Guideline No.: D-01(201510)

D-01

HYDRAULIC STEERING GEAR

Issued date: October 20,2015

Foreword

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 mp@ccs.org.cn.

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CONTENTS

HYDRAULIC STEERING GEAR

1 Application

1.1 This Guideline applies to hydraulic steering gears associated with classed sea-going ships. For other types of steering gears, reference may be made to in this Guideline.

1.2 The main constructional types of hydraulic steering gear rudder actuators to which this Guideline is applicable:

(1) Ram type rudder actuators;

(2) Piston type rudder actuators;

(3) Rotary vane type rudder actuators.

Other types of rudder actuators may be referred to in this Guideline.

1.3 Specific requirements for associated steering gear control systems (including autopilots, follow-up pilots and other steering consoles in navigation bridge, simple steering box in steering gear room, steering gear hydraulic servo control systems, etc.), start-up controls (including frequency inverters) of steering gear power units, electrical rudder angle indicators, steering gear monitoring/indication and alarm systems are referred to the relevant requirements for related products in CCS Rules for Classification of Sea-going Steel Ships and the Guidelines.

2 Normative references

2.1 The approval and inspection in this Guideline are to be based on the following documents:

(1) CCS Rules for Classification of Sea-going Steel Ships;

(2) International Convention for the Safety of Life at Sea (hereinafter referred to as “SOALS”).

2.2 The paragraphs in the above mentioned basis for approval and inspection quoted are part of this Guideline. For quoted documents marked with the date, their subsequent amendments (except corrigenda) or revisions will be inapplicable, hence, it is to meet the requirements of the latest edition of these documents during the product design, manufacture and inspection. However, for those quoted documents without any date marked, the latest edition applies to this Guideline.

3 Definitions

3.1 The terms and definitions given in SOALS and CCS Rules for Classification of Sea-going Steel Ships are applicable to this Guideline.

3.2 For the purpose of this Guideline:

(1) Steering gear is a combination of power actuating systems, steering gear control systems, monitoring/indication and alarm systems and rudder indicator.

(2) Hydraulic steering gear is hydraulic power actuating system in this Guideline, consisting of rudder actuator, power equipment (not including start-up control or frequency inverter of electric motors) and auxiliary pipe fittings.

(3) Nominal steering torque is obtained by multiplying the theoretical torque output of single rudder actuator calculated according to 7.2(1) of this Guideline by number of sets of rudder actuators.

(4) Nominal system pressure is to be calculated according to 7.2(2) of this Guideline, consisting of the difference between inlet and outlet pressures of rudder actuator cylinder at theoretical torque output of single power actuating system and pressure loss of the hydraulic power system through its piping.

4 Plans and documents

4.1 Unless expressly provided otherwise by CCS, generally, the following plans and documents are to be submitted to CCS for examination when applying for approval and inspection of hydraulic steering gear:

(1) Main performance specifications (which may be included in general arrangement or hydraulic system drawing), usually covering:

① nominal steering torque: if the maximum rudder angle is more than ±35°, the corresponding torque output value between ±35°and maximum rudder angle is also to be determined;
② nominal system pressure;
③ the maximum rudder angle;
④ limit rudder angle, identifying the internal limit of rudder actuator cylinder or the external limit of rudder actuator and indicating the structural rudder stops or mechanical buffers (if fitted on rudder actuator);
⑤ time required for rudder movement (in case of constant delivery pump) or time range

required for rudder movement (in case of variable delivery pump), with the minimum time being dependent on electric motor power, and giving necessary description if requiring simultaneous running of double units;

⑥ specification, type, nominal flow or diameter and setting pressure (usually 1.25 times the nominal system pressure) of safety valves (including relief valves which protect hydraulic pumps);

⑦ specification, type, nominal pressure, capacity and nominal speed of hydraulic pumps;

⑧ specification, type, power, rated speed and electrical power supply of prime movers (electric motors);

⑨ specification, type, nominal flow or diameter, nominal pressure and control power of associated solenoid valves; if these valves are controlled by direct current, the voltage fluctuation data of the applicable power source of these valves are to be provided;

⑩ specification, type, diameter of piston rod, bore diameter of cylinder, piston stroke, installation dimension and nominal pressure of rudder actuator cylinder, if purchased;

⑪ drawing number or type of steering gear servo control system, if applicable;

⑫ effective capacity of each oil tank (power unit oil tank, storage tank), taken usually as 80% of the total theoretical capacity of the oil tank);

⑬ arrangement of monitoring alarm points;

⑭ recommended type and applicable temperature range of hydraulic oil, complying with the minimum and maximum ambient temperatures;

⑮ intended purposes of products, indicating whether they are intended for ships complying with additional requirements of CCS Rules for Classification of Sea-going Steel Ships or for ships of which the rudder stock is to be strengthened for ice.

(2) General arrangement of products, usually stating the following clearly:

① scope of supply of products for inspection (delivery), e.g. including navigation bridge consoles, hydraulic servo controls, storage tanks or not;

② match relations between components, e.g. any tiller connecting rod being installed between

rudder actuators or not, connection between power systems (including oil tanks, pipes and valves) and connection relationship between rudder actuators, etc.;

③ required installation height of hydraulic oil tank (if the hydraulic pump is not integrated with oil tank).

(3) General arrangement of rudder actuator, usually stating the following clearly:

① main installation dimensions of rudder actuator, including the maximum permissible length of tiller connecting rod, (steering) tiller radius, etc.;

② relationship between parts which transfer mechanical forces to rudder stock;

③ requirements for means of connection of rudder actuator and hull and fitting of thrust plates (including forces acting thereon);

④ fitting of travel switches which limit max. rudder angle (including number and location of travel switches);

⑤ location of fitting mechanical rudder angle indicator.

(4) General assembly of rudder actuator cylinder, usually stating the following clearly:

① main structural dimensions;
② specification, type and dimensions of materials of main components and parts, including specifications, type and dimensions of main stress bolts;
③ nominal pressure;
④ fitting of seals and specification, type and material of seals;
⑤ specification, type and related parameters (such as nominal pressure, diameter) of isolating valves, bleeding air valves, pressure gauges and their switches, internal shuttle valves, if applicable, which provide pre-applied pressure for seals;
⑥ details of welded connections of oil cylinder (including connecting flanges) and requirements for welding consumables, non-destructive test;
⑦ relevant technical requirements for manufacturing inspection.

(5) General assembly of hydraulic power unit, usually stating the following clearly:

① location of oil suction of hydraulic pump;
② fitting of fluid level indicator;
③ fitting of monitoring and alarm sensors, such as those for oil temperature, fluid level, low pressure, filter blocking and hydraulic locking, if applicable;
④ main dimensions (capacity), shell materials;
⑤ relevant technical requirements for manufacturing inspection;
⑥ fitting of heater and/or cooler, if applicable.

(6) Drawings of the following components and parts:

① for ram type rudder actuator: rudder actuator cylinder, ram, ram pin, common seating of rudder actuator cylinder, if applicable;
② for piston type rudder actuator: rudder actuator cylinder, end cover of cylinder, piston and piston rod, end eye joint, base of rudder actuator cylinder;
③ for rotary vane type rudder actuator: rudder actuator cylinder housing, end cover of cylinder, fixed vane, rotary vane and rotor;
④ general components and parts: pin, rudder tiller, connecting rod of rudder tiller (synchronous pull rod of rudder), self-made connecting bolts of rudder tiller, assembly of isolating valve and related information, connection device between rudder stock or rotary vane rotor and rudder stock (if applicable), mechanical rudder angle indicator.

(7) Schematic diagram of hydraulic system, usually stating the following clearly:

① configuration of whole set of powered actuator hydraulic system (including internal control oil line) and interrelationship therein;
② specifications, types and main parameters (nominal pressure, nominal flow/diameter, rated speed, capacity, accuracy of oil filtering, etc.) of main components which usually include hydraulic hoses, hydraulic pumps, electric motors, safety valves, relief valves, pressure-reducing valves, back pressure valves, solenoid valves, filters, accumulators (if applicable), pressure gauges and their switches, shut-off valves, pressure/flow/temperature measuring means, heaters/coolers;
③ specification, type, diameter, wall thickness and material of pipelines;
④ setting of alarm points;

⑤ table of (solenoid) control valve actions in working cycles of each system.

(8) Storage tanks, usually stating the following clearly:

① dimension and effective capacity, shell material;
② fitting of liquid level meters.

(9) Calculations (for hydraulic system and for rudder actuator strength), usually covering check of the following:

① calculation of nominal steering torque;
② calculation for selection of nominal system pressure;
③ calculation of rudder actuator cylinder (system) capacity, which is to be rechecked with flow calculation and time required for rudder movement;
④ calculation for selection of hydraulic pumps;
⑤ calculation for driving power and selection of electric motors;
⑥ check of wall thickness of pipes;
⑦ check of rudder actuator cylinder stroke and its installation dimensions, or recheck of maximum rudder angle and limit angle;
⑧ for ram type rudder actuator: check of wall thickness of cylinder, check of end cover thickness/strength, check of flange cover bolts, strength of ram, strength of ram pin, strength of cylinder seating bolts (including strength requirements for thrust plates if necessary), strength check of rudder tiller fork, strength of artificial rudder stock (if applicable), etc.;
⑨ for piston type rudder actuator: check of wall thickness of cylinder tube, check of end cover connection strength, check of flange cover bolts, strength of piston rod (including thread at both sides or block), strength of support and its bolts (including strength requirements for thrust plates if necessary), check of pin strength, check of ear ring strength, etc.;
⑩ for rotary vane type rudder actuator: check of wall thickness of cylinder housing, check of cylinder cover and its bolts, strength of fixed vane/rotary vane and their connection devices, strength of cylinder seating bolts (including strength requirements for thrust plates if necessary), check of rotor strength, strength of connection between rotor and rudder stock, etc.;
⑪ check of rudder tiller: calculation for selection of dimension, check of section modulus, check of connecting bolts (if applicable), check of strength of connection (such as key or friction ring) with rudder stock (if applicable);
⑫ check of rudder tiller connecting rod strength: maximum permissible length, connecting rod section and section modulus (check of stability of compression rod);
⑬ related calculation of isolating valve, if applicable.

(10) Type test programme, stating the following clearly:

① test items and acceptance criteria;
② test method;
③ requirements for test instrumentation;
④ requirements for ambient conditions of the test;

⑤ requirements for oil used in the test;
⑥ requirements for load-applying equipment used for the test.

4.2 Generally, the following plans and documents are to be submitted to CCS for reference:

(1) Assembly drawings of non-standard self-made seals and oil manifold block, indicating type of the material.

(2) Product instructions, usually including the following:

① rules and standards with which product design is in compliance, application of product;
② scope of supply of products and their main technical parameters;
③ working principles (with related schematic diagram);
④ requirements for maintenance;
⑤ necessary safety caution;
⑥ emergency troubleshooting.

(3) Table of physical and chemical properties of material of main components and parts (or shown in drawings of parts clearly).

4.3 When manufacturing plant for the first time to apply for product approval and inspection, the main components (such as components of transfering mechanical force from steering mechanism to the rudder, pressure shell, piping, etc.)welding, heat treatment, nondestructive testing methods and the main acceptance standards, product nameplate, product traceability data (if applicable), please submit it to CCS review .

5 Materials and components

Materials and components are to comply with relevant requirements of CCS Rules.

5.1 Hydraulic steering gear is made up of the following parts as shown in Table 5.1.

Parts of hydraulic steering gear Table 5.1

Hydraulic steering gear	Hydraulic rudder actuator	Ram type rudder actuator	Rudder tiller, connecting rod of rudder tiller, pin	
			Ram type rudder actuator cylinder	Cylinder, ram, ram pin, isolating valve, seating, seal
		Piston type rudder actuator	Rudder tiller, connecting rod of rudder tiller, pin	
			Piston type rudder actuator cylinder	Cylinder, piston, piston rod, isolating valve, support, seal
		Rotary vane type rudder actuator	Rudder tiller, connecting rod of rudder tiller, pin	
			Rotary vane type rudder actuator cylinder	Cylinder housing, rotary vane, fixed vane, rotor, isolating valve, seal
	H	Hydraulic pump		

Continued Table 5.1

		Pump driver	Electrical motor

			Diesel engine
		Coupling	
	Pipe fittings	Control valve (solenoid valve, proportional control valve, servo valve), safety valve, relief valve, back pressure valve, balance valve, filter, oil cooler, (main/storage) oil tanks, steel pipe, high pressure hose, mechanical pipe joint, accumulator, heater, etc.	

5.2 The certified requirements of important purchased components of hydraulic steering gear should meet the related requirements of appendix 2A, Chapter 3, Part 1 of CCS Rules for Classification of Sea-going Steel Ships , and meet the intended use of this product, including:

(1) Rudder actuator cylinders are to comply with the relevant technical requirements in Section 1, Chapter 13, PART THREE of CCS Rules for Classification of Sea-Going Steel Ships and in this Guideline, and common engineering oil cylinders are not to be used.

(2) Energy accumulator is to comply with the relevant technical requirements in Chapter 6, Part 3 of CCS Rules for Classification of Sea-Going Steel Ships and this Guideline. The accumulator which couldn't coeffective insulate gas and liquid may not to be used to power steering system

(3) Solenoid valves are to comply with the relevant technical requirements in Chapter 2 of PART THREE, in PART FOUR and PART SEVEN of CCS Rules for Classification of Sea-Going Steel Ships and in this Guideline, clearly identifying the range of voltage fluctuation. If a solenoid valve is to be operated for the sake of safety or other reasons when its electrical control fails, as required in 2.8.8.4, PART THREE of CCS Rules for Classification of Sea-Going Steel Ships, it is to be provided with a manual emergency control (i.e. the solenoid valve is usually to be fitted with a manual emergency control button or similar means).

6 Evaluation of welding procedures

6.1 Welding procedures of the following main welded components of the rudder actuator are to be evaluated by CCS before manufacturing and to comply with the relevant requirements in PART THREE of CCS Rules for Materials and Welding:

(1) Rudder actuator cylinder, end cover, if applicable;

(2) Components and parts which transmit hydraulic force directly to the rudder stock: ram, piston and piston rod, rotary vane and rotor of rotary vane type rudder actuator cylinder, rudder actuator cylinder/unit seating, rudder tiller, connecting rod of rudder tiller, etc., if applicable.

6.2 Heat treatment procedures are to be approved by CCS and comply with the relevant requirements in PART THREE of CCS Rules for Classification of Sea-Going Steel Ships and PART THREE of CCS Rules for Materials and Welding.

(1) Piping is to comply with the requirements in 2.5.4, PART THREE of CCS Rules for Classification of Sea-Going Steel Ships, if applicable.

(2) Pressure cylinders are to comply with the requirements in 6.2.7, PART THREE of CCS Rules for Classification of Sea-Going Steel Ships, if applicable.

7 Design and technical requirements

7.1 Technical requirements

(1) The technical requirements for hydraulic steering gears are given in Table 7.1.

Technical Requirements for Hydraulic Steering Gear Table 7.1

No.	Specific requirements	Basis of inspection	Remarks
1	General		
1.1	Submission of plans	3.6.2.1, PART ONE and 1.1.3.2, 1.1.3.3, 2.1.2.4, 13.1.3.1, PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	To comply with the requirements of 4 of this Guideline
1.2	Certification of purchased components	13.1.1.2 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	To comply with the requirements of 5 of this Guideline
1.3	Ambient conditions	1.2.1.1 and 1.2.1.2 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Corresponding to column “Main and auxiliary machinery”; Corresponding to columns “Air” and “In enclosed spaces”, but possibly worse conditions in service are to be considered
1.4	General safety	1.3.6 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Exposed rotating parts (such as motor-driven pump unit coupling) are to be additionally fitted with protective cover

Continued Table 7.1

No.	Specific requirements	Basis of inspection	Remarks

1.5	Electrical apparatuses associated with hydraulic steering gear	PART FOUR of CCS Rules for Classification of Sea-Going Steel Ships	For apparatuses controlled by direct current, e.g. solenoid valves, particular attention is to be given to their capability of withstanding power and voltage variations in compliance with the requirements in 1.2.2.2, PART FOUR of CCS Rules for Classification of Sea-Going Steel Ships. None of these apparatuses which do not meet the criterion of 25% voltage drop is allowed in systems supplied directly by accumulators. Unless the requirements in 1.2.2.3, PART FOUR of CCS Rules for Classification of Sea-Going Steel Ships are complied with, none of these apparatuses which do not meet the criterion of 10% voltage drop is allowed. In practical application, consideration is to be given to testing voltage of electromagnetic coil terminals in operating condition of electromagnets, and the sum of total voltage drops of cables is to comply 2.12.4.2, PART FOUR of CCS Rules for Classification of Sea-Going Steel Ships
2	Basic performance of steering gear		
2.1	Relationship between main and auxiliary steering gears	13.1.5.1, 13.1.5.6, and 13.1.10.1 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
2.2	Rudder actuating by hydraulic steering gear as main steering gear	13.1.5.2 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Design, manufacturing and inspection are to be checked with nominal torque of hydraulic steering gear
2.3	Rudder actuating by hydraulic steering gear as auxiliary steering gear	13.1.5.3 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Design, manufacturing and inspection are to be checked with 25% of the nominal torque of hydraulic steering gear
2.4	Manually operated steering	13.1.5.4 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
2.5	Arrangement of power unit of hydraulic steering gears as main/auxiliary steering gears	13.1.5.5 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
2.6	Fitting of power unit of hydraulic steering gear as main steering gear	13.1.5.1, 13.1.5.6 and 13.1.10.1 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	The "piping system" mentioned in 13.1.5.6.3 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships is to include pipeline valves and related fittings between pump outlet of power unit and isolating valve of rudder actuator cylinder inlet. If the isolating valve is hydraulically controlled, the single failure isolation of its hydraulic control line is to be included
2.7	Conditions for exemption from fitting of auxiliary steering gear	13.1.5.6 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
2.8	Fitting of rudder angle limiter	13.1.5.8 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	At least two sets of limiters (such as electrical limit switches) are to be fitted, unless the failure or damage of the limiter will not cause loss of steering capability. The limiters are to be located at the maximum design rudder angle (usually ±35 °~ ±35.5 °)
2.9	Rudder stop	13.1.5.9 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	When the steering gear is not in follow-up or autopilot mode and when the torque of rudder stock is nominal, the rudder movement speed is not to be more then 0.5 °/min for ram type rudder actuator and piston type rudder actuator, and not to be more than 1 °/min for rotary vane type rudder actuator

Continued Table 7.1

No.	Specific requirements	Basis of inspection	Remarks

3	Construction and design		
3.1	Design of steering gear components subject to internal pressure	13.1.6.1 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Threaded connection is not to be used directly between related parts with their fittings and the pressure cylinder. Pads may be fitted to the cylinder for transition. Consideration may be given to appropriate relaxation of this requirement only for duplicated cylinders or rudder actuators complying with single failure isolation requirements or cylinders having good elongation regarding their material and with less nominal torque
3.2	Safety factor selection in design of hydraulic steering gear components subject to internal pressure	13.1.6.2 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Cylinder, cylinder cover and its bolts, cylinder flange and its bolts, shut-off valve and isolating valve installed on the cylinder, and internal shuttle valves (if applicable) which provide pre-applied pressure for seals
3.3	Welding of pressure parts	13.1.6.3 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
3.4	Welding of parts transmitting mechanical forces	13.1.6.3 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
3.5	Control of construction stress concentration	13.1.6.4 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
3.6	Selection of design pressure	13.1.6.5 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	At least 1.25 times the nominal system pressure is to be taken
3.7	General strength of steering gear components	13.1.6.6 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
3.8	Components which are not duplicated	13.1.6.6 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	1. The number of bolts of valves (including isolating valves) connected to rudder actuator cylinder directly and that of bolts of flanges of externally connected pipelines is not to be less than 4. The number of bolts of flange of cylinder cover is not to be less than 6, unless special consideration is given for flange connections and strength of bolts). 2. The maximum diameter of shut-off valves, bleeding air valves, non-return valves of pressure gauge switches that directly contact hydraulic oil in the cylinder and can not be isolated, and of internal shuttle valves (if applicable) providing pre-applied pressure to seals is to be limited as necessary. The leakage of hydraulic oil because of failures such as break of spring, block of valve core is not to affect the maintenance of steering capability (not less than that of auxiliary steering gear)

Continued Table 7.1

No.	Specific requirements	Basis of inspection	Remarks
3.9	Strength of	3.1.1.5, 3.1.2, 3.1.5.1,	1. The strength of components transmitting mechanical

	components transmitting mechanical forces to the rudder stock	3.1.5.2, 4.2.5 of PART TWO and 13.1.6.7 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	forces (through internal cylinder limiters) between connection of rudder stock with rudder tiller (rotor of rotary vane type rudder actuator cylinder) and bolts connecting rudder actuator and hull seating (including thrust plates) is to be equivalent to the rudder stock strength in way of the tiller. 2. Unless expressly required otherwise in CCS Rules for Classification of Sea-Going Steel Ships or this Guideline, the following strength criterion of components and parts is to be met: Permissible equivalent stress【σ】= $118/K_s$ where: K_s – material factor of rudder stock, as defined in 3.1.5.1 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships. For ships intended for navigation in ice, strengthening of rudder stock is to be considered, including the influence of intensity of rudder by speed change, Etc. 3. If structural rudder stop or mechanical buffer is installed at the rudder tiller and the limiting inside the cylinder is not reached for functioning of the stop or buffer (at least 10 mm clearance is to be reserved inside the cylinder in this case), the strength of components transmitting mechanical forces from connection of rudder stock and rudder tiller to location of structural rudder stop or mechanical buffer is to be equivalent to the strength of rudder stock in way of the tiller. 4. The strength of non-pressurized components protected by structural rudder stop or mechanical buffer is to comply with the following requirement: When the safety valve of rudder actuator cylinder is opened because of external load imposed on rudder blades, the stress of protected components is $\sigma \leq 90\% R_{eH}$ (where R_{eH} is the yield strength of material of corresponding components). 5. When internal limiting inside rudder actuator cylinder is reached at design pressure, the stress of related non-pressurized components is to be $\sigma \leq 90\% R_{eH}$ (where R_{eH} is the yield strength of material of corresponding components). For rudder actuators with double cylinders or multi-vane rotating cylinders, synchronous limiting is also to be considered, e.g. the condition in which the forces of the 2 cylinders simultaneously act on the limiting part of one cylinder. 6. Internal limit rudder angle is usually to be taken as maximum rudder angle plus 1.5°. 7. Strength check of rudder tiller connection bolts is to be carried out according the requirements of 8.8 of this Guideline. 8. Strength check of rudder tiller connection rod is to be carried out according the requirements of 8.9 of this Guideline. 9. The fitting of safety valve of rudder actuator cylinder is not related to protection by "structural rudder stop or mechanical buffer"
3.10	Securing of rudder actuator and seating	13.1.11.1 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	1. Thrust plates and bolts etc. are to be designed and fitted to bear all foreseeable forces. The clips are not to be subjected to shear forces so far as possible. 2. The fitted bolts bear the rotating torque and horizontal shear forces of the rudder actuator. In the combination of bolt and thrust plate, bolt bears turning moment imposed by rudder actuator, while thrust plate bears horizontal shear force

Continued Table 7.1

No.	Specific requirements	Basis of inspection	Remarks

3.11	Fitting of seals		13.1.6.8 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	1. For non-duplicated rudder actuator cylinders, a sight port for oil leakage is recommended in the double sealing between moving components which form external force interface so as to find the failure of seal ring as early as possible, unless this is technically impracticable or similar rigid sealing material is adopted. 2. For duplicated hydraulic cylinders of steering gear, double sealing may not be required between moving components which form external force interface, upon agreement of CCS
3.12	Hydraulic piping fittings		3.1.6.9 and 13.1.6.5 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Isolating valves, pressure gauges and bleeding air valves directly connected to rudder actuator cylinder are not included
3.13	Rudder tiller	Section modulus	3.1.15.1 and 3.1.15.2 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships	
3.14		Height of boss of tiller external diameter	3.1.15.2 , 3.1.15.5of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships	The size of rotor of rotary vane type rudder actuator is to be referred to this requirement
3.15		Connection with the rudder stock	3.1.15.4, 3.1.17and 3.1.15.3 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships	1. If the specific size of rudder stock is not clear in design (e.g. general rudder actuator design), the means and strength of connecting rudder stock and rudder tiller are to be examined and approved by ship plans examination department. 1. For the marine hydraulic steering gear additionally required in 13.1.10, PART THREE of CCS Rules for Classification of Sea-going Steel Ships, if it is matched with a single rudder, bolted tiller (quadrant) hub structure consisted of two-half blocks could not be used for the rudder tiller connecting with rudder stock
4	Materials			
4.1	General		1.2.8.1 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Mainly pressure components and components transmitting mechanical forces in 4.1(6)
4.2	Materials of pressure components and components transmitting mechanical forces to rudder stock		13.1.4.1 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	1. For the hydraulic valve and its casing between power pump and oil cylinder isolating valve (not including the isolating valve), the requirements for elongation of material may be relaxed appropriately: (1) Unless provided otherwise by CCS, brittle material with impact toughness α_k less than 50 Nm/cm^2 and elongation δ less than 5% is usually not to be used for marine hydraulic valves; (2) For Class I and Class II duplicated piping systems which could operate as each other's standby or those provided with independent emergency means, consideration may be given to using grey cast iron as casing material of hydraulic valve between power pump and oil cylinder isolating valve (not including isolating valve). 2. The elongation of hydraulic manifold block material is not to be less then 12%. 3. For cold-drawn steel pipes used to manufacture hydraulic cylinders, usually the pipes delivered in annealed condition are to be purchased to ensure compliance with elongation requirements

Continued Table 7.1

No.	Specific requirements	Basis of inspection	Remarks

4.3	Conditions for use of hose assemblies	13.1.4.2 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Use of flexible hoses between fixed pipelines or between fixed pipeline and fixed equipment parts is forbidden, unless specially approved by CCS
4.4	Technical requirements for hose assemblies	13.1.4.3 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
4.5	Burst pressure of hose assemblies	13.1.4.4 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
5	Hydraulic systems		Consideration is to be given to compliance with the relevant applicable requirements of the Guidelines for hydraulic equipment device and its components
5.1	General	4.7 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	No fuse plug, but only a safety valve is to be provided for an accumulator supplying emergency power source. Special consideration is to be given to reliability of the safety valve and selection of its orifice (safety valves may be selected according to ISO 4126 standard)
5.2	Technical requirements for pipes, flanges, valves and fittings	13.1.7.1 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	To include the required calculation for strength check in respect of wall thickness
5.3	Fitting of safety valves	13.1.7.2 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	1. For the safety valve or relief valve at power pump outlet, the set pressure is to be 1.25 times the nominal system pressure so that the system will have short-time overload capacity. 2. For the safety valve at rudder actuator cylinder, the set pressure is to be 1.25 times the nominal system pressure, but may be adjusted as follows upon agreement of CCS: (1) Where oil returns from safety valve to the other space of the cylinder, the set pressure may be equal to 1.25 times the difference between cylinder inlet and outlet pressures at nominal torque output of rudder actuator; (2) Where oil return from safety valve to oil tank of the system, the set pressure may be equal to 1.25 times the pressure of inlet at nominal torque outlet of rudder actuator
5.4	Fitting of isolating valves	13.1.7.3 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	For rudder actuators of piston type cylinder etc. with duplicated cylinders, isolating valve may be installed at the outside end of connection between flexible hose and oil cylinder. When the flexible hose breaks and single oil cylinder is isolated, however, hydraulic locking is not to occur in the isolated cylinder and the remaining rudder actuator cylinder is still to be capable of providing necessary steering, unless expressly required otherwise in Chapter 13 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships
5.5	Fitting of filters	13.1.7.4 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	The manufacturer is to ensure that the capacity of filter used in the system or independent filtering device meet the requirements of hydraulic components for oil impurity and particles contained therein. In addition, pressure gauge or alternative equivalent means is to be provided before the filter to reveal blocking of filter in time
5.6	Fitting of level alarms	13.1.7.5 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	The effects of inclination and roll of the ship are to be considered
5.7	Fitting of arrangements for bleeding air	13.1.7.6 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
No.	Specific requirements	Basis of inspection	Remarks

Continued Table 7.1

No.	Specific requirements	Basis of inspection	Remarks

5.8	Hydraulic locking		13.1.7.7 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	The difference of return oil mass in synchronic running is to be considered. For example, the daily oil circulation tanks in two systems are to be interconnected at high level and isolated from each other at normal level
5.9	Fitting of storage tanks		13.1.7.8 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
5.10	Arrangement of power piping		13.1.7.9 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
5.11	Design temperature of hydraulic system		13.1.9.1, 1.2.1.2 and 2.1.4.1 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	1. Usually from maximum ambient temperature to the temperature when the inside temperature of circulating oil tank (of open-type systems) reaches 60℃ ~ 65℃ (i.e. maximum ambient temperature + system temperature rise). The system temperature rise is usually controlled within 20 K. Unless special consideration is given to selection of hydraulic oil and hydraulic components, oil cooler is to be installed. 2. The working temperature range of the system and any component is not to exceed the limits required for safe use. 3. When a heater is used, its dissipation power per unit area is not to exceed the range recommended by the hydraulic oil manufacturer. Automatic temperature control is to be adopted to keep the expected hydraulic oil temperature
6	Monitoring and alarms			
6.1	Monitoring and alarm items	Failures of steering gear power unit	13.1.5.5.3, 13.1.9.1 and 13.1.9.3 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Where possible, failure signals from monitoring points are to be taken in the following sequence: (1) Failure of hydraulic pump; (2) Failure of driver (electric motor); (3) Failure of power supply
6.2		Power failures of steering gear control system	13.1.9.1 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	1. Hydraulic remote control systems are to be additionally provided with alarm for pressure loss of control system; 2. If control power is supplied by steering gear power unit, low pressure alarm is not necessary, but alarm for control power failure is to be provided
6.3		Low level of hydraulic oil tank	13.1.7.5 and 13.1.9.1 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	The effects of roll of the ship are to be considered
6.4		High hydraulic oil temperature	13.1.9.1 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Alarm is usually set at 60℃ ~ 65℃, not higher than 70℃. The rise of system temperature is usually controlled within 20 K. Unless special consideration is given to selection of hydraulic oil and hydraulic components, oil cooler is to be installed to keep oil temperature below 60℃
6.5		Blocked oil Filter	13.1.9.1 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Usually it is in accordance with the set value provided by the filter manufacturer for pressure difference sensors. Otherwise, alarm value is to be set for the pressure not exceeding 0.35 MPa at both ends of the filter (pressure on filter casing is to be considered)
6.6		Hydraulic locking	13.1.9.1 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
6.7	Hydraulic locking failures		13.1.9.5 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Following alarm condition may be considered in lieu of hydraulic locking caused by synchronic operation of the steering gear: Alarm is to be initiated when the steering order and the rudder actuator response are not consistent with each other

Continued Table 7.1

No.	Specific requirements	Basis of inspection	Remarks

7	Additional requirements for large special ships		
7.1	Provision of power equipment of hydraulic steering gear as main steering gear	13.1.10.1 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
7.2	Setting of hydraulic steering gear as main steering gear	13.1.10.2(1) of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Automatic or remote control instead of local manual means is to be adopted for failure isolation
7.3	Composition of hydraulic steering gear as main steering gear	13.1.10.2(2) of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	
7.4	Conditions for exemption from single failure criterion	13.1.10.3 (1) of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Where duplicated rudder actuators are provided or the single actuator complies with 13.1.10.3 (2) of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships, automatic or remote control instead of local manual means is to be preferred for failure isolation. Otherwise, the manufacturer is to give clear and operable instruction and safety caution for emergency troubleshooting in the product instructions and on the block diagram required in 13.1.11.3 of CCS Rules for Classification of Sea-Going Steel Ships to facilitate emergency control by crew within 45s required by CCS Rules for Classification of Sea-Going Steel Ships
7.5	Setting of single power actuating system	13.1.10.3 (2) and 13.1.10.4 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	The stress analysis required in 13.1.10.3 (2) is to include acceptance criteria.
8	Non-destructive test		
8.1	Non-destructive test of main components of rudder actuator		To be determined according to the drawings and parts manufacturing process
9	Indication of rudder angle		
9.1	Rudder angle indicator	13.1.8.3 of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	1. The operator is to be able to see the rudder angle indicator of controlled rudder actuator, which may be mechanical rudder angle indicator, at the steering gear or emergency steering gear control position in the steering gear compartment. 2. The deviation of angle displayed by mechanical rudder angle indicator from actual rudder angle is not to be more than ±1 °. 3. The graduation of rudder angle indicator is not to be more than 1 °. For mechanical rudder angle indicator, clear marks (e.g. different length and color of graduation lines) are to be given at the maximum rudder angle and internal limit rudder angle

7.2 Additional technical requirements

(1) The nominal torque of different rudder actuators is to be calculated as follows respectively:

① The following conditions are assumed for calculation of nominal rudder actuator torque in ② ~ ④:

(i) the torque refers to the theoretical nominal rudder actuator torque output in the condition of single rudder actuator driving single rudder stock. For service conditions in which two or three rudder stocks are driven by artificial rudder stock and rudder

tiller connecting rod, additional mechanical efficiency loss is to be considered when selecting the product. For two sets of cylinders of the ram type rudder actuator, four hydraulic cylinders of the piston type rudder actuator and double cylinders of the rotary vane type rudder actuator, the theoretical nominal rudder actuator torques calculated below is to be multiplied by 2 and so on;

(ii) hydraulic oil of a given type (viscosity) is to be used;

(iii) 40℃ is to be taken as reference criterion, if specific temperature conditions are not specified by the manufacturer;

(iv) maximum design rudder actuator speed is to be clearly indicated.

② For output torque M_1 of ram type rudder actuator with one set of cylinder:

$$M_1 = \pi D_1^2 R_1 \Delta P \eta_1 / 4 Cos^2\alpha \times 10^{-6} \quad \text{kNm}$$

where: D_1 – diameter of ram, in mm;

R_1 – radius of rudder tiller, in mm;

ΔP – pressure difference between oil inlet and oil outlet of rudder actuator cylinder, in MPa;

α – rotating angle, usually with nominal rudder actuator toque taken as the torque output at $\alpha = \pm 35°$;

η_1 – mechanical efficiency of rudder actuator for $\alpha = \pm 35°$, usually taken as 0.80 ~ 0.85; the correctness of efficiency valve calculated for the first one of rudder actuators of the same type is usually to be verified through test.

③ For output torque M_2 of piston type rudder actuator (with two double acting hydraulic cylinders):

$$M_2 = \pi (2D_2^2 - d_2^2) R_2 \Delta P \eta_2 Cos\alpha / 4 \times 10^{-6} \quad \text{kNm}$$

where: D_2 – bore diameter of rudder actuator hydraulic cylinder, in mm;

d_2 – action diameter of piston rod, in mm;

R_2 – radius of rudder tiller, in mm;

ΔP – pressure difference between oil inlet and oil outlet of rudder actuator cylinder, in MPa;

α – rotating angle, usually with nominal rudder actuator toque taken as the torque output at $\alpha = \pm 35°$;

η_2 – mechanical efficiency of rudder actuator for $\alpha = \pm 35°$, usually taken as 0.90 ~ 0.94; the correctness of efficiency valve calculated for the first one of rudder actuators of the same type is usually to be verified through test.

④ For output torque M_3 of rotary vane type rudder actuator (assuming that the action area of oil pressure of vanes being rectangular):

$$M_3 = 0.125\, i \Delta P\, H(D_3^2 - d_3^2)\, \eta_3 \times 10^{-6} \quad \text{kNm}$$

where: i – number of vanes;

ΔP – pressure difference between oil inlet and oil outlet of rudder actuator cylinder, in MPa;

H – height of working capacity, i.e. theoretical height of the vane, in mm;

D_3 – inside diameter of rudder actuator cylinder, i.e. theoretical outside diameter of the vane, in mm;

d_3 – outside diameter of rotor (rotating shaft), i.e. theoretical inside diameter of the vane, in mm;

η_3 – mechanical efficiency of rudder actuator at α = ±35°, the value of which being related to type, material of seal and position of sealing and to rotating shaft support, usually taken as 0.80 ~ 0.85; the correctness of efficiency valve calculated for the first one of rudder actuators of the same type is usually to be verified through test.

(2) The nominal system pressure is to be calculated according to the following formula:

$$P_0 = \Delta P_i + \Delta P_{in} + \Delta P_{out}$$

where: P_0 – nominal system pressure, i.e. pressure at pump outlet, in MPa;

ΔP_i – pressure difference between oil inlet and oil outlet of rudder actuator cylinder, in MPa;

ΔP_{in} – pressure loss through piping between pump outlet to cylinder oil inlet at the maximum system design flow, in MPa;

ΔP_{out} – pressure loss through piping between cylinder oil outlet and oil tank or pump oil inlet at the maximum system design flow, in MPa.

The conditions assumed for the above calculation of nominal system pressure are given in 7.2(1) of this Guideline. For hydraulic oils of different types and different reference test temperatures and flows, flow path loss of the system is different due to factors such as change of viscosity of hydraulic oil, and the manufacturer is to make clear the condition in which a value is taken. The first product is usually to be tested to verify the correctness of pressure loss of the system through its piping, with the same configuration and at the maximum flow.

(3) The calculation of rudder actuator cylinder system capacity is to be rechecked by calculation of flow needed and time required for steering as follows:

① Calculation of theoretical capacity of rudder actuator cylinder (corresponding to movement of single power rudder actuator from 35 °at one side to 30 °at the other side):

(i) for ram type rudder actuator (one set of cylinder):

$$V = \pi D_1^2 R(tg35° + tg30°)/4 \times 10^{-6} \quad l$$

(ii) for piston type rudder actuator (with two double acting hydraulic cylinders):

$$V = \pi(2D_2^2 - d_2^2) L_3/4 \times 10^{-6} \quad l$$

where: L_3 – the stroke of the rudder actuator cylinder from 35 °at one side to 30 °at the other side).

(iii) for rotary vane type oil cylinder (for movement to 65 °):

$$V = \pi(D_3^2 - d_3^2) H \times i \times 65°/(4 \times 360°) \times 10^{-6} \quad l$$

② The determination of flow of main oil pump of power system:

$$Q \geq 60V/T_0\eta_v \quad l/min$$

where: Q – the minimum selected flow of main oil pump, in /min;

V – capacity of oil cylinder corresponding to movement of rudder actuator from 35 °at one side to 30 °at the other side, in l;

T_0 – time required by design for rudder movement, taken as 28 s for sea-going ships;

η_v – capacity efficiency of power system; selected according to different hydraulic systems and rudder actuators.

③ Recheck of time required for rudder movement:

$$T_0 = 60V/Q_0 \quad sec$$

where: T_0 – time required by design for rudder movement, in sec;

Q_0 – actual flow of pump, calculated according to capacity of pump, speed of driving device and capacity efficiency of pump, in l/min.

(4) Calculation for driving power and selection of electric motors:

$$N \geq P_s\, Q_0/60\eta_b\, n_b \quad \text{kW}$$

where: N – driving power needed (power of electric motor), in kW;

P_s – system design pressure, in MPa;

Q_0 – actual flow of oil pump calculated according to 7.2(3) of this Guideline in l/min;

n_b – overload coefficient of electric motor, usually ≤ 1.6 unless specially approved by CCS;

η_b – total efficiency of the oil pump, to be selected according to data (such as pressure – flow – efficiency curve) provided by the manufacturer, usually with total efficiency of ram pumps being 0.80 ~ 0.85, that of vane pumps being 0.60 ~ 0.75, and that of gear pumps being 0.60 ~ 0.70.

For variable delivery pumps the flow of which can be adjusted by the user, the maximum permissible adjustment (corresponding to minimum time required for rudder movement) value is to be given:

$$Q_{0max} = 61.2\, \eta_b\, n_b\, N/\, P_s$$

$$T_{0min} = 60\, V/Q_{0max}$$

(5) Unless stated otherwise, the rudder actuator of hydraulic steering gear is not to be subjected to upward and/or downward axial forces and radial forces produced by rudder stock additionally.

7.3 Symbol

(1) Permanent nameplate for the products should be set up .Nameplate should be made by the corrosion resistant materials such as stainless steel or brass.

(2) Normally the following content should be etched in the nameplate at least:

① Name,type

② Factory name or registered trademark

③ The main technical parameters, such as nominal steering torque and maximum working pressure, time of rudder movement, maximum steering angle

④ Product ID

⑤ Manufacturing date

(3) Product ID should to be marked on the cylinder body(such as flange outer)

(4) Product specification mentioned in rticle 4.2 (2) in this guidance and mention of article 4.3 for the nameplate words often should use Chinese/English control mode identification. If the product non-chinese owners will use, can only use English.

8 Strength requirements

8.1 In addition to the strength calculation clearly required by CCS Rules for Classification of

Sea-Going Steel Ships, the strength of the following components of rudder actuators is to be checked by the manufacturers and meet the relevant requirements of permissible stresses in this Guideline:

(1) Ram type rudder actuator cylinder:

① bolts of flange cover;

② pressure strength and bending strength of ram;

③ bending strength and shear strength of ram pin;

④ strength of bolts of cylinder base against combined horizontal shear forces and combined tensile forces caused by axial and lateral moments of ram, and strength requirements for thrust plates as necessary;

⑤ bending strength and pressure strength (if roller is used) of fork of rudder tiller;

⑥ bending strength and shear strength by means of artificial rudder stock, if applicable;

⑦ compression strength of sliding bearing of cylinder;

⑧ compression strength of upper and lower sliding bearings of ram pin.

(2) Piston type rudder actuator cylinder:

① strength of end cover bolts (or threads, screws);

② tensile strength and stability of piston rod (including threads at both ends) for cylinder stroke $S \geq 10\ D_2$;

③ strength of support;

④ strength of bolts of support (strength requirements for thrust plates as necessary);

⑤ bending strength and shear strength of pin shaft;

⑥ compression strength of pin shaft bearing;

⑦ strength of cylinder and piston rod earring.

(3) Rotary vane type rudder actuator cylinder:

① bolts of cylinder cover;

② fixed vane bending strength and its connection structural strength;

③ rotary vane bending strength and its connection structural strength;

④ strength of bolts of cylinder seating (strength requirements for thrust plates as necessary);

⑤ strength of rotor;

⑥ strength of connection between rotor and rudder stock.

(4) Rudder tiller:

① joining bolts, if applicable;

② strength of connection with rudder stock, if applicable.

(5) Structural strength of rudder tiller connecting rod:

① check of strength of connecting rod sectional area;

② bending strength and shear strength of pin shaft connected with rudder tiller;

③ compression strength of pin bearing;

④ strength of earring.

8.2 If the isolating valve is non-standard and self-made, the strength of bolts connected with cylinder pads and bolts of compressing cover of valve core is to be checked.

8.3 Permissible stresses

Unless expressly provided otherwise in this Guideline, for the purpose of determining the dimensions of parts of rudder actuators, the permissible stresses are not to exceed the following

values:

$$\sigma_m \leq 【\sigma】$$

$$\sigma_l \leq 1.5【\sigma】$$
$$\sigma_n \leq 1.5【\sigma】$$
$$\sigma_l + \sigma_n \leq 1.5【\sigma】$$
$$\sigma_m + \sigma_n \leq 1.5【\sigma】$$
$$【\tau_j】 = (0.6 \sim 0.8)【\sigma】$$
$$【\tau_n】 = (0.5 \sim 0.6)【\sigma】$$
$$【\sigma_{jy}】 = (1.7 \sim 2)【\sigma】$$

where: σ_m – equivalent primary general membrane stress, in N/mm^2;
σ_l – equivalent primary local membrane stress, in N/mm^2;
σ_n – equivalent primary bending stress, in N/mm^2;
$【\tau_j】$ – permissible shear stress of steel, in N/mm^2;
$【\tau_n】$ – permissible torsional shear stress of steel, in N/mm^2;
$【\sigma_{jy}】$ – permissible compression stress, in N/mm^2;
$【\sigma】$ – the lesser of R_m/A or R_{eH}/B, in N/mm^2;
R_m – tensile strength of material at ambient temperature, in N/mm^2;
R_{eH} – yield point or proof stress of material at ambient temperature, in N/mm^2.

The values of A and B are to be selected respectively according to related definitions in Chapter 13 (Table 13.1.6.2, or Table 1.2.3 of Appendix 1), PART THREE of CCS Rules for Classification of Sea-Going Steel Ships.

8.4 Requirements for check of normal stresses:

(1) Check of pure shear strength:

$$\tau_j = Q_j/F_j \leq 【\tau_j】$$

where: Q_j – shear stress acting on the shear area, in N;
F_j – shear area, in mm^2.

(2) Check of shear strength for bending:

For beams of rectangular section: $\tau_j = 3Q_j/2bh \leq 【\tau_j】$

where: h – height, in m;
b – breadth, in m.

For beams of circular section: $\tau_j = 4Q_j/3\pi R^2 \leq 【\tau_j】$

where: R – radius of circle, in m.

(3) Check of pure compression strength:

$$\sigma_{jy} = Q_{jy}/F_{jy} \leq 【\sigma_{jy}】$$

where: Q_{jy} – compressive force on the compressed area, in N;
F_{jy} – compressed area surface, in mm^2.

(4) Check of pure bending strength:

$$\sigma_n = (M / W_z) \times 10^{-6} \leq 1.5【\sigma】$$

where: M – bending moment, in Nm;
W_z – bending section modulus, in m^3.

For rectangular section: $W_z = bh^2/6$

where: h – height, in m;
b – breadth, in m.

For circular section: $W_z = \pi D^3/32$

where: D – diameter of circle, in m.

(5) Check of pure torsional strength:

$$\tau_n = (M_n/W_n) \times 10^{-6} \leq 【\tau_n】$$

where: M_n – torque, in Nm;

W_n – torsional section modulus, in m^3.

For circular section: $W_n = \pi D^3/16$

where: D – diameter of circle, in m.

For hollow circular section: $W_n = \pi (D^4 - d^4)/16\ D$

where: D – outside diameter of circle, in m;

d – inside diameter of circle, in m.

(6) Check of strength for combined bending and torsional moments:

$$(\sigma_n^2 + 3\tau_n^2)^{1/2} \leq 【\sigma】$$

where: σ_n – pure bending stress, in N/mm^2;

τ_n – pure torsional stress, in N/mm^2.

8.5 Check of strength of thread of preloaded bolts and screws (the depth the thread screws in is not to be less than the diameter of the bolt)

Composite stress at the thread:

$$\sigma_L = 1.66\ (K_0 + K_c)\ F_L/d_L^2 \leq 【\sigma】 \quad \text{MPa}$$

where: K_0 – preloaded thread coefficient, with static load $K_0 = 1.2 \sim 2$; dynamic load $K_0 = 2 \sim 4$;

K_c – coefficient of rigidity, with $K_c = 0.2$ for connecting rod bolts and $K_c = 0.2 \sim 0.3$ for steel plate (or with metal gasket) connection;

F_L – maximum tensile force acting on a single bolt, in N;

d_L – inside diameter of thread, in mm.

8.6 Check of strength of seating and its fastening bolt group subjected to capsizing moment:

(1) The conditions assumed for calculation of (2):

① diameter and preloaded force of bolts are the same;

② the axis of capsizing moment is at the lower opposite angles of the seating in the direction of forces;

③ each row of bolts are symmetrically the same in the vertical direction of forces.

(2) The maximum tensile force acting on bolts due to capsizing moment:

$$F_L = L_{max}M/z\ (L_1^2 + L_2^2 + \ldots\ldots + L_i^2) \times 10^3 \quad \text{N}$$

where: F_L – maximum tensile force acting on a single bolt, in N;

L_{max} – the maximum distance between axis of capsizing moment and the farthest bolt, in mm;

M – capsizing moment, in Nm;

z – number of rows of the bolts in transverse direction;

$L_1, L_2, \ldots\ldots, L_i$ – distance between axis of capsizing moment of bolt group and bolts, in mm.

Combination of forces in different direction is to be considered.

8.7 Check of stability of compression rod

The stability of piston rod is to be checked for oil cylinder stroke $S \geq 10d_2$. For hydraulic cylinders with a steel piston rod articulated at both ends:

when $L > 21.25d_2$:

$$F_k = d_2^4/L^2 \times 10^5 \geq n_k F \quad \text{N}$$

when $L \leq 21.25d_2$:

$$F_k = 1.2d_2^4/(312.5d_2^2 + L^2) \times 10^5 \geq n_k F \quad \text{N}$$

where: F_k – limit force of stability of the compression rod of piston rod, in N;

F – maximum design thrust of oil cylinder, in N;

L – calculated length of piston rod (maximum distance between the two articulation holes), in mm;

n_k – safety factor; generally $n_k = 2 \sim 4$.

8.8 The strength of connecting bolts of rudder tiller may be checked according to 3.1.15.3, Part Two of the CCS Rules for Classification of Sea-going Steel Ships8.9 The strength of rudder tiller connecting rod may be checked according to 3.1.15.4, Part Two of the CCS Rules for Classification of Sea-going Steel Ships

9 Approval

9.1 Principles of selection of typical samples

9.1.1 One sample is to be selected randomly for type test when the manufacturer applies for design approval of products with single specification.

9.1.2 One sample which is the most representative or one with maximum specification is to be selected for type test when the manufacturer applies for type approval of product series with the same type but different specifications. When main technical data do not cover all the products, the number of samples may be increased appropriately or combined sampling is to be adopted to reach an effective coverage of the products.

9.1.3 Samples may be taken in groups or batches when the manufacturer applies for type approval of products with different types and specifications, i.e. hydraulic power systems, steering gear control systems and rudder actuators may be examined either separately or in combination:

(1) hydraulic systems: Categories may be based on principles of hydraulic power and control systems. For each type of hydraulic systems of which the parts are basically the same and only the nominal pressure or required flow is different, consideration is to be given to the maximum nominal pressure and flow in selection of samples;

(2) rudder actuators: For rudder actuators with the same drawing number/type which are only different in nominal pressure and (rotating) speed, the specifications with maximum nominal pressure and (rotating) speed are to be considered in selecting samples, covering different types of rudder actuators;

(3) conditions at minimum and maximum speeds are to be examined for pumps driven by diesel engine;

(4) if the general arrangement (system drawing) includes controls such as steering gear operation console, mechanical and electrical equipments are to be adjusted together in type test.

10 Type test

10.1 According to the requirements in Chapter 3, PART ONE of CCS Rules for Classification of Sea-Going Steel Ships, steering gears are to be subject design approval. However, the type approval may be selected by the manufacturer.

10.2 The type test programme provided by the applicant for design or type approval of hydraulic steering gears is usually at least to cover the following:
(1) Test items for which CCS surveyor is to be present:
Inspection and test items in 10.3 and 10.4 of this Guideline are involved.
Steering gears above 630kNm, which have mature structure and under normal working pressure on the base of sufficient design, manufacture and use experience may not carry out the load test in 10.4(5) ~ (9) in the manufacturer with the special approval by CCS, and navigational test results could be in lieu of load test. If the new designed steering gear does not meet these requirements, load test is to be carried out by proportionally reduced samples. The requirements of load test are the same as those for type test.
(2) Inspection items to be completed by the manufacturer:

Test items and requirements specified in the design standard(s) selected and shown in public by the manufacture.

10.3 At least the inspections and tests required in Table 10.3 are to be carried out at the manufacturer.

Tests at manufacturer **Table 10.3**

No.	Specific requirements	Basis of inspection	Remarks
1	Tests of pipes, flanges valves and fittings	13.1.12.1(1) of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Regarding requirements for Class I piping systems in Chapter 2, PART THREE of CCS Rules for Classification of Sea-Going Steel Ships , hydraulic test is to be carried out according to 2.7.1 and 2.7.1, with test pressure being kept for 5 min
2	Test of hydraulic steering gear components subject to internal pressure	13.1.12.1(2) of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	1. Mainly, the rudder actuator cylinder and the first closing device connected to the cylinder are to be tested according to the requirements for Class I pressure vessels in Chapter 6, PART THREE of CCS Rules for Classification of Sea-Going Steel Ships s, i.e. hydraulic test is to be carried out according to the requirements of 6.6.2, with test pressure being kept for 5 min (30 min for accumulators). 2. For purchased components, certification may be required in lieu of test
3	Type test of pump of power unit	13.1.12.1(3) of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	1. If the self-made hydraulic pump has been inspected satisfactorily by CCS Surveyor, it may be exempted from the 100 h individual test; 2. For purchased components, certification may be required in lieu of test
4	Test of diesel engine of driving power unit	13.1.12.1(4) of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Certification may be required in lieu of test
5	Test of electric motor of driving power unit	13.1.12.1(5) of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	Certification may be required in lieu of test

Continued Table 10.3

No.	Specific requirements	Basis of inspection	Remarks
6	Final inspection and operation test after general assembly	13.1.12.1(6) of PART THREE of CCS Rules for Classification of Sea-Going Steel Ships	1. It is to be carried out in accordance with the requirements of 10.4 of this Guideline, in special case, other equivalent test methods may be accepted by CCS. 2. During the matching test with electrical control system of steering gear, its test items, methods and requirements are also to comply with the "steering control system" of this Guidelines

10.4 Type test items, methods and requirements

(1) Trial test:

Recommended methods:

① The tested steering gear is under no-load operation condition, steering is to be carried out three times for each unit in turn within the range of ±5°,±10°,±15°,±20°,±25°,±30° and ±35° respectively. The error of rudder angle is to be inspected. When the rudder angle α of pump controlled hydraulic steer gear is inspected, the indicated location 5 s after the rudder reaches the angle $(\alpha-1)^\circ$ is regarded as the stopping location.

② Two units are to be transferred each other for three times, if the two units are designed to run synchronously, they are to work simultaneously and steering is to be carried out for three times within the range of ±35°, where the double units of pump control system run simultaneously, synchronous steering test may be carried out after the units run for 15 min at the meanwhile under the working condition of the oil pump displacement of zero.

Note: if the drawing includes the greater rudder angle exceeding ±35°, the maximum rudder angle is to be covered in the test.

The test is to verify:

① the maximum rudder angle, mechanical limit rudder angle inside the cylinder, time required for rudder movement (effect of volume capacity of system is to be considered) are to meet the design settings of the approved drawings;

② that two sets of stroke limit switches for maximum rudder angle are to be provided and located as far as possible, consideration is to be given that the steering actuator could not be damaged during its running to the mechanical limit rudder angle if the switches fail;

③ for the manually operated emergency steering gear, test is to be carried out and the operation is to be quickly and reliably;

④ the design performances verification, including operation correctness is to meet the settings of the approved drawings;

⑤ synchronic running of double units (if applicable), monitoring and alarm of hydraulic locking is also to be verified, as appropriate;

⑥ that the oil temperature sensors (if applicable), filter blocking sensors (indicators), pressure sensors (gauges), etc. are in normal working order;

⑦ no other abnormal phenomena.

(2) No-load operation test:

Recommended methods:

① The loading system is to be connected with the tested steering gear;

② According to the trial conditions, steering is to be carried out for 10 min for each power unit in turn within the range of ±35°. If the two units are designed to run synchronously, they are to work simultaneously, and steering is to be carried out for 5 min within the range of ±35°.

Note: if the drawing includes the greater rudder angle exceeding ±35°, the maximum rudder angle is to be covered in the test.

The verification requirements of test are referred to trail test.

(3) Tightness test:

Tightness test is to be carried out for hydraulic steering gear with the pressure of 1.25 times design pressure and maintained for 5 min. There are to be no leakage and other abnormal

phenomena.

(4) Safety valves test:

The settings of safety valves at maximum displacement (rudder movement speed) and pressure changing with the displacement are to meet the design requirements of approved drawings and the requirements in 13.1.7.2, PART THREE of CCS Rules for Classification of Sea-going Steel Ships. The test is to be repeated for three times, and the average value is to be taken.

The safety valves are to be operated quickly and reliably, without any abnormal phenomena.

(5) Load test:

Recommended methods:

The loading system is to be adjusted so that the steering gear could be operated at the 25%, 50%, 75% and 100% maximum working pressure, respectively, steering is to be carried out for 15 min for each power unit in turn within the range of ±35°. If the two units are designed to run synchronously, they are to work simultaneously and steering is to be carried out for 5 min within the range of ±35°.

The relevant test data are to be recorded, including rudder angle, oil pressure (including the outlet of main pumps, the inlet/outlet of rudder actuator cylinders, etc), output torque, time required for rudder movement, power of motor, oil temperature, etc.

Note: if the drawing includes the greater rudder angle exceeding ±35°, the maximum rudder angle is to be covered in the test. The load selection corresponding to the rudder angle is to meet the design requirements of drawings.

The test is to verify:

① that the output torques within the range of ±35° and at the maximum rudder angle are to meet the nominal torque requirements of the drawings;

② for mechanical or hydraulic operated steering gears, the sluggish rudder time is not to be less than 1s;

③ for the hydraulic or mechanical steering gears with wheels, the idling of hand wheel could not be exceeding half circle, the force on the hand wheel is not to be more than 160 N;

④ the rush rudder angle of non-mechanical feedback hydraulic steering gear is not to be greater than 2°.

⑤ the time required for rudder movement and overload of motor are to meet the design requirements;

⑥ transfer of hydraulic power source unit and operational mode is to be quickly and reliably;

(a) the transfer of power unit is to be quickly;

(b) the transfer period of power source operational mode made by one person is not more than 10s;

⑦ no obvious leakage for the system and the temperature rise is to meet the design requirements;

⑧ the rudder runs in a stable way, without serious overspeed, creep, hydraulic impact, etc.

(6) Rudder hold test:

Recommended methods:

When the hydraulic steering gear is not in follow-up or autopilot mode, the rudder runs to the position of ±35°, the loading system is adjusted so as that the torque of rudder stock is the nominal torque of rudder movement required by drawings, the rudder movement speed is to be measured.

The test is to verify:

that the rudder movement is not to exceed 0.5°/min for ram type rudder actuator and piston type rudder actuator, and not to exceed 1°/min for rotary vane type rudder actuator, and without any abnormal phenomena.

(7) Steering test with minus torque (if applicable):

Recommended methods:

① steering is carried out at no-load operation condition, and the time required for rudder movement *t* from the range from ±35° to ±5° is to be recorded;

② When the hydraulic steering gear is not in follow-up or autopilot mode, the rudder runs to the position ±35°, the loading system is adjusted (for the displacement and pressure of oil pump for loading system) so as that the equivalent speed of rudder movement corresponding to the displacement of oil loading pump is obviously more than the

no-load running speed of tested rudder when the loading system pushes counter to the tested rudder, the torque of rudder stock reaches the nominal torque required by drawings, the simulated working conditions with minus torque occurs for the steering from the range of ±35° to ±5°, the time required for rudder movement *t* is to be recorded. Each unit is to be carried out for three times in turn.

The test is to verify:

that the ratio between the time *t'* required for rudder movement from 35° to 5° with balance valve acting at minus torque and the time required for rudder movement *t* from 35° to 5° in normal condition without minus torque is not to be less than 0.9, and without any abnormal phenomena.

(8) Overload test:

Recommended methods:

The loading system is to be adjusted so as that the steering gear is tested at 110% maximum working condition. Steering is carried out for 5 min for each unit within the range of ±35° (safety valve and time required for rudder movement are not required to adjust).

The test is to verify: that the steering gear has a certain capability of working under overloading condition, the rudder movement speed is not to be reduced obviously and without any other abnormal phenomena.

(9) Continuous running test:

Recommended methods:

① The loading system is to be adjusted so as that the steering gear runs reciprocately at maximum design rudder angle and the maximum working pressure. The test period: the two power units run simultaneously for 12h for the steering gear with the nominal steering torque less than or equal to 100kNm; totally run 12h for the steering gear with the nominal steering torque more than 100kNm; the test period for novel structured or special required steering gear is to be of 50h. Test data are to be recorded every 2h.

② If the continuous running test is stopped due to the failure other than the tested steering gear, the repairing time is to be deducted from accumulated test period.

③ After the continuous running test is finished, the output torque of steering gear is to be retested, the method is the same as load test in (5).

The test is to verify:

① the temperature rise of the system meets the design requirements and the output torque of steering gear after test is still to be in compliance with the design requirements of drawings.

② there is no abnormal phenomena.

(10) Dismantling

Recommended methods:

The main components and parts under force, friction parts and sealed parts (excluding purchased standard hydraulic equipment units) are to be dismantled, the clearness of hydraulic oil in the system is to be inspected.

The test is to verify:

there is no excessive wear of components and parts, the clearness of hydraulic oil is normal without any abnormal phenomena.

(11) Low level test:

Recommended methods:

Each tank of steering gear power unit is discharged in turn and the liquid level indicator is to be observed.

The test is to verify:

① the level of tank is to meet the design requirements of the approved drawings when the liquid level indicator is working, the unit of steering gear could still be in normal working order when the ship's inclination is taken into consideration and there is no abnormal phenomena.

② the pumps are to be capability of starting quickly and reliably at the working critical point of liquid level indicator.

(12) Pressure loss test of auxiliary piping (if applicable):

Recommended methods:

① One power unit is started to simulate the failure of pressure loss for the steering gear by

discharging oil or reducing pressure of the auxiliary piping system, each indicator of alarm and isolation of single failure of steering gear and transfer device is to be observed.

② Another unit is transferred to carry out the simulation test as above-mentioned.

③ The above-mentioned tests are to be repeated for three times.

The test is to verify:

the alarm output of single failure, (automatic or manual) isolation and transfer time of unit, steering capability after isolation due to single failure, etc. are to meet the relevant requirements of CCS Rules for Classification of Sea-going Steel Ships, this Guideline and the design requirements of the approved drawings.

(13) Pressure loss test of main piping (if applicable):

Recommended methods:

① One power unit is started to simulate the failure of pressure loss for the steering gear by discharging oil or reducing pressure of the main piping system, each indicator of alarm and isolation of single failure of steering gear and transfer device is to be observed.

② Another unit is transferred to carry out the stimulation test as above-mentioned.

③ The above-mentioned tests are to be repeated for three times.

The test is to verify:

the alarm output of single failure, (automatic or manual) isolation and transfer time of unit, steering capability after isolation due to single failure, etc. are to meet the relevant requirements of CCS Rules for Classification of Sea-going Steel Ships, this Guideline and the design requirements of the approved drawings.

(14) Double units failure transfer test (if applicable):

Recommended methods:

Two power units are started at the meanwhile to simulate the single failure of steering gear by discharging oil of the main and auxiliary piping systems at any side of the steering gear in turn. Each indicator of alarm and isolation of single failure of steering gear and transfer device is to be observed. The above-mentioned tests are to be repeated for three times.

The test is to verify:

the alarm output of single failure, (automatic or manual) isolation and transfer time of unit, steering capability after isolation due to single failure, etc. are to meet the relevant requirements of CCS Rules for Classification of Sea-going Steel Ships, this Guideline and the design requirements of the approved drawings.

10.5 Test conditions

10.5.1 The test is to be carried out on a special test bench. The load characteristics of loading device are to simulate the ship's actual steering conditions. It is recommended to carry out the test in accordance with the requirements of CB/T3130 Test Methods for Hydraulic Steering Gears.

10.5.2 The test oil is to meet the following requirements:

(1) oil temperature: during the test, it is usually maintained within the range of 40℃ ~ 55℃ . Where it is not permitted or it has special requirement, other consideration may be taken after discussion. If necessary, all the test data are to be converted to the performance values at the specified oil temperature of the test. Ambient temperature and oil temperature of tested hydraulic steering gear system are to be recorded.

(2) viscosity: test oil of the tested hydraulic steering gear is to be used in accordance with the specifications provided by the manufacturer. Brand of test hydraulic oil is to be recorded.

(3) requirements of test instruments:

① direct reading instrument: its accuracy doesn't lower than Grade 1 for type test and does not lower than Grade 1.6 for routine test, instrument installed in the steering gear could be accepted for use in the special cases.

② sensors and associated secondary instrument are to be provided with certificates, term of service and calibration card.

11 Unit/batch inspection

11.1 Quality assurance

11.1.1 The manufacturer is to ensure the hydraulic steering gear is so designed, manufactured, inspected and tested as to meet the performance characteristics of sample approved by CCS or type test sample.

11.11.2 The manufacturer is to ensure to carry out quality control for product design, manufacture, inspection and identification in accordance with the relevant requirements of this Guideline. The hydraulic steering gear which does not meet the requirements of this Guideline are not allowed to sale with the mark related to inspection requirements of CCS,

11.2 Inspection

(1) The manufacturer is to provide all necessary suitable conditions to the CCS site surveyor in order to verify that the provided documents are in compliance with the requirements of this Guideline, at least including:

(1) quality documents of the main components and parts;

(2) manufacturer’s inspection and test report (inspection and test items are to meet the requirements in 11.3 ~ 11.4);

(3) document of compliance or certificate of product.

11.3 According to the requirements in Chapter 3, PART ONE of CCS Rules for Classification of Sea-going Steel Ships, The test items after CCS approval usually is to include the followings:

(1) Pressure test prior to assembly;

(2) Operational test after assembly, unless expressly provided otherwise in inspection programme mentioned in 11.5 of this Guideline, the test items and requirements usually include the contents in 10.4(1) ~ (7) and (11) ~ (14) of this Guideline, in which load test may only be carried out at 50% and 100% maximum working pressure.

11.4 The manufacturer is also to ensure completion of the following inspection items:

(1) routine inspection and test items specified in the design standard(s) selected and shown in public by the manufacture;

(2) special test items added in the technical contract for delivery, if applicable.

11.5 The manufacturer is to carry out inspection and test for the hydraulic steering gear intended to apply for survey in accordance with the above-mentioned items, if it is qualified, then to apply CCS for survey. Where the manufacturer or product has been approved by CCS, the sampling proportion and sampling inspection and test items made by CCS site surveyor are to be in accordance with the inspection programme issued together with the certificate of type approval by CCS.

11.6 The sampling for type approval products are usually 10% by our surveyor to the scene , and no less than 1; The sampling to those which does not approved or only made design approval, if the nominal steering torque is less than 63 KNm is 20%, when the nominal steering torque is greater than or equal to 63 KNm is 50%, and no less than 1;Specific sampling proportion according to the manufacturer's quality assurance system can float up and down.

11.7 Necessary mechanical and electrical commissioning test, load test and operational test are to be carried out in accordance with the requirements of 13.1.12.4, PART THREE of CCS Rules for Classification of Sea-going Steel Ships after hydraulic steering gear is installed onboard in order to be in compliance with the relevant requirements of the CCS rules and the intended purposes.