Guideline No. T-12(202502)

T-12

Natural Gas/Ammonia Compressor

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Foreword

The product inspection guideline of China Classification Society (hereinafter referred to as "CCS") specifies the applicable technical requirements and inspection and test requirements for classification products and authorized statutory products of ships to be approved/inspected by CCS.

The Guidelines allow users to adopt alternative test methods and requirements, provided they meet or exceed the standards set by the Guidelines.

The Guidelines are prepared and updated by CCS and published on http://www.ccs.org.cn. In case of any comments and suggestions, please contact CCS via service@ccs.org.cn.

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Main modifications in this version: None

Contents

Natural Gas/Ammonia Compressor

1 Scope of Application

1.1 This chapter is applicable to the product survey of centrifugal, screw and reciprocating combustible gas compressors for natural gas/ammonia carriers and natural gas/ammonia-powered ships, including boiled-off gas (BOG) compressor, cargo compressor, return air compressors and fuel gas compressor.

1.2 Compressors for similar purposes on other ships may also refer to the relevant requirements of the Guidelines.

2 Normative References

2.1 Chapters 5, 6 and 16 of Part 3 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk

2.2 Chapters 3, 6 and 12 of CCS Rules for Natural Gas Fuel Used in Ships

2.3 Chapter 2 of Part 3 of the CCS Rules for Classification of Sea-going Steel Ships and its Amendment Notification

2.4 CCS also accepts other recognized compressor standards as the survey basis, provided that the requirements are not less stringent than those of CCS. For example,

(1) API 617 Axial and Centrifugal Compressors and Expander-Compressors for Petroleum, Pretrochemical and Natural Gas Industries

(2) API 618 Reciprocating Compressors for Petroleum, Pretrochemical and Natural Gas Industries

(3) ISO 13707 Petroleum and Natural Gas Industries - Reciprocating Compressors

(4) API 619 Rotary-type Positive Displacement Compressors for Petroleum, Pretrochemical and Natural Gas Industries (5)GBT

25357 Petroleum, Petrochemical and Natural Gas Industries - Process Positive-displacement Rotary-type Compressors (ISO10440-1)

3 Terms and Definitions

3.1 Maximum allowable working pressure: the maximum continuous pressure at which the equipment (or any part involved in this term) has been designed by the manufacturer to deliver the specified fluid at the specified maximum working temperature.

3.2 Pressure casing: combination of all static pressure parts of the unit, including all nozzles and other auxiliary parts.

3.3 Stability Analysis: using a complex-valued analysis to determine the natural frequencies and corresponding logarithmic decrements of a damped rotor/support system.

3.4 Shaft-end seal: a process gas seal at the end of the shaft to limit leakage of process gas to the atmosphere.

4 Drawings and Data

4.1 The following drawings and data shall be submitted for review:

(1) Technical performance specification or data sheet: including medium, inlet and outlet design pressure, inlet and outlet working temperature, flow, shaft power, speed range, etc.; auxiliary system parameters (power, seal gas, instrument air source, lubricating oil, cooling water, steam, etc.); impeller parameters, shaft end seal, gearbox, etc.;

(2) General assembly drawing and sectional drawings;

(3) Drawings of important parts, pressure casing, crankshaft, impeller and screw;

(4) Drawings of control, lubrication, cooling, gas circuit, sealing and safety alarm systems;

(5) Attached piping, coolers, separators, safety valves, etc., if applicable;

(6)Technical conditions and survey outline;

(7) Specifications for physical and chemical properties of materials of important parts, and technical requirements for non-destructive testing and trimming;

(8) Driver and transmission mechanism;

(9) Piston, piston rod, connecting rod, crosshead, cylinder, cylinder head and air valve; coupling, nozzle, diffuser, bend, return channel, volute chamber; gear, rolling bearing, shaft end seal, etc. (when applicable).

(10) Design calculations, such as structural strength calculation, torsional vibration calculation, vibration analysis, level I stability analysis, level II stability analysis and safety valve calculation (if applicable);

(11) Quality control plan, including survey points and survey methods;

(12) Welding procedure specification approved by CCS (if applicable);

(13) Product instructions;

(14) Nameplate.

(15) Other drawings that CCS considers necessary to be supplemented according to specific compressors.

4.2 Approved drawings/materials shall at least include the following contents:

(1) Factory overview: factory name, address, production history, production capacity, technical and inspection personnel, main products, affiliation, product trademarks, etc.;

(2) Details of the product to be approved;

(3) List of main production equipment;

(4) List of main testing equipment;

(5) Brief production process of the product to be approved;

(6) Quality management documents or quality system certificates;

(7) Enterprise registration certificate;

(8) Qualification certificate and/or production license, if applicable;

(9) Product quality certificate or sample of certificate;

(10) Quality control plan, if applicable;

(11) List of qualified suppliers, if applicable;

5 Technical Requirements

5.1 The compressor and its auxiliary equipment can generally be designed with reference to recognized standards.

5.2 General technical requirements

5.2.1 The compressor shall be suitable for its intended use and all equipment and machinery shall ensure their suitability in a marine environment. Factors to be considered include, but are not limited to:

(1) Environmental factors;

(2) Ship vibration and acceleration;

(3) The influence of pitch, heave and roll motions of the ship;

(4) Gas composition.

5.2.2 The compressor shall be equipped with accessories and instruments required for effective and reliable operation, and at least 1 local display pressure

gauge shall be installed on the outlet pipeline of each compressor.

5.2.3 The prime mover of the compressor supplying gaseous fuel shall be adjustable to maintain a positive suction pressure, and automatically shut down when the compressor suction pressure is lower than 3.5 kPa or other allowable pressure suitable for the liquid cargo hold system. Valves shall be installed at the inlet and outlet of the compressor to cut off gas fuel.

5.2.4 The compressor startup control in the fuel preparation room shall be interlocked, and the compressor can only be started after the ventilation system runs for 10 min.

5.2.5 The compressor for the gas supply system shall also be arranged with local manual emergency cut-off.

5.2.6 If the compressor is driven by a shaft that passing through a bulkhead or deck, then the bulkhead transits are to be gas-tight. The bulkhead shaft stuffing box and bearings are to be temperature monitored.

5.2.7 If necessary, the compressor unit shall be equipped with control devices for gas pressure and flow.

5.2.8 If a separator or purifier is arranged at the compressor inlet or between stages, a sewage drain port and a high liquid level alarm shall be set to prevent liquid from entering the compressor.

5.2.9 The control and safety alarm equipment shall meet the requirements for environmental conditions of marine electrical equipment. The compressor shall be provided with the following security measures:

Compressor Security Items **Table 5.2.9**

Alarm and Shutdown Items	Compressor supplying gaseous fuels	Boiled-off gas (BOG) compressor
Alarm and shutdown for high bearing temperature	X	X
Alarm and shutdown for low lubricating oil pressure	X	X

Low lubricating oil level alarm	X	X
Alarm and shutdown for high discharge temperature	X	X
Low intake pressure alarm	X	-
Low discharge pressure alarm	X	-
High discharge pressure alarm	X	-
Compressor operation fault alarm	X	X

Note: Mark "X" for applicable and "-" for not applicable.

5.2.10 The raw materials used for the compressor shall be of corresponding grades according to the medium temperature, and API617, API618, API619 or other recognized standards approved by CCS may be referred to. The material performance shall meet the requirements of Rules for Materials and Welding of CCS or national standards, ISO, ASTM, ANSI, ASME or SAE approved by CCS. For compressors used for ammonia medium, the corrosivity of ammonia shall be considered. Materials susceptible to ammonia corrosion such as copper, copper-containing alloys, zinc, zinc-containing alloys, and those containing cadmium and mercury shall not be used in pipelines, valves, accessories and other equipment in contact with ammonia. For non-metallic materials, the suitability of ammonia in different states shall be considered.

5.2.11 The raw materials of all important parts shall be tested for mechanical properties and chemical composition, and radiographic inspection, ultrasonic inspection, magnetic particle inspection and penetrant inspection shall be carried out as required. Detailed technical requirements for flaw detection shall be formulated to clarify the scope, standards and qualification criteria of flaw detection. Residual magnetism shall be eliminated after magnetic particle inspection. Defects such as cracks and cold shut are not allowed, and the allowable range of minor defects shall be limited. Mechanical methods such as grinding, shoveling and turning are allowed to trim the defects. Trims shall have rounded transitions and be sharpened. When the adopted standard does not specify the requirements for part flaw detection, refer to Table 5.2.11.

Nondestructive Testing of Important Parts **Table 5.2.11**

Part Name	Testing Method			
	Magnetic	Radiography/RT	Ultrasonic/UT①	Dye penetrant/PT②
Crankshaft	X	-	X	-
Connecting rod	X	-	X	-
Crosshead pin	X	-	X	-
Piston rod	X	-	X	X④
Big-end bolt	X	-	X	-
Connecting bolt between piston rod	X	-	X	-
Cast compressor casing	X	X③	Or X③	Or X
Compressor casing assembled by	X	X	X	Or X
Compressor inner casing	X	X	Or X	Or X
Butt weld of compressor casing	X	X	Or X	Or X
Fillet weld of compressor casing	X	-	-	Or X
Interstage partition	X	-	-	Or X
Shaft	X	-	X	Or X
Impeller	X	X	Or X	Or X
Shaft sleeve and balance disk	X	-	-	Or X
Screw	X	-	X	Or X
Gear	X	-	X	Or X

Note: ① "Or" means that radiographic testing may be substituted for ultrasonic testing;

② "Or" means that magnetic particle testing may be substituted for dye penetrant inspection;

③ Applicable to steel castings;

④ Applicable to non-magnetic materials;

Mark “X” for applicable and “-” for not applicable.

5.2.12 The welding, heat treatment and nondestructive testing of compressor parts shall meet the requirements of CCS.

5.2.13 Hydrostatic test and air tightness test shall be carried out for pressure parts. The hydrostatic test pressure is 1.5 times of the maximum allowable working pressure, and the air tightness test pressure is the maximum allowable operating pressure.

5.2.14 Pipelines, pipeline accessories, pressure vessels and coolers shall meet the requirements of corresponding chapters in specifications of CCS. A nitrogen purge

pipeline connection shall be provided to allow inerting of the compressor.

5.3 Technical requirements for reciprocating compressor

5.3.1 Each stage of reciprocating compressor shall be equipped with pressure gauge and safety valve. The released gas shall be vented to the suction or discharge pipeline of the compressor. The safety valve shall be set to operate at a pressure not greater than the maximum allowable operating pressure, but not less than that specified in Table 5.3.1.

Setting Values of Safety Valve **Table 5.3.1**

Rated discharge pressure (G) (each stage)		Minimum safety valve set pressure margin above rated discharge pressure (G)
bar	psig	
≤10	≤150	1 bar (15 psig)
>10 to 170	>150 to 2,500	10%
>170 to 240	>2,500 to 3,500	8%
>240 to 345	>3,500 to 5,000	6%
>345	>5000	See footnote a
a For discharge gauge pressure above 345 bar (5,000 psig), safety valve settings shall be agreed upon by the purchaser and the vendor.		

5.3.2 In general, alarm and shutdown device for high discharge temperature shall be provided.

5.3.3 The maximum allowable operating pressure of the cylinder shall be at least equal to the specified setting pressure of the safety valve. If the set pressure is not specified, the maximum allowable operating pressure of the cylinder shall exceed the maximum discharge gauge pressure by at least 10% or 1.7 bar, whichever is greater.

5.3.4 Crankshaft strength shall be designed to meet the requirements of recognized design specifications.

5.3.5 The crankcase of natural gas/ammonia compressor shall be airtight, and a safety valve shall be set in the partition chamber or crankcase.

5.3.6 For compressors above 150 kW, the crankshaft and connecting rod shall be forged. For compressors equal to or less than 150 kW, nodular cast iron can be used for the crankshaft.

5.4 Technical requirements for centrifugal compressor

5.4.1 The compressor shall be designed to operate without danger at trip speed and maximum allowable operating pressure.

5.4.2 If the compressor has adjustable inlet guide vanes, there shall be a vane control system consisting of valve positioners with a local position indicator and other components as specified. The design of the vanes shall make the vanes tend to open when the control signal is lost.

5.4.3 There shall be monitoring alarms for the temperature and pressure of the inlet and outlet medium at each stage of compressor, the pressure of the medium before and after the cooler and the outlet medium temperature, the pressure of seal gas, the liquid level, pressure and temperature of lubricating oil, the difference in pressure before and after the filter, gearbox shaft temperature, radial vibration and axial displacement of high-speed shaft, bulkhead sealing temperature and sealing oil pressure, motor bearing temperature, winding temperature, etc. Process valves and actuators shall be provided with corresponding position indication.

5.4.4 Carbon steel and low alloy steel for all cryogenic pressure parts of the compressor, including nozzles, flanges and weldments, shall be subject to impact tests according to the requirements of corresponding standards.

5.4.5 The pressure parts of the compressor shall be welded in full penetration. Connections welded to the casing shall comply with the requirements of the casing, including impact values.

5.4.6 The compressor casing shall be made of steel or alloy approved by CCS. The maximum allowable operating pressure of the casing shall be at least equal to the specified setting pressure of the safety valve. When the setting pressure of the safety valve is not specified, the maximum allowable operating pressure of the casing shall be at least 1.25 times the maximum specified discharge pressure (gauge

pressure).

5.4.7 All natural gas/ammonia nozzles on the compressor that are connected to the casing shall be flanged or connected by pillar (stud) bolts on the machined plane. The design pressure of this nozzle shall be greater than or equal to the maximum allowable operating pressure.

5.4.8 Alarm and shutdown device for radial vibration and shaft displacement shall be considered for the high-speed shaft of compressor. The rotor shaft sensing part detected by the radial vibration sensor shall be concentric with the bearing journal. The sensor shall be calibrated before installation.

5.4.9 Each impeller of the compressor shall be subject to an overspeed test at least 1 min at 115% of the maximum continuous speed . After the overspeed test of the impeller, magnetic particle or dye penetrant inspection shall be carried out comprehensively.

5.4.10 The compressor dynamic analysis shall meet the requirements of recognized design specifications.

5.4.11 The suction side of the compressor shall be provided with 1 suction filter to protect the compressor impeller.

5.5 Technical requirements for screw compressor

5.5.1 The compressor shall be provided with a safety valve after each stage of compression, and the action shall be sensitive and reliable. The opening pressure of the interstage safety valve shall be no more than 1.2 times the maximum operating pressure of the stage, and the opening pressure of the last stage safety valve shall be no more than 1.1 times the rated discharge pressure.

5.5.2 The maximum continuous speed of the compressor driven by a variable frequency motor shall not be less than 105% of the rated speed, and the trip speed of the motor shall not be less than 110% of the maximum continuous speed. The maximum continuous speed of the compressor driven by an industrial frequency motor shall be equal to the rated speed.

5.5.3 For other requirements, refer to the applicable parts of "Technical requirements for centrifugal compressor", such as 5.4.4~5.4.8, 5.4.10 and 5.4.11.

6 Raw Materials, Parts and Components

6.1 The raw materials and parts of a product shall be controlled according to the relevant requirements of the current specifications and technical documents of CCS.

6.2 Components for which CCS product certificate is required or those shall undergo relevant survey include the motor (power greater than 50 kW), cryogenic valve (working temperature ≤-55°C), compressor electrical control box, pipes, forgings, castings and accessories (elbows, tees, nipples, reducers, etc.) used for natural gas piping with design temperature ≤0°C

6.3 Components for which CCS approval certificate is required include temperature sensors, pressure sensors and motors (power less than 50 kW) related to the gas control system and gas safety system

6.4 For pipe fittings, castings and forgings for which certificates are required, if there is no certificate, the materials can be re-surveyed.

7 Type Test

7.1 Selection of typical samples

During approve, the selected compressor shall cover the processing capacity and manufacturing level of the factory. The test prototype shall be selected according to the cooling mode of the series products applied for approval and the principle of maximum volume flow under rated discharge pressure.

7.2 See Table 7.2 for the type test items of the compressor

Type Test Items Table 7.2

Test Items	Reciprocating	Centrifugal	Screw
Mechanical property test of raw materials for important parts	X	X	X

Nondestructive testing of important parts	X	X	X
Pressure test of pressure parts	X	X	X
Impeller overspeed test	-	X	-
Rotor dynamic balance test	-	X	X
Visual inspection of the whole machine	X	X	X
Air tightness test of complete machine	X	X	X
Safety valve adjustment test (if applicable)	X	X	X
Mechanical operation test	X	X	X
Performance test	X	X	X
Noise test	-	X	X
Vibration test	-	X	X
Low-temperature operation test	X	X	X
Suction and discharge valve leakage test for the cylinder	X	-	-
Automatic control and safety alarm device test (if applicable)	X	X	X
Overhaul	X	X	X

Notes:① Important parts: For a reciprocating compressor, they are the crankshaft, connecting rod, cylinder and cylinder head, crosshead, piston, piston rod, air valve body and pressure parts。 For a centrifugal compressor, they are the casing, impeller, shaft, inlet guide vane and diffuser vane.For a screw compressor, they are the rotor, machine body, suction and discharge end cover, speed increasing gear and synchronous gear. Material test and nondestructive inspection shall be carried out according to the requirements of approved drawings.

② Air tightness test of complete machine e, impeller overspeed test, rotor dynamic balance test, mechanical operation test and performance test can be carried out in accordance with recognized standards.

③ The performance test of centrifugal compressor shall be carried out in accordance with ASME PTC 10-1997, IS0 5389 or other nationally recognized standards. The performance test of reciprocating compressor shall be carried out in accordance with ISO1217 or applicable ASME power test codes or other nationally recognized standards.

④ Overhaul scope: For a reciprocating compressor, the moving parts of at least one cylinder bank shall be inspected, including cylinder liner, cylinder head, air valve,

piston, piston rod, bearing, etc. For a centrifugal compressor, check all bearings and shaft end seals, impellers and labyrinths, gearboxes, etc. For a screw compressor, check the screw and gearbox.

⑤ The noise test can be carried out with reference to ISO1996 or other nationally recognized standards.

⑥ The vibration test can be carried out according to ISO10816, ISO20816 or other nationally recognized standards.

⑦ Mark "X" for applicable and "-" for not applicable.

⑧ Compressors with working medium temperature lower than -55°C shall be subject to low-temperature operation test.

In principle, the low-temperature operation test shall be carried out at the minimum working temperature, rated speed and rated flow. However, centrifugal compressors may be tested in accordance with the following requirements due to limitations of test stand or safety conditions.

The inlet temperature of the compressor reaches the minimum working temperature, the rotation speed is 20%~40% of the rated rotation speed, and the compressor runs at the minimum IGV opening for at least 30 minutes. During operation, the compressor vibration, shaft temperature and sound are normal. When the compressor stops at low temperature, IGV drive is flexible without jamming. After low-temperature operation, the compressor shall be disassembled for inspection. The impeller, casing, front labyrinth and other parts shall be inspected, and fasteners shall be free of looseness.

7.3 Determination and exemption of test items

Generally, all test items shall be performed during initial approval. If the following conditions are met, the applicant may apply in writing for exemption of some test items. CCS will consider it according to the production situation of the applicant, the production history and use records of the product.

(1) The applicant shall provide the recent (within one year) test report of corresponding test items issued by a recognized technical authority;

(2) The applicant shall provide (within one year) the test report of corresponding test items signed by IACS member classification societies;

(3) Long-term use experience has proved that it is safe and reliable.

8 Unit/Batch Inspection

8.1 After obtaining the approval of CCS, the compressor shall be surveyed by CCS for single piece/single batch before shipment for use. The surveyor shall survey the products applied for survey one by one, and issue the product certificate if they are qualified.

8.2 Refer to Table 8.2 for single piece/single batch test items of the compressor

Delivery Test Items **Table 8.2**

Test Items	Reciprocating Compressor	Centrifugal Compressor	Screw Compressor
Important parts certificates and material test	X	X	X
Nondestructive testing of important parts	X	X	X
Pressure test of pressure parts	X	X	X
Impeller overspeed test	-	X	-
Rotor dynamic balance test	-	X	X
Visual inspection of the whole machine	X	X	X
Air tightness test of complete machine	X	X	X
Safety valve adjustment test (if applicable)	X	X	X
Mechanical operation test	X	X	X
Performance test	X	X	X
Low-temperature operation test Note 1	X	X	X
Suction and discharge valve leakage test for the cylinder	X	-	-
Automatic control and safety alarm device test (if applicable)	X	X	X
Overhaul	X	X	X

Note: ① Mark "X" for applicable and "-" for not applicable.

② If there is a rich application experience on board and a mature and reliable equivalent program, the low-temperature operation test can be exempted.

8.3 After the survey is completed, the records or reports to be submitted by the manufacturer shall at least include the following:

(1) Certificates of raw materials and parts;

(2) Material test report, nondestructive inspection report, pressure test report and air tightness test report;

(3) Operation test records;

(4) Function test and safety valve adjustment records;

(5) List of test equipment and inspection equipment used.