct connection of pipe lengths (without flanges)

The types of connections defined in 5.8.2.1 to 5.8.2.3 of the IGC Code ~~(Resolution MSC.370(93))~~ may be considered.

G3.7.3 Flange connections

(a) Flanges are to be of the welding neck, slip-on or socket welding type.

(b) Flanges are to be selected as to type, made and tested in accordance with the Rules of the Classification Society. For all piping (except open end lines) the restrictions defined in 5.8.3.2.1 and 5.8.3.2.2 of the IGC Code ~~(Resolution MSC.370(93))~~ apply.

G3.7.4 Other types of pipes connections

Acceptance of types of piping connections other than those mentioned in G3.7.2 and G3.7.3 may be considered by the Classification Society in each particular case.

G3.7.5 Bellows and expansion joints

Where bellows and expansion joints are provided, requirements in 5.8.4 of the IGC Code ~~(Resolution MSC.370(93))~~ are to be complied with.

G3.7.6 Welding, post-weld heat treatments and non-destructive tests

(a) Welding is to be carried out in accordance with ~~W1~~ 5.9 of the IGC Code and requirements of the Classification Society.

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(b) Post-weld heat treatments are required for all butt welds of pipes made with carbon, carbon-manganese, and low alloy steels.

The Classification Society may waive the requirement for thermal stress relieving for pipes having a wall thickness less than 10 mm in relation to the design temperature and pressure of the concerned piping system.

(c) In addition to normal procedures before and during the welding and also visual inspection of the finished welds, as necessary for proving that the manufacture has been carried out in a correct way according to the requirements, the following inspections are required:

(i) 100% radiographic or ultrasonic inspection testing of butt-welded joints for piping systems with service temperatures lower than -10°C, and with inside diameters of more than 75 mm or wall thickness greater than 10 mm.

(ii) For butt welded joints of pipes not included in (i), spot radiographic controls or other non-destructive controls are to be carried out at the discretion of the Classification Society depending upon service, position and materials. In general, at least 10% of butt welded joints of pipe are to be subjected to radiographic or ultrasonic inspection.

G3.8 Tests onboard

G3.8.1 General

The requirements of this section apply to piping inside and outside the cargo tanks.

G3.8.2 Pressure tests (strength and leak test)

(a) After assembly, all cargo and process piping should be subjected to a strength test with a suitable fluid in accordance with 5.13.2.2 of the IGC Code ~~(Resolution MSC.370(93))~~.

(b) The additional requirements regarding leak tests defined in 5.13.2.3 of the IGC Code ~~(Resolution MSC.370(93))~~ are to be complied with.

(c) The additional requirements regarding double wall gas-fuel piping system defined in 5.13.2.4 of the IGC Code ~~(Resolution MSC.370(93))~~ are to be complied with.

G3.8.3 Functional tests

All piping systems including all valves, fittings and associated equipment for handling cargo or vapours are to be tested under normal operating conditions not later than at the first loading operation, in accordance with recognized standards acceptable to the Classification Society.

G3.9 Cargo piping insulation system

G3.9.1 Requirements regarding cargo piping insulation in 5.12.3.1 and 5.12.3.2 of the IGC Code ~~(Resolution MSC.370(93))~~ are to be complied with.

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1. The following standards can be used as guidance:

   - ISO 7919-3:2009/AMD 1:2017, Mechanical vibration - Evaluation of machine vibration by measurements on rotating shafts – Part3 Coupled industrial machines

   - ISO 10816-3:2009/AMD 1: 2017, Evaluation of machine vibration by measurements on non-rotating parts — Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ.

   - ISO 10816-7:2009, Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 7: Rotodynamic pumps for industrial applications, including measurements on rotating shafts

   - ISO 10816-8:2014, Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 8: Reciprocating compressor systems

   - ISO 20816-1:2016, Mechanical vibration - Measurement and evaluation of machine vibration – Part 1: General Guidelines

   - ISO 20816-8:2018, Mechanical vibration - Measurement and evaluation of machine vibration - Part 8: Reciprocating compressor systems.

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