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All aluminium conductors (AAC) for overhead power transmission and Distribution — Specification

Draft East African Standard for Public Review

EAST AFRICAN COMMUNITY

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Second Edition

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0 Foreword

Development of the East African Standards has been necessitated by the need for harmonizing requirements governing quality of products and services in the East African Community. It is envisaged that through harmonized standardization, trade barriers that are encountered when goods and services are exchanged within the Community will be removed.

The Community has established an East African Standards Committee (EASC) mandated to develop and issue East African Standards (EAS). The Committee is composed of representatives of the National Standards Bodies in Partner States, together with the representatives from the public and private sector organizations in the community.

East African Standards are developed through Technical Committees that are representative of key stakeholders including government, academia, consumer groups, private sector and other interested parties. Draft East African Standards are circulated to stakeholders through the National Standards Bodies in the Partner States. The comments received are discussed and incorporated before finalization of standards, in accordance with the Principles and procedures for development of East African Standards.

East African Standards are subject to review, to keep pace with technological advances. Users of the East African Standards are therefore expected to ensure that they always have the latest versions of the standards they are implementing.

The committee responsible for this document is Technical Committee EASC/TC 053, Electric Cables Transmission and Distribution Systems.

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INTRODUCTION

In view of rapid growth of electricity generation and distribution coupled with manufacture of electrical conductors for overhead transmission; necessity has been felt for standardizing the different types of overhead conductors.

This standard is therefore addressing the technical requirements relating to hard-drawn stranded aluminium conductors (AAC) used for overhead transmission and distribution purposes.

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All Aluminium conductors (AAC) for overhead power transmission and distribution — Specification

1 Scope

This Draft East Africa Standard specifies the requirements, and methods of tests for all stranded aluminium conductors (AAC) for overhead power transmission and distribution purposes.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EAS 124:1999, *Rounding off numerical values*

IEC 62641, Conductors *for overhead lines - Aluminium and aluminium alloy wires for concentric lay stranded conductors*

IEC 61394:2011, Overhead lines - Requirements for greases for aluminium, aluminium alloy and steel bare conductors

DEAS 112: Aluminium conductors galvanized steel-reinforced (ACSR) – Specification

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
stranded conductor
a conductor consisting of a number of aluminium wires of the same nominal diameter twisted together in concentric layers. When the conductor consists of more than one layer, alternate (successive) layers are twisted in opposite directions

3.2
diameter
the mean of two measurements at right angles taken at the same cross-section

3.3
direction of lay
defined as right-hand or left-hand. With right-hand lay, the wires conform to the direction of the central part of the letter Z when the conductor is held vertically. With left-hand lay, the wires conform to the direction of the central part of the letter S when the conductor is held vertically.

3.4
lay ratio
the ratio of the axial length of a complete turn of the helix formed by an individual wire in a stranded conductor to the external diameter of the helix

3.3
wire
a conductor material, uniform in diameter and circular in cross-section produced by drawing

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4 Physical characteristics

4.1 Material composition

4.1.1 The conductors shall be of hard-drawn aluminium having the electrical and mechanical properties specified in this standard.

4.1.2 Where required by the purchaser, the centre strand and specified internal layers of stranded aluminium conductors shall be coated with a suitable neutral grease conforming to IEC 61394:2011.

4.1.3 The greases of different designation shall not be mixed within a length of conductor.

4.1.4 The coating shall be carried out evenly in accordance with Annex D of EAS 112 throughout the length of the cable.

Note: This coating may be used for conductors used in coastal areas to minimize corrosion due to atmosphere laden with salts.

4.2 Aluminium properties

The properties of hard drawn aluminium used in the construction of the conductors, including resistivity, density, coefficient of linear expansion, and constant mass temperature coefficient shall be in accordance to IEC 62641

5 Dimensions and construction

5.1 Joints and strands

The wires shall be smooth and free from inequalities, spills and splits.

5.1.1 Conductor having seven wires or less

There shall be no joints in any wire forming a stranded conductor containing seven wires or less, except those made in the base rod or wire before final drawing.

5.1.2 Conductor having more than seven wires

5.1.2.1 Joints in individual strands are permitted in addition to those made in the base rod or wire before final drawing, but no two such joints shall be less than 15 m apart in the complete stranded conductor.

5.1.2.2 Such joints shall be made by resistance or cold pressure butt-welding.

5.1.2.3 While the joints specified in 5.1.2.1 are not required to meet the requirements of unjointed wires, they shall withstand a stress of not less than 75 N/mm² for annealed electric butt-welded joints, and not less than 130 N/mm² for cold pressure joints. The number of joints is specified in table 1.

Table 1 - Number of joints permitted in a given length

Conductor length L (m)				Number of joints permitted
Number of aluminium layers				
1	2	3	4	
L ≤ 1 500	-	-	-	2
1 500 < L ≤ 2 000	L ≤ 1 500	-	-	3
L > 2 000	1 500 < L ≤ 2 000	L ≤ 1 500	-	4
-	2 000 < L ≤ 2 500	1 500 < L ≤ 2 000	L ≤ 1 500	5
-	L > 2 500	2 000 < L ≤ 2 500	1 500 < L ≤ 2 000	6
-	-	2 500 < L ≤ 3 000	2 000 < L ≤ 2 500	7

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-	-	L > 3 000	2 500 < L ≤ 3 000	8
-	-	L > 3 500	3 000 < L ≤ 3 500	9
-	-	-	3 500 < L ≤ 4 000	10
-	-	-	L > 4 000	11

5.2 Standard sizes, resistances and mass of wire

Before stranding, the aluminium wires for the standard constructions covered by this specification shall have the physical properties specified in **Table 2**.

5.3 Standard sizes, resistances and mass of stranded aluminium conductors

The sizes of standard stranded aluminium conductors shall be as given in Table 2. The mass (excluding the mass of grease for corrosion protection) and resistances shall be taken as being in accordance with the given values in Table 2.

Table 2 — Standard aluminium stranded conductors

Code	Area (mm²)	No. of wires	Wire diameter (mm)	Conductor diameter (mm)	Mass per unit length (kg/km)	Rated strength (kN)	DC resistance (Ω/km)
23-AL1	23,3	7	2,06	6,18	63,8	4,20	1,2249
27-AL1	26,9	7	2,21	6,63	73,4	4,83	1,0643
37-AL1	36,9	7	2,59	7,77	100,8	6,27	0,7749
43-AL1	42,8	7	2,79	8,37	117,0	7,28	0,6678
50-AL1	49.5	7	3.00	9,00	135,5	8,17	0,5776
53-AL1	52,8	7	3,10	9,30	144,4	8,72	0,5409
56-AL1	55,6	7	3,18	9,54	151,9	9,17	0,5140
64-AL1	63,6	7	3,40	10,2	173,7	10,49	0,4497
74-AL1	73,6	7	3,66	11,0	201,3	11,78	0,3880
79-AL1	78,6	7	3,78	11,3	214,7	12,57	0,3638
84-AL1	84,1	7	3,91	11,7	229,7	13,45	0,3400
88-AL1	87,5	7	3,99	12,0	239,2	14,01	0,3265
96-AL1	95,6	7	4,17	12,5	261,3	15,30	0,2989
106-AL1	106,0	7	4,39	13,2	289,6	16,95	0,2697
123-AL1	122.5	7	4,72	14.16	334.8	19.60	0.2333
106-AL1	106,4	19	2,67	13,4	292,4	18,08	0,2701
132-AL1	132,0	7	4,90	14,7	360,8	21,12	0,2165
158-AL1	157,6	19	3,25	16,3	433,2	26,01	0,1823
186-AL1	185,9	19	3,53	17,7	511,1	29,75	0,1546
213-AL1	213,2	19	3,78	18,9	586,0	34,12	0,1348
238-AL1	237,6	19	3,99	20,0	652,9	38,01	0,1210
266-AL1	265,7	19	4,22	21,1	730,4	42,52	0,1081
323-AL1	322,7	19	4,65	23,3	886,8	51,63	0,0891
373-AL1	373,1	19	5,00	25,0	1 025,3	59,69	0,0770
372-AL1	372,4	37	3,58	25,1	1 027,1	59,59	0,0774
415-AL1	415,2	37	3,78	26,5	1 145,1	66,43	0,0695
486-AL1	486,1	37	4,09	28,6	1 340,6	77,78	0,0593
530-AL1	529,8	37	4,27	29,9	1 461,2	84,77	0,0544

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628-AL1	628,3	37	4,65	32,6	1 732,9	100,54	0,0459
NOTE: Direction of lay of external layer is right-hand (Z).							

NOTE 1 For the basis of calculating of this table see Annex A.

NOTE 2 The sectional area of stranded conductor is the sum of the cross-sectional areas of the individual wires.

5.4 Stranding

The wires used in making a stranded conductor shall, before stranding, satisfy all the relevant requirements of this standard.

5.4.1 The lay ratio of the different layers shall be within the limits given in Table 3.

5.4.2 In all constructions, the successive layers shall have opposite directions of lay, the outermost layers being right-handed. The wires in each layer shall be evenly and closely stranded.

5.4.3 In aluminium stranded conductors having multiple layers of wires, the lay ratio of any layer shall be not greater than the lay ratio of the layer immediately beneath it.

Table 3— Lay ratios for aluminium stranded conductors

Number of wires in conductor	Lay ratio					
	6 wire layer		12-wire Layer		18 wire layer	
	min	max	min	max	min	max
7	10	14	-	-	-	-
19	10	16	10	14	-	-
37	10	16	10	16	10	14

5.5 Completed conductor

5.5.1 The completed conductor shall be free from dirt, grit, excessive amounts of drawing oil and other foreign deposits.

5.5.2 All wires shall lie naturally in their position in the stranded core, and where the core is cut, the wire ends shall remain in position or be readily replaced by hand and then remain approximately in position

5.6 Lengths and variations in lengths

5.6.1 Unless otherwise agreed between purchaser and manufacturer, conductors shall be supplied in the manufacturer's usual production lengths and with a permitted variation of 5 % in the length of any one-conductor .

5.6.2 Random lengths may constitute up to 5 % of the total conductor length in an order, provided that each random length is not less than one-third of the manufacturer’s standard production length.

6 Packing and labelling

6.1 The conductor shall be wound in reels or drums.

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6.2 The drum, and reel shall be legibly and indelibly marked with the following information:
a) trade name, if any;
b) name and address of the manufacturer;
c) size and type of conductor;
d) length of conductor; and country of origin;
e) Gross weight and net weight;
f) Standard of manufacture.
g) Specification for reels and drums for bare wire:

6.3 The conductor may also be marked with the respective country's certification mark.

NOTE The Certification Mark may be used by manufacturers only under licence from the Bureau of standards of the respective country. Particulars of conditions under which the licences are granted may be obtained from the respective country's Bureau of standards.

7 Testing

7.1 Selection of test samples

7.1.1 Samples of individual wires for the tests specified in 7.3 shall normally be taken by the manufacturer before stranding from the outer ends of not less than 10 % of the spools.

7.1.2 If desired by the purchaser at the time of placing an order that the tests be made in the presence of his representative, samples of wire shall be taken from lengths of stranded conductors. Samples shall then be obtained by cutting 1.2 m from the outer end of the finished conductor from not more than 10 % of the finished reels or drums. If there is more than one length on any reel or drum, the sample shall be taken from the outer length.

7.1.3 Spools/drums offered for inspection shall be divided into equal lots, the number of lots being equal to the number of samples to be selected, a fraction of a lot being counted as a complete lot. One sample spool shall be selected at random from each lot.

Note: The division may be done physically or on the basis of identification numbers of the drums offered for supply.

7.2 Place of testing

Unless otherwise agreed between the purchaser and the manufacturer at the time of ordering, all tests and inspections shall be made at the place of manufacture prior to shipment.

7.3 Tests

The test samples taken under 7.1.1 shall be subjected to the following tests (see also Annex C):
– tensile test;
– wrapping test;
– resistivity test.
-Lay ratio
-Breaking stress
-Mass per unit length of the greasing

7.3.1 Test samples taken under 7.1.2 shall be subjected to the same tests, but in the case of the tensile test the tensile strength of the sample shall be not less than 95 % of the appropriate minimum value specified in Table 2.

7.3.2 The resistance measurement shall be in accordance with the method given in the Annex c.4.

8 Rejections and retests

8.1 Should any sample not fulfill any of the test requirements, the particular spool/drum from which the sample was taken shall be withdrawn.

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In respect of each failure, two samples shall be selected from two different spool/drums in the lot and subjected to the test in which failure occurred. If either of the two samples fails to pass that test, the lot shall be rejected.

8.2 If any selected spool/drum fails after retest, the manufacturer may test each spool/drum and submit those for further inspection.

9 Certificate of compliance

The manufacturer shall, if requested. furnish the purchaser with a certificate giving the results of the tests made on samples taken in accordance with 7.1.

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Annex A

(Normative)

Notes on the calculation of conductor properties

A.1 Increase in length due to stranding
When straightened out, each wire in any particular layer on a stranded conductor, except the central wire, is longer than the stranded conductor by an amount depending on the lay ratio of that layer.

A.2 Resistance end mass of conductor
The resistance of any length of a stranded conductor is the resistance of the same length of anyone wire multiplied by a constant, as set out in Table 5.

The mass of each wire in any particular layer of stranded conductor, except the central wire, will be greater than that of an equal length of straight wire by an amount depending on the lay ratio of that layer (see A.1). The total mass of any length of an aluminium stranded conductor is, therefore, the product of the mass of an equal length of straight wire and an appropriate constant as set out in Table 5.

In calculating the stranding constants in Table 5, the mean lay ratio, that is, the arithmetic mean of the relevant minimum and maximum values in Table 3, has been assumed for each layer.

A.3 Calculated breaking load of conductor

The breaking load of an aluminium stranded conductor containing not more than 19 wires, in terms of the strength of the individual component wires, may be taken to be 95 % of the sum of the strengths of the individual aluminium wires calculated from the specified minimum tensile strength.

Table 4 — Constants for converting resistances at various temperatures to the standard temperature of 20 °C and reciprocals of the constants for converting resistances at 20 °C to other temperatures.

Temperature, °C	Multiplier constant	Reciprocal of constant
10	1.042	0.960
10.5	1.040	0.962
11	1.037	0.964
11.5	1.035	0.966
12	1.033	0.968
12.5	1.031	0.970
13	1.029	0.972
13.5	1.027	0.974
14	1.025	0.976
14.5	1.022	0.978

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15	1.020	0.980
15.5	1.018	0.982
16	1.016	0.984
16..5	1.014	0.986
17	1.012	0.988
17.5	1.010	O.990
18	1.008	0.992
18.5	1.006	0.994
19	1.004	0.996
19.5	1.002	0.998
20	1.000	1.000
20.5	0.998 0	1.002
21	0.996 0	1.004
21.5	0.994 0	1.006
22	0.992 1	1.008
22.5	0.990 1	1.010

Table 4 (Continued)

Temperature, °C	Multiplier constant	Reciprocal of constant
23	0.988 1	1.012
23.5	0.986 2	1.014
24	0.984 3	1.016
24.5	0.982 3	1.018
25	0.980 4	1.020
25.5	0.978 5	1.022
26	0.976 6	1.024
26.5	0.974 7	1.026
27	0.972 8	1.028
27.5	0.970 9	1.030
28	0.969 0	1.032
28.5	0.967 1	1.034

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29	0.965 3	1.036
29.5	0.964 4	1.038
30	0.961 5	1.040
30.5	0.959 7	1.042
31	0.957 9	1.044
31.5	0.956 0	1.046
32	0.954 2	1.048
32.5	0.952 4	1.050
33	0.950 6	1.052
33.5	0.948 8	1.054
34	0.947 0	1.056
34.5	0.945 2	1.058
35	0.943 4	1.060
35.5	0.941 6	1.062

Table 4 (Continued)

Temperature, °C	Multiplier constant	Reciprocal of constant
36	0.939 9	1.064
36.5	0.938 1	1.066
37	0.936 3	1.068
37.5	0.934 6	1.070
38	0.932 8	1.072
38.5	0.931 1	1.074
39	0.929 4	1.076
39.5	0.927 6	1.078
40	0.925 9	1.080
40.5	0.924 2	1.082
41	0.922 5	1.084

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41.5	0.920 8	1.086
42	0.919 1	1.088
42.5	0.917 4	1.090
43	0.915 8	1.092
43.5	0.914 1	1.094
44	0.912 4	1.096
44.5	0.910 7	1.098
45	0.909 1	1,100
45.5	0.907 4	1,102
46	0.905 8	1.104
46.5	0.904 2	1.106
47	0.902 5	1.108
47.5	0.900 9	1.110
48	0.899 3	1.112
48.5	0.897 7	1.114
49	0.896 1	1.116
49.5	0.894 5	1.118
50	0.8929	1.120

NOTE 1 Given the resistance of a wire at T °C, the resistance of 20 °C is found by multiplying the resistance at T °C by the constant for T °C given in column 2. Conversely, given the resistance at 20 °C, the corresponding resistance at T °C is found by multiplying the resistance at 20 °C by the reciprocal for T °C, given in column 3.

NOTE 2 The values given in this table have been calculated to six significant figures and rounded off.

Table 5— Stranding constants

Number of wires in conductor	**Stranding constants**	
	mass	**Electrical resistance**
7	7.091	0.144 7
19	19.34	0.053 57

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Annex B

(Informative)

Note on modulus of elasticity and coefficient of linear expansion

The practical moduli of elasticity given below are based on analysis of the final moduli determined from a large number of short term stress/strain tests and may be taken as applying to conductors stressed between 15 % and 50 % of the breaking load of the conductor.

Number of wires in conductor	Practical (Final) modulus of elasticity, N/mm^3	Coefficient of linear expansion, / °C
7	59 000	23.0×10^{-6}
19	56 000	23.0×10^{-6}
37	56 000	23.0×10^{-6}

NOTE These values are given for information only.

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Annex C

(Normative)

Tests on aluminium wires

C.1 General

Wire of the same diameter, produced in the same way and of the same condition, shall be grouped into batches not exceeding the mass given below, and test samples shall be cut from such lengths selected from each batch. Before the test samples are cut off they shall be marked to identify them. The test samples shall be taken from the wires as supplied and shall not be annealed or mechanically worked other than straightening before testing

Wire diameter, mm	Mass of batch, kg
0,4 up to and including 1.25	250
Over 1.25	1 000

C.2 Tensile test

This test shall apply to wires of all diameters forming part of stranded aluminium and steel-reinforced conductors. Wherever practicable, tests on wires shall be made before stranding.

The load shall be applied uniformly and gradually and the rate of separation of the jaws of the testing machine shall be not less than 25 mm per min and not greater than 100 mm per min.

C.3 Wrapping test

One sample cut from each of the samples taken under 7.1.1 or 7.1.2 shall be wrapped round a mandrel of diameter equal to the wire diameter to form a close helix of eight turns. Six turns shall then be unwrapped and again closely wrapped in the same direction as before. The wire shall not break or show any cracks.

NOTE Slight surface cracks should not constitute cause for rejection.

C.4 Resistivity test

The resistivity shall be determined by direct measurement on the wire in accordance with the routine method, hereunder explained.

C.4.1 Test sample

When it is required to determine for routine purposes the resistance per unit length or the resistance per unit length corrected to standard mass of an electrical conductor, the test sample shall be a suitable length of conductor in the form of a straight conductor of substantially uniform cross section throughout its length within the limits prescribed by the appropriate specification.

If the test sample is cut from material in bulk, care shall be taken that in preparing it the properties of the material are not appreciably changed. For example, bending a wire to straighten it work, hardens the material and tends to raise the resistivity, while heating anneals it with the resulting reduction in resistivity. The characteristics of test sample shall be as follows:

a) no joints or splicing;

b) a test length of at least 30 cm;

c) no surface cracks, grease, dirt, or other visible defects;

d) a resistance of at least 10 micro-ohms in the test length between potential contacts.

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C.4.2 Apparatus

For test sample resistance of less than one ohm, a Kelvin double bridge or a potentiometer shall be used to measure resistance. For resistance of one ohm or more, a Wheatstone bridge shall be used.

C.4.3 Procedure

C.4.3.1 The resistance test length shall be sufficiently well defined to permit its determination with an accuracy of at least 0.05 %.

When a Kelvin double bridge or a potentiometer is used, the potential contacts shall be substantially sharp needle points or knife-edges. On flat surfaces needle points are in general preferable. The resistance test length shall be determined either from the known distance between the potential contacts or by measuring the distance between the marks left on the sample by the potential contacts. The test sample shall not be under appreciable strain during the determination of resistance.

C.4.3.2 When the resistivity of a sample is required, the mean area of its cross section shall be determined to an accuracy of at least 1 %.

Where the shape of the sample permits and where no dimension is less than 1,3 mm a hand micrometer may be used. For dimensions below 1.3 mm down to 0.5 mm a bench micrometer shall be used.

In other cases the mean cross-sectional area shall be deduced from measurements of mass in air and length of a sample and an assumed density for the material. If this sample is not the one that has been used in the resistance test it shall have been taken from the same sample of material. The mass and length shall each be determined to an accuracy of 0.2 %

When the resistance per unit length corrected to standard mass is required, the mass and length of the sample shall each be determined to an accuracy of 0.2 %.

C.4.3.3 Where potential leads are used, the distance between each potential contact and the corresponding current contact shall be at least equal to one and a half times the cross-sectional perimeter of the sample. Where the double bridge method is used, the yoke resistance, between reference standard and test sample, shall be appreciably smaller than that of either the reference standard or the test sample, unless a suitable lead compensation method is used, or it is known that the coil and lead ratio are sufficiently balanced so that variation in yoke resistance shall not decrease the bridge accuracy below requirements.

C.4.3.4 Resistance measurements shall be made to an accuracy of 0.2 %. The temperature of the surrounding air shall be measured with a thermometer, which is accurate to 0.5 °C placed as close to the sample as possible. The test sample shall be allowed to come to the same temperature as the surrounding air. In all resistance measurements, the measuring current tends to raise the temperature of the sample above that of the surrounding medium. Therefore, care shall be taken to keep the magnitude of the current low. To eliminate errors due to thermal e.m.f.s, two readings, with current reversed, shall be taken in quick succession.

C.4.4 Calculation of resistivity and resistance per unit length (km)

The resistivity shall be determined from the formula:

$$\rho = \frac{AR}{L} \times 10^{-5}$$

where ρ is the resistivity in micro-ohm, cm;

A is the wire cross-sectional area in square millimeters (mm^2);

L is length in kilometre (km);

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R is the resistance in micro-ohm.

The electrical resistance per unit length, as measured, can be corrected to standard resistance per unit length (for example, km) by multiplying by:

$$\frac{WC}{K}$$

where

W is the mass per km of test samples;

K is the standard mass per km; and

C *is the* multiplier constant for correction to 20 °C, as given in Table. 4.

The standard resistance so calculated shall not exceed the maximum values given in Table 2.

Other relevant test for aluminium wires shall be as prescribed in table 5 of EAS 112

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