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M-03 HEAT EXCHANGERS

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Foreword:

This Guide is a part of CCS Rules, which contains technical requirements, inspection and testing criteria related to classification and statutory survey of marine products.

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1 Application

1.1 This Guideline applies to approval and inspection of marine heat exchangers, including shell and tube heat exchangers (such as coolers, condensers, heaters and evaporators), finned-tube heat exchangers (such as air coolers), plate heat exchangers (with plates, finned-plates, etc); design pressure is not more than 2.5 MPa and medium temperature not more than 250℃. For other types of heat exchangers, reference may be made to in this Guideline.

2 Normative references

2.1 CCS Rules for Classification of Sea-going Steel Ships.
2.2 CCS Rules for Materials and Welding.

3 Terms and definitions

3.1 Related definitions in CCS Rules for Classification of Sea-going Steel Ships are applicable to this Guideline.
3.2 Heat exchange surface area is the total surface area of metal cooled, heated or contacted by condensing medium.

4 Plans and documents

4.1 When products are applied for approval, the following plans and technical documents are to be submitted to CCS for approval:
(1) Main performance specifications (including heat exchange surface area, design/working pressure, design/working temperature and working medium of the entire series of products to be approved);
(2) General assembly;
(3) Drawings of main components and parts (shells, tube plates, end plates, bundles of tube, heat exchange plates, clamping plates, clamping bolts, etc.);
(4) List of physical and chemical properties of main components and parts;
(5) Calculations of heat exchange surface area, strength of pressure-containing parts;
(6) Type test program.

4.2 The following plans/technical documents are to be submitted to CCS for information:
(1) Technical standards applicable to the products;
(2) Performance test report for the product manufactured for the first time (if any);
(3) Product instructions;

(4) Specimens of product nameplates and manufacturer's quality certificate etc.;
(5) Main workmanship documents, such as welding procedure of shells and connection technology of tube plates.
4.3 For manufacturers applying for CCS type approval B, the following documents are additionally to be submitted:
(1) Particulars of the manufacturer (including history and current situation) and description of production history. If the products have been specifically verified or appraised, related reports and certificates may be attached;
(2) A quality control plan for the products to be approved is to be developed by the manufacturer and submitted to CCS for approval. This quality control plan is to specify the quality assurance and control methods used in the manufacturing process according to the technical requirements or standards for the products. The quality control plan is to include an inspection plan after approval, and to reflect in particular the inspection and test requirements of CCS.
4.4 For manufacturers applying for CCS type approval A, a whole set of quality management system documents covering the products to be approved and complying with ISO 9000 standard or an equivalent standard is additionally to be submitted, of which the workmanship documents of inspections and tests according to requirements of CCS rules are to be approved by CCS.

5 Materials and components

5.1 Materials and components mainly include shells, tube plates, end plates, bundles of tube, heat exchange plates, clamping plates, clamping bolts and spool pipes, etc.
5.2 For pressure-containing parts such as shells, end plates, bundles of tube, 100% hydraulic test is required before being assembled.
5.3 If the components and parts referred to in 5.1 are purchased, the applicant must establish perfect means to control subcontractors for ensuring the quality of such parts and must provide material quality certificates.

6 Qualification of welding procedures

6.1 If the shells of heat exchangers are of welded construction, the welding procedure is to be evaluated and approved according to the relevant requirements of CCS Rules for Materials and Welding.

7 Design and technical requirements

7.1 Material requirements
7.1.1 The materials of main components and parts of marine heat exchangers are to be selected for the type, temperature and pressure of working medium.
7.1.2 For the steel plates used in manufacturing heat exchangers of a marine refrigerating plant,

the lower limit of calibrated tensile strength is not to exceed 430 MPa.

7.1.3 The heat exchange tubes in contact with seawater are not to be made of red copper.

7.1.4 The thickness of copper layer of processed clad interface of copper/steel clap plates is not to be less than 3 mm. Ultrasonic testing is to be carried out to inspect the clad quality. See Section 9, Guideline 3, PART ONE of CCS Rules for Materials and Welding for relevant requirements.

7.1.5 The Ω-shaped expansion joint of shell and tube heat exchangers are usually made of bent seamless steel tubes. The Ω-shaped expansion joint is to have an opening of more than 15 mm and a height more than 1.6 R. The wall thickness of seamless tubes is not to be less than minimum thickness obtained by shell strength calculation (R being external radius of seamless tubes).

7.1.6 The nominal plate thickness of plate heat exchangers is not to be less than 0.5 mm. The thickness reduction in plate molding is not to exceed 25% of plate thickness.

7.1.7 The sealing materials are to be selected for the type, temperature, pressure of working medium and the environmental protection requirements. The gasket thickness of plate heat exchangers is to have positive tolerance, as shown in Table 7.1.7:

Tolerance of Gasket Thickness Table 7.1.7

Nominal heat exchange surface area of single plate, in m^2	**≤0.3**	**>0.3~1.0**	**>1.0**
Tolerance of gasket thickness, in mm	+0.1 0	+0.2 0	+0.3 0

7.1.8 The deviation of plate corrugation depth and gasket slot depth is given in Table 7.1.8.

Deviation of Corrugation Depth, Gasket Slot Depth Table 7.1.8

Depth deviation, in mm	**Nominal heat exchange surface area of single plate, in m^2**		
	≤0.3	>0.3~1.0	>1.0
Corrugation	±0.1	±0.15	±0.20
Gasket slot			

7.1.9 The fin of air coolers is to be of disturbing construction with a thickness of 0.15 ~ 0.2 mm to intensify heat transfer.

7.1.10 The heat exchange tube is to be tested as follows:

(1) Flattening test: the tube is to be flattened till the interior surfaces of the tube contact each other without damage and crack.

(2) Expanding test: the end of the tube is to be expanded with a punch having an angle of 45° to increase its outside diameter by 30% without damage and crack.

(3) Tensile test: the test is to be carried out on a universal material test machine according to the requirements not inferior to material standards.

7.2 Requirements for manufacturing

7.2.1 For shell heat exchangers, the clearance between the cylindrical shell inside wall and the baffle is not to be more than that specified in the following Table.

Clearance between Cylindrical Shell Inside Wall and Baffle Table 7.2.1

Cylindrical shell inside diameter	Fit clearance, in mm
<150	1.8
≥150~800	2.6
>800	3.6

7.2.2 The number of bolts joining the tube plate and cylindrical shell flange is not to exceed half of the total number of bolts.

7.2.3 The steel balls with diameters specified in Table 7.2.3 are to be capable of smoothly passing finished U-tubes and coil tubes.

Ball Diameter Table 7.2.3

r/d bending radius/tube diameter	Ball diameter		r/d bending radius/tube diameter	Ball diameter	
	Without connector	With connector		Without connector	With connector
2~3.5	0.70d	0.65d	>5~10	0.85d	0.80d
>3.5~5	0.75d	0.70d	>10	0.90d	0.85d

7.2.4 If the heat exchange tube and tube plate are joined by expansion, the minimum size of tube bridge of tube plate hole is to be greater than 3 times wall thickness of the tube.

7.2.5 The roughness of tube plate hole is to be up to 6.3μm. The expansion joint length of heat exchange tube and tube plate is not to exceed 90% of thickness of tube plate. The reduction of wall thickness of joined heat exchange tube and tube plate is to be calculated as follows and the value obtained is not to exceed 12%:

$$q = (t_0 - t_1)/ t_0 \times 100\%$$

where: q —— wall thickness reduction, in %;

t_0—— wall thickness of heat exchange tube and tube plate before joining, in mm;

t_1—— wall thickness of heat exchange tube and tube plate after joining, in mm.

7.2.6 Zinc cure is to be provided if the end cover of heat exchanger is in contact with seawater.

7.2.7 The joint of air cooler fin and heat exchange tube is to be firm and close. The joint perimeter is not to be less than 85% of the total perimeter of tube hole.

7.2.8 The joint of air cooler heat exchange tube and tube plate is to be firm and reliable.

7.3 Strength requirements

7.31 The strength of pressure-containing parts (shell, tube plate, end cover and heat exchange tube, etc) is to be calculated according to relevant requirements in Guideline 6, PART THREE of CCS Rules for Classification of Sea-going Steel Ships. The strength of pressure-containing parts of the heat exchanger of a refrigeration system is also to comply with the requirements in Section 3, Guideline 2, PART FIVE of CCS Rules for Classification of Sea-going Steel Ships.

7.3.2 The strength of spool pipe of heat exchanger shell is to be calculated according to relevant requirements in Guideline 2, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

7.3.3 The joint type of welded flange of heat exchanger shell is to comply with the relevant

requirements in Guideline 2, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

7.3.4 The hole and strengthening of heat exchanger shell is to be calculated according to relevant requirements in Guideline 6, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

7.3.5 The minimum thickness of heat exchanger tube plate is not to be less than 14 mm.

7.3.6 For threaded tubes (integral low ribbed tubes usually used for lubricating oil coolers), the outside diameter of outside ribbed wall is not to be more than the outside diameter of smooth portions at both ends. The minimum wall thickness of finished integral threaded tubes is to comply with the requirements of 7.3.1.

7.4 Pressure testing requirements

7.4.1 Main pressure-containing parts including shell, end cover and bundle of tube of heat exchanger are to be subjected to hydraulic test separately or as an assembled unit.

7.4.2 Both sides of assembled heat exchangers are to be hydraulically tested to 1.5 times the design pressure but not less than 0.4 MPa (except the air side of air cooler).

8 Type test

8.1 Selection of typical samples

8.1.1 When applying for approval for the first time, the heat exchangers selected are to cover the manufacturer's processing ability and manufacturing level. Usually 1~2 heat exchangers are to be selected from each product series to be approved, according to maximum working pressure, maximum heat exchange surface area and medium value of working pressure/heat exchange surface area. If the product series has a narrow performance scope, either one with maximum working pressure and one with maximum heat exchange surface area or a single one with maximum working pressure may be selected.

8.1.2 When renewing the approval, only one type which is the most representative or the most demanded in market may be selected from each product series.

8.1.3 In order to ensure that approved products meet prospective operating requirements, the manufacturer is responsible for carrying out thermal performance test and fluid resistance test or function test and ensuring satisfactory results.

8.2 Type test items are to include:

(1) tests of chemical composition and mechanical properties of materials of main parts such as heat exchange tube/plate, tube plate, shell ,end plate, clamping bolts and clamping plates ;

(2) inspection of heat exchange tubes;

(3) inspection of heat exchange plates;

(4) hydraulic test of main pressure-containing parts such as shell, end plate and bundle of tube;

(5) vibration test (only for air cooler);

(6) non-destructive test (shell, finished heat exchange plate);

(7) whole set pressure test;

(8) welding procedure testing;

(9) other type test items required by CCS plan examination department for special type heat exchangers.

8.3 Testing conditions are to be in accordance with the following requirements:

(1) CCS Surveyor is to check the manufacturer's test laboratory/test bench used as approval test location and confirm compliance with the requirements of 8.3(2). Otherwise, all tests are to be carried out at certification and test organizations recognized by CCS.

(2) Measuring instruments/meters used in the tests are to have valid calibration certificates. The precision of pressure gauges is not to be less than 1.6%.

8.4 Testing methods and requirements are as follows.

(1) Test of physical and chemical properties of raw materials of main components and parts is to be in accordance with the following requirements:

① tests of physical and chemical properties of raw materials are to be carried out for main components such as heat exchanger shell, end cover, heat exchange tube/plate, tube plate, clamping bolts and clamping plates, except for those purchased raw materials or castings furnished with CCS product certificates;

② where appropriate, castings are to be sampled and sealed at the casting manufacturer supplying the applicant, in the presence of CCS Surveyor. If sampling on site is not convenient, the additionally cast samples attached to delivered castings may be accepted instead;

③ testing method and result evaluation are to be in accordance with requirements in related Guidelines of CCS Rules for Materials and Welding.

(2) Inspection of heat exchange tubes is to be carried out according to 7.1.10 of this Guideline. Inspection of threaded tubes, U-tubes and coil tubes are to be carried out according to the following requirements:

① threaded tubes are to be inspected in accordance with 7.1.10 and in addition, 7.3.6 of this Guideline;

② U-tubes and coil tubes are to be inspected in accordance with 7.1.10 and in addition, 7.2.3 of this Guideline.

(3) Inspection of heat exchange plates is to be carried out according to 7.1.6 ~ 7.1.9 of this Guideline.

(4) Hydraulic strength tests of main pressure-containing parts are to be in accordance with the following requirements:

① main pressure-containing parts includes shell, end cover and bundle of tube of the heat exchanger and are normally to be subjected to hydraulic test separately or as an assembled unit;

② the hydraulic test pressure of different types of heat exchanger pressure-containing parts is to be determined as follows:

(a) for shell, end cover and bundle of tube of the heat exchanger, the testing pressure is to be 1.5 times the design pressure and last for 15 min;

(b) if the cast iron or copper end cover has not gone through anti-corrosion processing, the testing pressure for heat exchange tube is to be 2 times the design pressure and last for 15 min;

③ the surface of test pieces is to be clean and have no coating, free from leakage and "sweat".

(5) The vibration test of air coolers is to be in accordance with the following requirements:

① the aim of vibration test is to check the reliability of joining technology for heat exchange tube and tube plate;

② the test is to be carried out on a vibration test machine with the test cooler being installed horizontally and its weather side in rigid screwed connection with the test machine; the water jacket space is to be full of water; water pressure is to be water side working pressure of the tested heat exchanger;

③ tentative vibration test is to determine whether any resonance occurs throughout the testing frequency (4 ~ 50 Hz). Test frequencies and amplitudes are given in Table 8.4:

Frequency of vibration test **Table 8.4**

Vibration frequencies, in Hz	Frequency interval, in Hz	Amplitude, in mm	Residence time, in s
4~33	1	±0.25	15
34~50	1	±0.076	15

④ if a resonance frequency is revealed during tentative vibration test, the vibration test is to be carried out at the resonance frequency for at least 2 h; if no resonance occurs, the vibration test is to be carried out with 50Hz frequency and ±0.4 mm amplitude for 2 h;

⑤ a thorough examination of the tested heat exchanger is to be carried out for loosening, disordering, distortion and leakage upon the completion of testing;

⑥ vibration test may be carried out in conjunction with durability test of diesel engines;

⑦ For air coolers, vibration test of the type can be considered to be exempted if the record and data of this type running well on board are submitted to CCS and approved satisfied.

(6) Non-destructive test (for shell of heat exchangers, finished heat exchange plate of plate heat exchangers) is to be in accordance with the following requirements:

① the welded shell of heat exchangers is to be subjected to non-destructive test according to the requirements in Guideline 7, PART THREE of CCS Rules for Materials and Welding;

② the finished heat exchange plate of plate heat exchangers is to be tested by penetration means, and discarded where any minor crack is revealed.

(7) The whole unit test is to be in accordance with the following requirements:

① both sides of assembled heat exchangers are to be hydraulically tested to 1.5 times the design pressure but not less than 0.4 MPa (except air cooler) for 15 min, clean water with normal temperature is to be used as test medium and no leakage is allowed;

② the air side of air coolers is to be tested to design pressure for 15 min and no leakage is allowed;

③ the vacuum space of vacuum heat exchangers is to be tested to design pressure plus 0.1 MPa for 15 min and no leakage is allowed;

④ the refrigerant side of satisfactorily hydraulically tested heat exchangers of refrigeration systems is to be tested for airtightness to design pressure for 30 min and no leakage is allowed;

⑤ both jacket spaces of plate heat exchangers are to be hydraulically tested respectively to 1.25 times the design pressure for 15 min; clean water with normal temperature is to be used as test medium and no leakage and interconnection of the two jacket spaces are

allowed;

⑥ if the tube-side design pressure of shell and tube heat exchangers is greater than the shell-side design pressure, the joint pressure test is to be carried out in accordance with the plan or by the method agreed with CCS. In the case of pressure test of the whole unit, equal pressure may be applied to tube/shell if the shell-side material stress is less than or equal to 0.9 times σ_s; alternatively, if the test is not to be carried out in the above way, the shell-side is to be tested for ammonia leakage in addition to the original pressure test.

(8) The welding procedure test is to be in compliance with 6 of this Guideline.

(9) In addition to the above items, the test items for special or strange type products and those deemed necessary by CCS or specified by plans/specifications are to be agreed between CCS Surveyor and the applicant.

8.5 Determination of test items and exemption

8.5.1 Usually all test items applicable in 8.2 of this Guideline are to be carried out when the applicant applies for approval for the first time. The applicant may apply for exemption from the test items specified in 8.2(5) of this Guideline in written form, and CCS will consider the application according to the applicant's production, history of production and usage record of his products provided that the following conditions are met:

(1) the applicant is to be able to provide a test report of corresponding test items issued by an authoritative technical organization (General Administration of Quality Supervision, or a national defense laboratory) recently (within last 12 months);

(2) the applicant is to be able to provide a test report of corresponding test items signed by an IACS member society within last 12 months;

(3) the products to be approved are to be manufactured upon technology transfer or authorization, and the products so manufactured are to have been approved by CCS for their design;

(4) the applicant is to be able to provide a test report of corresponding test items issued by the user (associated diesel engine manufacturer) recently (within last 12 months).

8.5.2 Re-approval is to be requested when the approval certificate is to be renewed. If there is no change to design plans and production process of products and if there is no change to technical requirements of CCS Rules for Classification of Sea-going Steel Ships for such type of products, the tests specified in 8.2(2)~8.2(5) and in 8.2(8) may be omitted. However, CCS still reserves the right to require type test again.

9 Unit/batch inspection

9.1 Upon CCS design/type approval, the marine heat exchangers manufactured according to approval conditions (including equipment, workmanship, etc) may be installed on board only after satisfactory unit/batch inspection by CCS.

9.2 Specific inspection methods after approval will be notified by CCS to the manufacturer in written form when issuing the design/type approval certificate.

9.3 The unit/batch inspection is to be carried out in accordance with Table 9.3.

Test Items of the unit/batch inspection **Table 9.3**

Inspection upon type approval B	Inspection upon design approval
1. Review of test reports of material properties of main parts	1. Review of test reports of material properties of main parts
2. Review of manufacturer's pressure test report for whole units	2. Review of manufacturer's pressure test report for whole units
3. Review of non-destructive test report (if required)	3. Review of non-destructive test report (if required)
4. Visual examination	4. Visual examination
5. 5% sample of each product type for pressure test of whole units	5. Pressure test of whole unit one by one

9.4 Inspection of products by the manufacturer with CCS type approval A

9.4.1 Periodical audits are to be requested by manufacturers with CCS type approval A according to the requirements in Section 4 Guideline 3 PART ONE of CCS Rules for Classification of Sea-going Steel Ships;

9.4.2 The inspection is basically to review reports and all test items are to be completed by the manufacturer independently; inspection application is to be submitted before product delivery, together with reports/records/documents covering all tests/inspections in items 1~4 of Table 9.3, for review by CCS Surveyor.

9.5 Reports or documents of completed tests (except those required to be witnessed by CCS) and product quality certificates are to be submitted by the manufacturer when applying for product inspection. If CCS requires witnessing related tests, the certificate is to be issued by the Surveyor after completion of inspection.

9.6 During heat exchanger approval/inspection, the relevant requirements in this Guideline are to be applied and in addition, reference is to be made to specific requirements in Guideline 3, PART ONE of CCS Rules for Classification of Sea-going Steel Ship.