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MARINE DIESEL ENGINE FUEL INJECTION PUMP

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Foreword

China Classification Society (hereinafter referred to as CCS) Product Inspection and Testing Guideline (hereinafter referred to as this Guideline) contains the technical requirements, inspection and testing criteria related to classification and statutory survey of marine products to be applied for CCS approval/inspection.

This Guideline frees the users to adopt other test methods and requirements which are equivalent to or are stricter than this Guideline.

This Guideline is published and updated by CCS, and is released at http://www.ccs.org.cn. Your comments or suggestions are welcomed and may be sent to our email addressed service@ccs.org.cn.

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Main changes:

Deleted the requirements for 5.3.4 non-destructive testing.

CONTENTS

1 Application 4

2 Basis for approval and inspection 4

3 Terms and definitions 4

4 Plans and documents 4

5 Design and technical requirements 5

6 Materials and components 9

7 Type test 9

8 Unit/batch inspection 16

MARINE DIESEL ENGINE FUEL INJECTION PUMP

1 Application

This Guideline applies to the type approval and product inspection of single-cylinder camshaftless type and multi-cylinder driveshaft type marine diesel engine high-pressure fuel injection pumps of plunger spiral groove control mode.

2 Basis for approval and inspection

2.1 CCS Rules for Classification of Sea-Going Steel Ships (hereinafter referred to as “Sea-going Rules”);

2.2 CCS Rules for Materials and Welding (Hereinafter referred to as “Material Rules”);

2.3 Technical Specifications Established by the Low-Speed Diesel Engine Patent Awarded Factory and Approved by CCS.

3 Terms and definitions

For definitions of product inspection, design approval, type approval, prototype test, sample, unit/batch inspection and final inspection, refer to Article 3.1.2, Chapter 3, Part One of *Sea-going Rules*.

4 Plans and documents

When applying for the approval or inspection of marine high-pressure fuel injection pump assembly, the applicant is to submit the following plans and technical documents to CCS for approval and information.

4.1 The following plans and documents are to be submitted for approval:

(1) General plans (longitudinal and transverse section plans);

(2) Plans of main parts and components (fuel injection pump housing, plunger and barrel assembly, delivery valve assembly, etc. which may be properly added or deleted as the case may be);

(3) Main performance specification table;

(4) List of physicochemical properties of main parts and components;

(5) Technical conditions for delivery and acceptance, factory test program and type test program.

4.2 The following plans and documents are to be submitted for information:

(1) Product Operation Instructions and nameplate, certificate of inspection / warranty certificate (templates), etc. (Chinese-English bilingual edition);

(2) Nondestructive test standard (including UT, MT and PT);

(3) Pressure test standard.

5 Design and technical requirements

5.1 Material requirements

5.1.1 The fuel injection pump housing is to be made of forgings or castings. Forgings are to be in accordance with the provisions of Chapter 5, Part One of CCS *Rules for Materials and Welding*, and castings are to be in accordance with the provisions of Chapter 7, Part One of *CCS Rules for Materials and Welding*.

5.1.2 The plunger and barrel assembly and the delivery valve assembly are to be made of steels meeting the technical requirements of relevant standards on properties.

5.1.3 When the fuel injection pump is produced according to the technical specifications established by the diesel engine patent awarded factory, the chemical compositions of the materials of main parts and the mechanical properties after heat treatment are to be in accordance with the provisions of the above-mentioned technical specifications.

5.1.4 The raw materials and the casting and forging blanks are to be purchased generally from the manufacturer approved by CCS.

5.2 Structural requirements

5.2.1 For type-approved fuel injection pumps, the fuel injection pump assembly and its main parts for the same engine model, except the plunger and barrel assembly and the delivery valve assembly, are to be interchangeable.

5.2.2 The size of the interface between the fuel injection pump and the diesel engine, the high pressure fuel pipe assembly or the injector assembly is to be as agreed upon between the purchaser and the supplier.

5.2.3 The method and position for marking the top dead center of the upper plunger of fuel injection pump or the fuel delivery beginning are to be as agreed upon between the user and the manufacturer or in accordance with relevant technical documents.

5.2.4 The control rack of fuel injection pump is to be flexible in operation without retardance.

5.3 Requirements on working accuracy

5.3.1 The main dimensional and geometric tolerances of the plunger and barrel assembly and the delivery valve assembly are to comply with the requirements of relevant technical standards.

5.3.2 The main surface roughness of the plunger and barrel assembly and the delivery valve assembly is to comply with the requirements of relevant technical standards.

5.3.3 In case of any discrepancy on the surface roughness series between the supplier and the designer, the supplier is to comply with the design requirements comparable to those provided in the product plan.

5.4 Nondestructive test

5.4.1 The plunger and barrel assembly and the delivery valve and valve seat assembly are to be subjected to a magnetic particle test.

5.4.2 The fuel injection pump housing of low-speed diesel engine is to be subjected to an ultrasonic test.

5.5 Heat treatment

5.5.1 The heat treatment of fuel injection pump housing is to comply with the requirements of Chapters 5 and 7, Part One of *CCS Rules for Materials and Welding*.

5.5.2 The mechanical properties and surface hardness of the plunger and barrel assembly and the delivery valve assembly after heat treatment are to comply with the requirements of relevant technical standards.

5.5.3 The internal metallographic structure and case depth of the plunger and barrel assembly and the delivery valve assembly after heat treatment are to comply with the requirements of relevant technical standards.

5.5.4 The plunger and barrel assembly and the delivery valve assembly with dimensional stability requirements are to be subjected to low temperature treatment.

5.6 Pressure test and tightness test

5.6.1 The plunger and barrel assembly is to be subjected to a diametral leakage test.

5.6.2 The diametral part and the sealed cone of delivery valve assembly are to be subjected to a tightness test.

5.6.3 The low pressure area of fuel injection pump is to be subjected to a tightness test.

5.6.4 The high pressure face of high-pressure fuel pump housing (including the split type pump housing and cover) is to be subjected to a pressure test at a test pressure of 1.5 P or P+30 MPa, whichever is the less (P means the maximum working pressure of the tested part). When the fuel

injection pump is produced according to the technical specifications established by the diesel engine patent awarded factory, the pressure test of the pressure face of high-pressure fuel pump housing is to be conducted in accordance with such technical specifications.

5.7 Performance requirements

5.7.1 When the light diesel oil and the heavy fuel oil with a kinematic viscosity of lower than 380 mm^2/s at 50 ℃ are used, the fuel injection pump is to function properly. If heavy fuel oil is used, the inlet temperature is to be 130 ℃ ~ 150 ℃.

5.7.2 The fuel delivery characteristics of the fuel injection pump are to comply with the following provisions in general. Any special requirement is to be as agreed upon between the purchaser and the supplier.

(1) The deviation ratio σ of the fuel delivery of single-cylinder camshaftless fuel injection pump is to be not more than that stated in Table 5.7.2 (1).

Deviation Ratio of Fuel Delivery **Table 5.7.2 (1)**

Diesel engine model	Deviation ratio of fuel delivery δ %	
	Rated working condition	Minimum steady speed condition
High speed engine	±1.5	±10
Medium speed engine	±1.5	±15

The deviation ratio δ of fuel delivery is to be calculated by Formula (1):

$$\delta = \frac{Q_1 - Q_0}{Q_0} \quad \text{.....(1)}$$

Where: δ— deviation ratio value of fuel delivery, in %;

Q_0— rated fuel delivery value, in ml;

Q_1— measured fuel delivery value, in ml.

When the injector matched with the fuel injection pump is used for the adjustment test, the deviation ratio σ of fuel delivery is also to be not more than that stated in Table 5.7.2 (1).

(2) The fuel delivery unevenness σ of cylinders of multi-cylinder driveshaft fuel injection pump is to be not more than that stated in Table 5.7.2 (2).

Fuel Delivery Unevenness **Table 5.7.2 (2)**

Number of fuel injection pump cylinders	Fuel delivery unevenness of cylinders σ %	
	Rated working condition	Minimum steady speed condition
6,7	2.5	20
8,9	2.5	25
10,11	2.5	30
> 12	3	35

The fuel delivery unevenness σ of cylinders is to be calculated by Formula (2):

$$\sigma = \frac{2(Vmax - Vmin)}{Vmax + Vmin} \quad \text{..... (2)}$$

Where: σ— fuel delivery unevenness value of cylinders, in %;

Vmax— fuel delivery value of the cylinder with the maximum fuel delivery, in ml;

Vmin— fuel delivery value of the cylinder with the minimum fuel delivery, in ml.

When the injector matched with the fuel injection pump is used for the adjustment test, the fuel delivery unevenness σ of cylinders is also to be not more than that stated in Table 5.7.2 (2). Any special requirement is to be as agreed upon between the purchaser and the supplier.

5.7.3 The fuel delivery prestroke of fuel injection pump is to be as agreed upon between the purchaser and the supplier.

5.7.4 The static fuel delivery beginning of cylinders of multi-cylinder driveshaft fuel injection pump is to be as agreed upon between the purchaser and the supplier.

5.7.5 The fuel delivery sequence of cylinders of multi-cylinder driveshaft fuel injection pump is to be as agreed upon between the user and the manufacturer.

5.7.6 The interval angle deviation between the fuel delivery beginning of cylinders of multi-cylinder driveshaft fuel injection pump under the rated working condition and that of the specified reference cylinder is to be ±30′ camshaft angle (static measurement). The fuel delivery beginning of the specified reference cylinder is to be marked with a scribed line at an obvious place and recorded in the relevant document.

5.8 Reliability

The first maintenance interval for the fuel injection pump is to be in line with the medium maintenance interval for the diesel engine.

6 Materials and components

6.1 The materials and components of the product are to be controlled according to relevant requirements of the CCS Rules currently in effect.

6.2 The main parts of the fuel injection pump assembly are to include fuel injection pump housing, plunger and barrel assembly, delivery valve assembly, etc.

7 Type test

7.1 Selection of typical samples

Generally, one prototype of each series of fuel injection pump is to be selected for type test for the first approval. The prototype selected is to be inclusive of the series in terms of technical parameters, representative in terms of the structure and manufacturing process, and able to reflect the processing capability and manufacturing level of the factory.

7.2 Test items

Generally, the type tests on the fuel injection pump are to include the type tests on the plunger and barrel assembly, the chemical compositions of the materials and the mechanical properties after heat treatment for pump housing, the delivery valve assembly and the fuel injection pump assembly.

7.2.1 Type test items for plunger and barrel assembly

(1) Sliding;

(2) Diametral tightness;

(3) Cleanliness;

(4) Reliability;

(5) Magnetic particle test;

(6) Main dimensional and geometric tolerances;

(7) Main surface roughness.

7.2.2 Type test items for delivery valve assembly

(1) Magnetic particle test;

(2) Sliding;

(3) Sealed cone tightness;

(4) Diametral tightness;

(5) Cleanliness;

(6) Reliability;

(7) Main dimensional and geometric tolerances;

(8) Main surface roughness.

7.2.3 Type test items for the materials and the mechanical properties after heat treatment for pump housing

7.2.4 Type test items for fuel injection pump assembly

(1) Static fuel delivery beginning;

(2) Fuel delivery prestroke;

(3) Fuel delivery interval angle (only for multi-cylinder driveshaft fuel injection pumps);

(4) Control rack shifting resistance;

(5) Fuel delivery characteristics;

(6) Hydraulic test of pump housing and sealing test of low pressure room of the assembly;

(7) Cleanliness;

(8) Reliability.

7.2.5 Type test items for low-speed diesel engine fuel injection pump produced according to the technical specifications established by the diesel engine patent awarded factory

The materials and the mechanical properties after heat treatment for pump housing, is to be subjected to the type test described in 7.2.3 of this Guideline. The hydraulic test should to be conducted on the fuel injection pump housing (including the split type pump housing and cover).

7.3 Exemption of the type test items

All applicable test items described above are to be conducted for the first approval. If the following conditions are met, the manufacturer may submit a written application on exemption of part of test items to CCS, and the Surveyor is to give his/her comments based on the production situation and the product history and usage records of the factory and fax such comments along with the written application of the manufacturer to the Headquarters. Only after being approved can the test items be exempted:

(1) The manufacturer applying for approval is to provide the test reports of relevant test items recently issued by an authoritative testing agency (such as the General Administration of Quality Supervision, Inspection and Quarantine or the Defense Science and Technology Laboratory);

(2) The test approval applicant is to provide the test reports of relevant test items recently signed by IACS members.

7.4 Type test methods and requirements

7.4.1 Type test methods for plunger and barrel assembly

(1) Sliding test

The parts are cleaned and lubricated with light diesel oil. When the plunger and barrel assembly is at an angle of 45 °to the horizontal plane, the plunger is pulled out for 1/3 of the length of the cylindrical working surface from the barrel and rotated around its axis to any position. After the plunger is released, it is to slide down freely by virtue of its dead weight without retardance.

(2) Diametral tightness test

① The diametral tightness test of plunger and barrel assembly is to be conducted under the following conditions:

(a) The test fluid is the mixture of diesel oil and engine oil, with a kinematic viscosity of 10.2 mm^2/s ~ 10.7 mm^2/s at 20 ℃;

(b) The ambient temperature is 20 ℃ ± 2 ℃;

(c) The accuracy of the pressure display device is not lower than Class 1.5;

(d) The inlet pressure of compressed air is 0.2 MPa ~ 0.5 MPa.

An equal-pressure method or pressure-reducing method may be used in the diametral tightness test of the plunger and barrel assembly.

When the standard tightness sample of the plunger and barrel assembly is used for the comparative test, the viscosity of test fluid and the ambient temperature are not specified, but the sample must be re--calibrated if the ambient temperature variation exceeds 4 ℃ during the test.

Other methods (such as assembly clearance measurement) are allowed to be used for assessing the tightness of the plunger and barrel assembly, but the measuring method is to comply with the requirements of relevant technical standards.

② The diametral tightness test procedures by the equal-pressure method are as follows:

(a) The sealed face of the barrel is blocked;

(b) The angular position of the plunger bevelled slot relative to the return port of the barrel is set at the fuel delivery position of the diesel engine under rated working condition;

(c) The test fluid of specified pressure is added to the upper space of the plunger and the test fluid leakage time is checked. The result is to meet the requirements of approved rules.

③ The diametral tightness test procedures by the pressure-reducing method are as follows:

(a) The return port center of the barrel is set at the middle of the fuel delivery stroke of the plunger at the fuel delivery of the diesel engine under rated working condition.

(b) The initial test pressure is set in accordance with the product plans. During the test, the test fluid is pumped in from the upper end of the barrel. When the test fluid pressure is increased to 3 MPa higher than the initial pressure, the time required for the test fluid pressure to drop 5 MPa from the initial pressure is measured. The result is to meet the requirements of approved rules.

For the test bench where the diametral tightness test of plunger and barrel assembly by the pressure-reducing method is conducted, all connections in its high-pressure passage and the sealed parts of the plunger end face are to be kept tight. When the test bench is tested with a non-porous process pad, the pressure drop under a fuel pressure of 30 MPa for 3 min is not to exceed 1 MPa.

(3) Determination of cleanliness

The plunger and barrel assembly and the delivery valve assembly are rinsed with 120# gasoline which is then contained in a clean vessel, filtered with a 5 μm strainer, dried and weighed. The weight of impurities is the cleanliness of the plunger and barrel assembly. The specific limit value is to be as agreed upon between the purchaser and the supplier.

(4) Reliability test

The reliability test items and assessment method for the plunger and barrel assembly are to be as agreed upon between the purchaser and the supplier.

(5) Magnetic particle test

The magnetic particle test method for the plunger and barrel assembly is to be in accordance with relevant standard requirements.

7.4.2 Type test methods for delivery valve assembly

(1) Magnetic particle test

The magnetic particle test method for the delivery valve assembly is to be in accordance with relevant standard requirements.

(2) Sliding test

The parts are cleaned and lubricated with light diesel oil. When the delivery valve assembly is placed vertically, the delivery valve is pulled out for 1/3 of the length of the cylindrical working surface from the delivery valve seat and rotated around its axis to any position. After the delivery valve is released, it is to slide down into the seat freely by virtue of its dead weight without retardance.

(3) Tightness test of sealed cone

① Test conditions:

(a) The tightness test of sealed cone is to be conducted on an air-tight test bench;

(b) The length of the air header of test bench is to be not more than 300 mm and the inside diameter is to be not less than 5 mm. The depth of the outlet end of air header inserted into water is to be not more than 20 mm;

(c) The delivery valve assembly is to be rinsed with applicable light diesel oil and blow-dried before the test;

(d) The pressing force acted on the delivery valve is to comply with the product plans.

② Test method:

(a) Compressed air of 0.4 MPa to 0.6 MPa is pumped in and held for 10 s, and then the delivery valve is immersed into water for inspection. Any air leakage is not allowed;

(b) Each delivery valve assembly is to be tested at three different matching positions.

(4) Diametral tightness test

The diametral tightness (clearance) test is generally conducted by comparison with the sample whose clearance value is approved according to the specified procedures.

If tested by a pneumatic measuring instrument or other methods, the delivery valve is to be lifted slightly and dipped into water for inspection, and the result is to comply with the requirements in approved plans or technical documents.

(5) Determination of cleanliness

The delivery valve assembly is rinsed with 120# gasoline which is then contained in a clean vessel, filtered with a 5 μm strainer, dried and weighed. The weight of impurities is the cleanliness of the delivery valve assembly. The specific limit value is to be as agreed upon between the purchaser and the supplier.

(6) Reliability test

The reliability test items and assessment method for the delivery valve assembly are to be as agreed upon between the purchaser and the supplier.

7.4.3 Type test methods for the materials and the mechanical properties after heat treatment for the pump housing

The materials and the mechanical properties after heat treatment of pump housing is to be be in accordance with the provisions of CCS Rules for Materials and Welding.

7.4.4 Type test methods for fuel injection pump assembly

(1) Test equipment and test fluid

① The pump calibration fluid is to be used, and the light diesel oil may be used;

② The cam profile used by the test bench is to be in accordance with the provisions on the fuel cam of the matching diesel engine;

③ The standard fuel injector used for the fuel delivery adjustment test is to have the performance parameters of fuel injector of the matching diesel engine;

④ The high-pressure fuel pipe connecting the fuel injection pump with the standard fuel injector is to comply with the requirements for the matching diesel engine;

⑤ The measuring instrument for the test is to have the metrological calibration certificate and be used within the period of validity, and the accuracy of the test instruments is to comply with the requirements for the type test.

(2) Static fuel delivery beginning

With the fuel injection pump camshaft rotated slowly and steadily, the hydraulic pressure fluctuation is observed through a transparent tube and the fuel delivery beginning of single-cylinder camshaftless fuel injection pump is measured at the fluctuation moment of liquid level; for the multi-cylinder driveshaft fuel injection pump, the same method is also used for measuring the fuel delivery beginning of cylinders in the fuel delivery sequence in the case of declared rotation direction.

(3) Fuel delivery prestroke

With the delivery valve spring of the fuel injection pump removed, the test fluid with a pressure of 0.015 MPa is delivered in from the inlet port of the fuel injection pump and out from the spill port. The flywheel of the fuel injection pump test bench is rotated to make the plunger slightly rise from the bottom dead center. When the test fluid at the spill port stops flowing, the plunger stroke measured is the fuel delivery prestroke.

(4) Fuel delivery interval angle (only for multi-cylinder driveshaft fuel injection pumps)

With the spill valve of the standard injector on the fuel injection pump test bench released, the test fluid with a certain pressure (the pressure is set as per the delivery valve opening pressure) is delivered in from the inlet port of fuel injection pump and out from the spill pipe of fuel injector on the fuel injection pump via the delivery valve. Then the flywheel of the fuel injection pump test bench is rotated slowly, and the moment when the fuel at the spill pipe stops flowing out is the fuel delivery beginning. With the fuel delivery beginning of the reference cylinder taken as the base point, the interval angles between the fuel delivery beginning of cylinders and that of the reference cylinder are measured in the fuel delivery sequence, and their deviations are calculated.

(5) Control rack shifting resistance

The control rack is placed in a horizontal position, and moved in the fuel increasing or decreasing direction within the full stoke. There should be no sticking. The stroke range should be measured.

(6) Fuel delivery characteristics

With the fuel injector valve opening pressure set to the specified value and the fuel injection pump adjusted to the specified rack position and speed, the fuel delivery within a certain number of cycles is measured.

(7) Tightness

With the fuel injection pump assemble in place, a pressure equal to 1.5 times the maximum working pressure or design pressure is applied from the inlet port with other fuel ports blocked for 5 min, and then the sealed parts of fuel injection pump are checked for leakage.

(8) Determination of cleanliness

After the fuel injection pump is disassembled, the inner cavities of parts are rinsed though a syringe with 120# gasoline which is then contained in a clean vessel, filtered with a 5-μm strainer, dried and weighed. The weight of impurities is the cleanliness of the fuel injection pump.

(9) Reliability test

The reliability test items and assessment method for the fuel injection pump are to be as agreed upon between the purchaser and the supplier.

7.4.5 Type test methods for low-speed diesel engine fuel injection pump produced according to the technical specifications established by the diesel engine patent awarded factory

(1) The materials and the mechanical properties after heat treatment

The approved plans and technical specifications established by the patent awarded factory are to be complied with.

(2) Hydraulic test

The approved plans and technical specifications established by the paten awarded factory are to be complied with.

8 Unit/batch inspection

For the specific inspection methods for products after type approval, the inspection plan at the time of issuing the type approval certificate by CCS is to be complied with.

8.1 For unit/batch inspection of products produced by the manufacturer type-approved by CCS:

8.1.1 Inspection items

(1) The inspection items of fuel injection pump assembly are to comply with the factory test program approved at the time of type approval but be inclusive of, at a minimum, the following tests:

① Fuel delivery interval angle (only for multi-cylinder driveshaft pumps)

② Fuel delivery characteristics

③ Hydraulic test of pump housing and sealing test of low pressure room of the assembly, the test methods are the same as that in 7.4.3 of this Guideline.

(2) For low-speed diesel engine fuel injection pumps produced according to the technical specifications established by the patent awarded factory, only the hydraulic test of fuel injection pump housing is to be conducted if only the fuel injection pump housing is subjected to certified inspection.

8.1.2 The above tests may be carried out independently by the manufacturer with a complete test report to be submitted to the Surveyor for approval.

8.1.3 The sampling quantity taken by the Surveyor is to depend on the quantity declared by the factory for inspection. In principle, for batch-produced products, 2% of the same series but not less than 2 sets may be sampled; for single-piece and small-batch produced products, the sampling quantity may be taken as appropriate but at least one set per model. The sampled products are to be subjected to re-test against the above-mentioned inspection items or on-site test witness at the manufacturer’s premises.

8.1.4 When the manufacturer applies for unit/batch inspection each time, the following documents are to be submitted at the same time to the Surveyor for approval:

(1) Inspection of fuel injection pump assembly:

① Material quality certificates of the pump housing;

② Reports on inspections or tests carried out according to 8.1.1 of this Guideline.

(2) Inspection of fuel injection pump housing of low speed diesel engine:

① Material quality certificate;

② Heat treatment inspection report;

③ Hydraulic test report.