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Guidelines for Type Approval of Aluminum Conductor Cables

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CHAPTER 1 GENERAL

Section 1 General

101. Background

1. Cables with aluminum conductors(hereinafter referred to as 'aluminum conductor cables') have advantages such as lower price and light weight compared to conventional cables with copper conductors(hereinafter referred to as 'copper conductor cables'), so the aluminum conductor cables with large conductor diameters are emerging as an alternative to copper conductor cables.
2. First of all, aluminum conductor cables are lighter than copper cables, so the effect of reducing the overall weight of the ship can be expected, and benefits such as reducing musculoskeletal disorders that may occur to workers when laying cables can be expected. Additionally, due to the flexible nature of aluminum conductor cables, less force is required to bend the cable than copper conductor cables, which is advantageous in terms of workability.
3. Aluminum has a lower conductivity than copper, which means it has a higher conductor resistivity. Accordingly, aluminum conductors have higher power loss and lower current capacity, so conductors with a larger cross-sectional area shall be used compared to copper conductors. In addition, due to its weak mechanical strength, more careful consideration is needed for terminal processing such as crimping.

102. Application

1. This Guideline is applicable for type approval of aluminum conductor cables and associated terminal lugs.
2. Aluminum conductor cables and associated terminal lugs approved in accordance with this Guideline may be applied to newly built ships and ships in service.

Section 2 References

201. References

1. Aluminum conductor cables and associated terminal lugs may apply the relevant parts of the following documents in the latest version, including revisions.
   (1) **Ch 3, Sec 21** of the **Guidance for Approval of Manufacturing Process and Type Approval, etc.**
   (2) IEC 60092-350, Electrical installations in ships — Part 350: General construction and test methods of power, control and instrumentation cables for shipboard and offshore applications
   (3) IEC 60092-352, Electrical installations in ships — Part 352: Choice and installation of electrical cables
   (4) IEC 60228, Conductors of insulated cables
   (5) IEC 61238-1-1, Compression and mechanical connectors for power cables — Part 1-1: Test methods and requirements for compression and mechanical connectors for power cables for rated voltages up to 1 kV (Um = 1.2 kV) tested on non-insulated conductors
   (6) IEC 61238-1-2, Compression and mechanical connectors for power cables — Part 1-2: Test methods and requirements for insulation piercing connectors for power cables for rated voltages up to 1 kV (Um = 1.2 kV) tested on insulated conductors
   (7) IEC 61238-1-3, Compression and mechanical connectors for power cables — Part 1-3: Test methods and requirements for compression and mechanical connectors for power cables for rated voltages above 1 kV (Um = 1.2 kV) up to 30 kV (Um = 36 kV) tested on non-insulated conductors
   (8) ISO 6722-1, Road vehicles — 60 V and 600 V single-core cables — Part 1: Dimensions, test methods and requirements for copper conductor cables
   (9) ISO 6722-2, Road vehicles — 60 V and 600 V single-core cables — Part 2: Dimensions, test methods and requirements for aluminium conductor cables ⚓

CHAPTER 2 ALUMINUM CONDUCTOR CABLES

Section 1 General

101. General

1. Conductor cross-sectional area

(1) The conductor cross-sectional area is to be set based on the overcurrent and short-circuit protection level used.

2. Tensile strength of aluminum conductor

(1) Aluminum conductors are to be made of aluminum with limits in accordance with standards acceptable to the Society, such as ISO 6722-2 and IEC 60228.

102. Application of cables

1. Insulating materials

Insulating materials are to be as given in **Pt 6, Ch 1, Table 6.1.11** of **Rules for the Classification of Steel Ships**.

2. Sheath and armour

Cables are to be protected by sheath or armour in accordance with the following requirements.

(1) Cables fitted on weather decks, and in bath rooms, cargo holds, in any other location where water, oil or explosive gases may be present, are to have an impervious sheath.

(2) Cables fitted where they are likely to suffer from mechanical damages are to be metal armoured except where effective metallic casings or non-metallic casings are provided or except where approved by this Society.

3. Fire safety

Cables are to be satisfied with the required characteristic of flame retardant type.

103. Installation of cables

1. Maximum internal radius of bend

When cables are to be installed bent, the minimum internal radius of bend is to be not less than the following values:

(1) Rubber and PVC insulated cables with metal covering : 6 d

(2) Rubber and PVC insulated cables without metal covering.

(A) Diameter 25 mm or less : 4 d

(B) Diameter exceeding 25 mm : 6 d

(d = overall diameter of cable)

104. Current rating of cable

1. Current rating of copper conductor cables

(1) Current rating of cables for continuous services
The current rating of cables for continuous services is not to exceed the values given in **Table 2.1.**

(2) Correction factor of ambient temperature
Where the ambient temperature is different from that specified in (1) above, the current rating of cables is to be calculated by multiplying the correction factor given in **Table 2.2.**

(3) Current rating of cables for short-time services
The current rating of cables for short-time services (30 minutes or 60 minutes) is to be in accordance with **Pt 6, Ch 1, 503., 5** of **Rules for the Classification of Steel Ships**.

(4) Current rating of cables for intermittent services
The current rating of cables for intermittent services (for periods of 10 minutes, of which 4 minutes are with a constant load and 6 minutes without load) is to be in accordance with **Pt 6,**

Ch 1, 503., 5 of **Rules for the Classification of Steel Ships**.

(5) Where more than 6 cables belonging to the same circuit are bunched together, a correction factor of 0.85 is to be applied.

Table 2.1 Current Rating of Cables (for continuous services) (Based on ambient temperature 45℃)

Nominal sectional area of conductor (mm^2)	Current rating (A)					
	Maximum rated conductor temperature (90℃)			Maximum rated conductor temperature (95℃)		
	1 core	2 core	3 core	1 core	2 core	3 core
1	18	15	13	20	17	14
1.5	23	20	16	24	20	17
2.5	30	26	21	32	27	22
4	40	34	28	42	36	29
6	52	44	36	55	47	39
10	72	61	50	75	64	53
16	96	82	67	100	85	70
25	127	108	89	135	115	95
35	157	133	110	165	140	116
50	196	167	137	200	170	140
70	242	206	169	255	217	179
95	293	249	205	310	264	217
120	339	288	237	360	306	252
150	389	331	272	410	349	287
185	444	377	311	470	400	329
240	522	444	365	553	470	387
300	601	511	421	636	541	445

Table 2.2 Correction Factor for Various Ambient Temperature

Maximum rated conductor temperature of insulation	Ambient temperature										
	35℃	40℃	45℃	50℃	55℃	60℃	65℃	70℃	75℃	80℃	85℃
60℃	1.29	1.15	1.00	0.82	–	–	–	–	–	–	–
65℃	1.22	1.12	1.00	0.87	0.71	–	–	–	–	–	–
70℃	1.18	1.10	1.00	0.89	0.77	0.63	–	–	–	–	–
75℃	1.15	1.08	1.00	0.91	0.82	0.71	0.58	–	–	–	–
80℃	1.13	1.07	1.00	0.93	0.85	0.76	0.65	0.53	–	–	–
85℃	1.12	1.06	1.00	0.94	0.87	0.79	0.71	0.61	0.50	–	–
90℃	1.10	1.05	1.00	0.94	0.88	0.82	0.74	0.67	0.58	0.47	–
95℃	1.10	1.05	1.00	0.95	0.89	0.84	0.77	0.71	0.63	0.55	0.45

2. Current rating of aluminum conductor cables

(1) The current rating for aluminum conductor cables is to be applied taking into account the lower conductivity and temperature variation of aluminum conductors compared to copper conductors. If necessary, the current rating may be referenced to the manufacturer's specifications.

Section 2 Type Approval Criteria

201. Test method of aluminum conductor cables

1. The details of test are to comply with the recognized code ISO, IEC, etc. given in Table 2.3. Where deemed necessary, the ambient temperature may be modified.
2. In addition to 1 above, tests for vertical flame spread of vertically bunched cable are to be carried out in accordance with IEC 60332-1 or IEC 60332-3-22:2018.

Table 2.3 Type test items of aluminum conductor cables

No.	Test items	IEC code
1	Visual inspection	
2	Conductor diameter and cross-sectional area	**ISO 6722-2, 5.3**
3	Conductor resistance	**IEC 60092-350**
4	Withstand voltage test	**IEC 60092-350**
5	Insulation volume resistivity	**IEC 60092-350**
6	Insulation thickness	**IEC 60092-350, 6.5 & 8.2**
7	Non-metallic sheaths thickness	**IEC 60092-350, 6.6 & 8.3**
8	External diameter	**IEC 60092-350, 6.7**
9	Hot-set test for insulations and sheaths	**IEC 60092-350, 6.8**
10	Mechanical properties of insulation before and after ageing	**IEC 60092-350, 8.4**
11	Mechanical properties of sheaths before and after ageing	**IEC 60092-350, 8.5**
12	Compatibility test	**IEC 60092-350, 8.6**
13	Loss of mass test on PVC ST2 sheath	**IEC 60092-350, 8.7**
14	Test for the behaviour of PVC ST2 and halogen-free SHF1 sheaths at high temperatures (hot pressure test)	**IEC 60092-350, 8.8**
15	Test for the behaviour of PVC sheath ST2 and halogen-free SHF1 and SHF2 sheaths at low temperature	**IEC 60092-350, 8.9**
16	Special test for low temperature behaviour (when required)	**IEC 60092-350, 8.10**
17	Test for resistance of PVC ST2 and halogen-free SHF1 sheaths to cracking (heat shock test)	**IEC 60092-350, 8.13**
18	Ozone resistance test for insulation and for sheaths	**IEC 60092-350, 8.14**
19	Oil immersion test for sheaths	**IEC 60092-350, 8.15**
20	Mud drilling fluid test (when required)	**IEC 60092-350, 8.16**
21	Fire tests	**IEC 60092-350, 8.17**
22	Determination of hardness for HEPR	**IEC 60092-350, 8.18**
23	Determination of elastic modulus for HEPR	**IEC 60092-350, 8.19**
24	Durability of print	**IEC 60092-350, 8.20**

CHAPTER 3 TERMINAL LUGS FOR ALUMINUM CONDUCTOR CABLES

Section 1 General

101. General

1. Compression terminal lugs for LV power cables with aluminum conductors are to be designed according to acceptable standard. Mechanical terminal lugs may be designed according to manufacturer's specification.
2. For terminal lugs(including compression and mechanical lugs types), the following applies:
   (1) Terminal lugs are to be suitable for aluminum conductors complying with IEC 60228 class 2 or ISO 6722-2 structure B.
   (2) Terminal lugs are to have metric dimensions and hole size.
   (3) Terminal lugs are to be made of material suitable for direct connection to copper bus bars.
   (4) Terminal lugs are to be supplied with heat shrink tubing with hot melt glue.
   (5) Terminal lugs are to be water tight.
   (6) Terminal lugs are to be supplied with complete assembly procedure.
3. For compression lugs the following applies:
   (1) Terminal lugs are to be supplied with complete assembly and crimp procedure.
4. During installation all terminal lugs shall be properly sealed with heat shrink tubing with melt glue in order to prevent moisture to penetrate into terminal lug. This is important to avoid corrosion and risk of bad electrical connection creating voltage drop and overheating.

Section 2 Type Approval Criteria

201. Test method of terminal lugs for aluminum conductor cables

1. Tests for type approval for terminal lugs for aluminum conductor cables are in accordance with Table 3.1.

Table 3.1 Type test items of terminal lugs for aluminum conductor cables

No.	Test items	Test method	Criteria
1	Visual Inspection		The products are to be visually inspected for good workmanship, conformity with the manufacturers drawings and specifications. All terminations are to be free of fractures, irregularities, sharp edges and damages in the surface.
2	Water tightness test	Specifications	Air with overpressure 0.5 bar is to be applied to both new and installed cable lugs, which are submerged in water. No air leak/bubbles are to be seen.
3	Pull out force	**IEC 61238-1, 7.1**	Each required test to be followed by destructive test until break. Tensile strength at break to be recorded.
4	Long-term reliability test (Heat cycles test)	**IEC 61238-1, 6.3**	Electrical resistance is to be measured before and after short-circuit test.
5	Vibration test	**Ch 3, Sec 23** of **Guidance for Approval of Manufacturing Process and Type Approval, Etc.**	
6	Salt mist test	**Ch 3, Sec 23 of Guidance for Approval of Manufacturing Process and Type Approval, Etc.**	

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