

**Road Vehicles - 60 V and 600 V Single Core
(ISO/Metric) Cables - Dimensions,
Test Methods and Requirements**

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**SAE/USCAR23-1
July 2017**

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ISBN: 978-0-7680-8443-6



SAE/USCAR-23 REVISION 1

Issued	2002-09
Stabilized	2017-07

ROAD VEHICLES – 60 V AND 600 V SINGLE CORE (ISO/METRIC) CABLES – DIMENSIONS, TEST METHODS AND REQUIREMENTS

RATIONALE

The wire sizes called out are no longer being specified in new designs. Cable per ISO 19642-3 are now the preferred specification for automotive primary copper cable used in the U.S.

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1. SCOPE:

This International Standard specifies the dimensions, test methods, and requirements for single core 60 V cables intended for use in road vehicle applications where the nominal system voltage is $\leq$ (60 V DC or 25 V AC). It also specifies additional test methods and/or requirements for 600 V cables intended for use in road vehicle applications where the nominal system voltage is $>$ (60 V DC or 25 V AC) to $\leq$ (600 V DC or 600 V AC). It also applies to individual cores in multi-core cables. See ISO 6722 for "Temperature Class Ratings".

2. NORMATIVE REFERENCES:

The following normative documents contain provisions, which through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

- ASTM B1, Standard Specification for Hard-Drawn Copper Wire
- ASTM B3, Standard Specification for Soft or Annealed Copper Wire
- ASTM B33, Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes
- ASTM B298, Standard Specification for Silver-Coated Soft or Annealed Copper Wire
- ASTM B355, Standard Specification for Nickel-Coated Soft or Annealed Copper Wire
- ISO 1817, Rubber, vulcanized - Determination of the effect of liquids
- ISO 6722, Road Vehicles – 60 V and 600 V single core cables – Dimensions, test methods and requirements

3. TERMS AND DEFINITIONS:

For the purposes of USCAR-23, the following apply:

3.1 60 Volt (V) Cable:

Cable intended for use in road vehicle applications where the nominal system voltage is $\leq$ (60 V DC or 25 V AC)

3.2 600 Volt (V) Cable:

Cable intended for use in road vehicle applications where the nominal system voltage is $>$ (60 V DC or 25 V AC) to $\leq$ (600 V DC or 600 V AC). AC tests are performed at 50 or 60 Hz. Applications at higher frequencies may require additional testing.

3.3 Cable Family:

A group with multiple conductor sizes having the same conductor strand coating, insulation formulation, and wall thickness type.

3.4 Nominal (Value):

A suitable approximate value used to designate or identify a component.

4. GENERAL:

4.1 Cable Types:

The following example shows the method for defining cable options. See Figure 1.

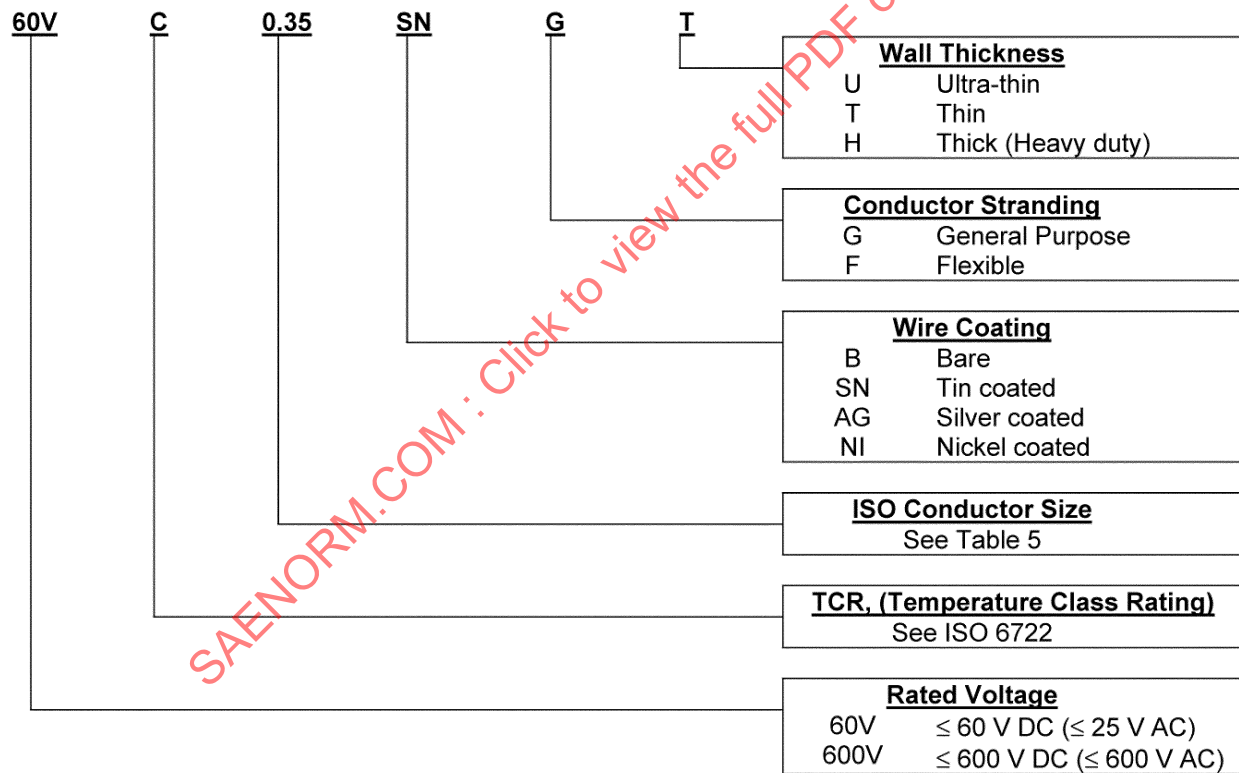


FIGURE 1 - Descriptions of “Cable Types”
(Ref. Clause 4.1)

4.2 Caution:

Special care shall be taken for cables used with voltages above (60 V DC or 25 V AC) to protect them from mechanical stress to avoid shock hazard. Regardless of wall thickness, 600 V cables shall meet the “Resistance to abrasion” requirements for thick wall cable.

4.3 Conductors:

4.3.1 Conductor Specifications: See ISO 6722 for “Conductors”.

4.3.2 Conductor Stranding: The use of “General Purpose” or “Flexible” stranding will be established by agreement between customer and supplier. See Table 1 for “Conductor stranding”.

TABLE 1 - Conductor Stranding
(Ref. Clause 4.3.2)

ISO conductor size mm ²	General Purpose		Flexible	
	Number of Strands	Reference strand diameter mm	Number of strands	Reference strand diameter mm
0.13	7	0.15	19	0.09
0.22	7	0.19	19	0.12
0.35	7	0.24	19	0.15
0.5	7	0.29	19	0.18
0.75	7	0.35	19	0.22
1	7	0.41	19	0.25
1.5	19	0.30	37	0.22
2	19	0.35	37	0.25
2.5	19	0.39	37	0.28
3	19	0.43	65	0.23
4	19	0.49	65	0.25
5	19	0.54	65	0.28
6	37	0.43	84	0.29
10	80	0.39	133	0.30
16	126	0.39	192	0.31
25	196	0.39	259	0.34
35	276	0.39	665	0.25
50	396	0.39	779	0.28
70	360	0.48	1007	0.29
95	475	0.48	1254	0.30
120	608	0.48	--	--

NOTE: The “Reference strand diameter” values in this table are for reference only. They are approximate values and are not intended for certification requirements.

- 4.3.3 Conductor Dimensions: The “Conductor dimensions” values in Table 2 are for reference only. They are approximate values and are not intended for certification requirements.

TABLE 2 - Conductor Dimensions, for Reference Only
(Ref. Clause 4.3.3)

ISO conductor size mm ²	Typical conductor diameter mm	Conductor area mm ²	
		Minimum	Maximum
0.13	0.47	0.13	0.14
0.22	0.59	0.20	0.22
0.35	0.74	0.31	0.34
0.5	0.90	0.46	0.50
0.75	1.1	0.69	0.75
1	1.3	0.92	1.0
1.5	1.5	1.3	1.5
2	1.8	1.8	2.0
2.5	2.0	2.2	2.4
3	2.2	2.8	3.0
4	2.5	3.6	3.9
5	2.8	4.3	4.7
6	3.1	5.4	5.9
10	4.0	9.4	10
16	5.1	15	16
25	7.1	23	25
35	8.4	32	35
50	10	46	50
70	12	66	70
95	14	87	92
120	16	112	117

NOTE: The conductor area is calculated from the conductor resistance using specific conductance of 58.5 Sm/mm².

4.4 Tests:

The cable shall be submitted to the tests as specified in Table 3.

TABLE 3 - Tests
(Ref. Clause 4.4)

Clause	Test Description	Certification	
		Initial	Periodic ¹
5	Dimensions		
5.1	Outside Cable Diameter	X	X
5.2	Insulation thickness	X	X
6	Electrical characteristics		
6.1	Conductor resistance	X	X
6.2	Withstand voltage	Note 2	Note 2
6.3	Insulation faults	Note 2	Note 2
6.4	Insulation volume resistivity	Note 3	--
7	Resistance to pinch	X	X
8	Low temperature winding	X	X
9	Resistance to sandpaper abrasion	X	X
10	Heat aging		
10.1	Long term aging, 3000 h	X	--
10.2	Short term aging, 240 h	X	X
11	Resistance to chemicals		
11.1	Fluid compatibility	X	X
11.2	Durability of cable marking	Note 4	Note 4
11.3	Resistance to ozone	X	--
11.4	Resistance to hot water	X	--
11.5	Temperature and humidity cycling	X	--
12	Resistance to flame propagation	X	X
13	Color code		
13.1	Color targets	X	X
NOTE 1: The frequency of periodic testing will be established by agreement between the customer and the supplier.			
NOTE 2: Some cables are rated at 60 V and others at 600 V. See clauses 6.2 and 6.3 for details.			
NOTE 3: This test is only used as part of clause 11.4, "Resistance to hot water".			
NOTE 4: This test is only applicable to cables with printed, ink markings.			

4.5 General Test Conditions:

See ISO 6722.

4.6 Ovens:

See ISO 6722.

4.7 Testing Representative Conductor Sizes:

When a test is required, all combinations of conductor size, wall thickness, and insulation formulation shall meet the appropriate requirements. However, if testing representative conductor sizes is permitted, compliance for a cable family may be demonstrated by testing examples of large and small conductor sizes only. Testing of cables with conductor sizes of 0.35 mm² and 2.5 mm² is preferred.

5. DIMENSIONS:

5.1 Outside Cable Diameter:

5.1.1 Test Sample: See ISO 6722.

5.1.2 Apparatus: See ISO 6722.

5.1.3 Procedure: See ISO 6722.

5.1.4 Requirement: All measurements shall be within the limits of the appropriate maximum and minimum "Outside cable diameter" specified in Table 4.

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ROAD VEHICLES – 60 V AND 600 V SINGLE CORE (ISO/METRIC) CABLES –
DIMENSIONS, TEST METHODS AND REQUIREMENTS

TABLE 4 - Outside Cable Diameter

ISO conductor size mm ²	Thick Wall				Thin Wall				Ultra-thin wall			
	Insulation thickness		Outside cable diameter		Insulation thickness		Outside cable diameter		Insulation thickness		Outside cable diameter	
	Nom mm	Min mm	Min mm	Max mm	Nom mm	Min mm	Min mm	Max mm	Nom mm	Min mm	Min mm	Max mm
0.13	--	--	--	--	0.25	0.20	0.95	1.05	0.20	0.16	0.85	0.95
0.22	--	--	--	--	0.25	0.20	1.10	1.20	0.20	0.16	0.95	1.05
0.35	--	--	--	--	0.25	0.20	1.20	1.30	0.20	0.16	1.10	1.20
0.50	0.60	0.48	2.00	2.30	0.28	0.22	1.40	1.60	0.20	0.16	1.20	1.40
0.75	0.60	0.48	2.20	2.50	0.30	0.24	1.70	1.90	0.20	0.16	1.40	1.60
1	0.60	0.48	2.40	2.70	0.30	0.24	1.90	2.10	0.20	0.16	1.55	1.75
1.5	0.60	0.48	2.70	3.00	0.30	0.24	2.20	2.40	0.20	0.16	1.90	2.10
2	0.60	0.48	3.00	3.30	0.35	0.28	2.50	2.80	0.25	0.20	2.20	2.40
2.5	0.70	0.56	3.30	3.60	0.35	0.28	2.70	3.00	0.25	0.20	2.50	2.70
3	0.70	0.56	3.80	4.10	0.40	0.32	3.10	3.40	--	--	--	--
4	0.80	0.64	4.00	4.40	0.40	0.32	3.40	3.70	--	--	--	--
5	0.80	0.64	4.50	4.90	0.40	0.32	3.90	4.20	--	--	--	--
6	0.80	0.64	4.60	5.00	0.40	0.32	4.00	4.30	--	--	--	--
10	1.00	0.80	6.00	6.50	0.60	0.48	5.50	6.00	--	--	--	--
16	1.00	0.80	7.00	8.30	0.65	0.52	7.00	7.50	--	--	--	--
25	1.30	1.04	9.40	10.40	0.65	0.52	8.50	9.00	--	--	--	--
35	1.30	1.04	10.80	11.60	--	--	--	--	--	--	--	--
50	1.50	1.20	12.50	13.50	--	--	--	--	--	--	--	--
70	1.50	1.20	14.50	15.50	--	--	--	--	--	--	--	--
95	1.60	1.28	17.00	18.00	--	--	--	--	--	--	--	--
120	1.60	1.28	18.70	19.70	--	--	--	--	--	--	--	--

5.2 Insulation Thickness:

5.2.1 Test Samples: See ISO 6722.

5.2.2 Apparatus: See ISO 6722.

5.2.3 Procedure: See ISO 6722.

5.2.4 Requirement: No single value shall be less than the appropriate minimum insulation thickness specified in Table 6.

6. ELECTRICAL CHARACTERISTICS:

6.1 Conductor Resistance:

6.1.1 Test Sample: See ISO 6722.

6.1.2 Apparatus: See ISO 6722.

6.1.3 Procedure: See ISO 6722.

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- 6.1.4 Requirement: The corrected value shall be within the limits of the appropriate maximum and minimum resistance specified in Table 5.

TABLE 5 - Conductor Resistance
(Ref. Clause 6.1)

ISO Conductor size mm ²	Conductor resistance per length mΩ/m at 20°C					
	Plain & Ag plated copper		Sn plated copper		Ni plated copper	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
0.13	125	136	129	140	130	142
0.22	77.9	84.8	79.5	86.5	80.8	87.9
0.35	50.0	54.4	51.0	55.5	52.2	56.8
0.50	34.1	37.1	35.1	38.2	35.5	38.6
0.75	22.7	24.7	23.3	25.4	23.6	25.7
1	17.0	18.5	17.6	19.1	17.7	19.3
1.5	11.7	12.7	11.9	13.0	12.1	13.2
2	8.66	9.42	8.91	9.69	9.03	9.82
2.5	6.99	7.60	7.19	7.82	7.28	7.92
3	5.66	6.15	5.85	6.36	5.89	6.41
4	4.33	4.71	4.46	4.85	4.52	4.91
5	3.62	3.94	3.70	4.02	3.78	4.11
6	2.89	3.14	2.97	3.23	3.01	3.27
10	1.68	1.82	1.70	1.85	1.75	1.90
16	1.07	1.16	1.09	1.18	1.12	1.21
25	0.688	0.743	0.701	0.757	0.716	0.774
36	0.489	0.527	0.500	0.538	0.510	0.549
50	0.343	0.368	0.350	0.375	0.357	0.383
70	0.243	0.259	0.248	0.264	0.254	0.270
95	0.185	0.196	0.189	0.200	0.193	0.204
120	0.146	0.153	0.149	0.156	0.152	0.159

6.2 Withstand Voltage:

See ISO 6722.

6.3 Insulation Faults:

See ISO 6722.

6.4 Insulation Volume Resistivity:

See ISO 6722.

7. RESISTANCE TO PINCH:

This test is only applicable to cable with an ISO Conductor Size $\leq 6 \text{ mm}^2$.

7.1 Test Sample:

25 mm of insulation shall be removed from one end of a 900 mm sample of finished cable.

7.2 Apparatus:

The apparatus shall be as shown in Figure 3. The counter balance shall be adjusted so that no force will be exerted on the sample until a mass is applied to the end of the lever with a mechanical advantage of 10.

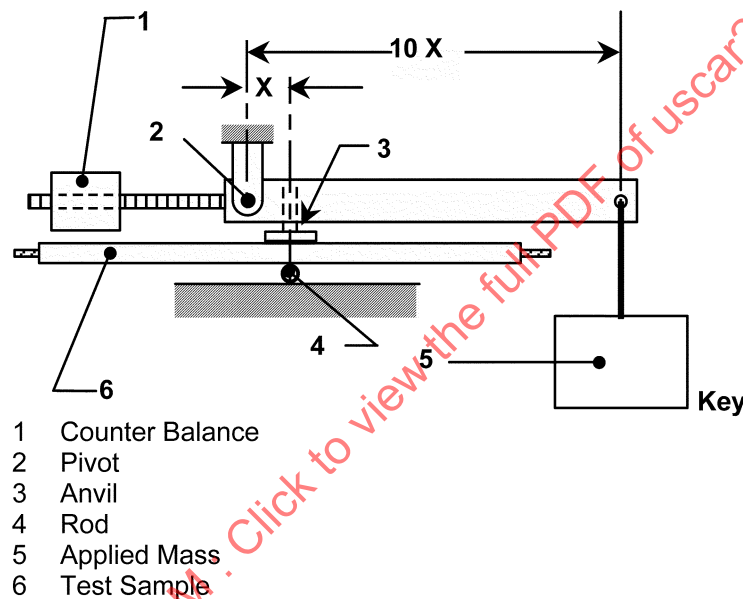


FIGURE 2 - Apparatus for "Resistance to Pinch" Test
(Ref. Clause 7)

7.3 Procedure:

The sample shall then be placed taut without stretching across a 3 mm diameter steel rod as shown in Figure 2. The sample shall then be subjected to an increasing force applied through the steel anvil by increasing the applied mass at a rate of 2.3 kg per min. At the moment the insulation is pinched through, the test shall stop. The applied mass shall then be recorded. After each reading the sample shall be moved 50 mm and rotated clockwise 90°. Four readings shall be obtained for each sample. The mean of the four readings shall determine the pinch resistance of the cable under test.

7.4 Requirement:

The minimum value for each cable type and size is shown in Table 6.

TABLE 6 - Minimum “Resistance to Pinch”
(Ref. Clause 7)

ISO conductor Size mm ²	60V			600V
	Wall Thickness			
	Ultra Thin kg	Thin kg	Thick kg	kg
0.13	TBD	TBD	--	2.3
0.22	0.3	1.2	--	2.3
0.35	0.4	1.2	--	2.3
0.5	0.5	1.5	2.3	2.3
0.75	0.7	1.5	2.7	2.7
1	0.9	2.0	2.7	2.7
1.5	1.1	2.0	3.6	3.6
2.5	1.3	2.5	3.6	3.6
4	1.5	2.5	4.5	4.5
6	1.7	3.0	5.0	5.0

8. LOW TEMPERATURE WINDING:

8.1 Test Samples:

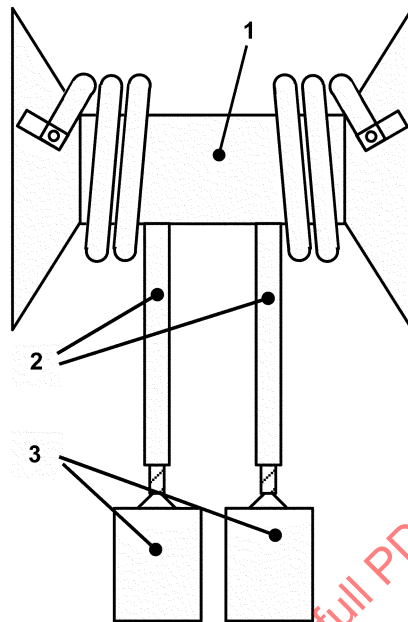
Prepare two test samples of 600 mm and remove 25 mm of insulation from each end.

8.2 Apparatus:

A freezing chamber at $(-40 \pm 2)^{\circ}\text{C}$. Either a rotatable or a stationary mandrel may be used. See Table 7 for “Mandrel diameter”.

Rotatable mandrel - When a rotatable mandrel is used, it shall conform to Figure 3. See Table 7 for mass.

Stationary mandrel - When a stationary mandrel is used, no mass is used.



Key:

- 1 Mandrel
- 2 Test sample(s)
- 3 Mass(es)

FIGURE 3 - Apparatus for "Winding"
(Ref. Clause 8)

8.3 Procedure:

The test samples and mandrel shall be conditioned for a minimum of 4 h in the freezing chamber

Rotatable mandrel - When a rotatable mandrel is used, the test samples shall be fixed on the mandrel as shown in Figure 3. The free ends are loaded with the mass. Position the mandrel with the test samples hanging vertically.

Stationary mandrel - When a stationary mandrel is used, the test samples shall be wrapped around the mandrel by hand.

Wind at least the "Minimum number of turns" specified in Table 7 around the mandrel within the freezing chamber at "Winding speed" as specified in Table 7. Take care to ensure that there is continuous contact between the test samples and the mandrel.

After the cold winding, allow the test sample to return to room temperature, and make a visual examination of the insulation. If no exposed conductor is visible, perform the "Withstand voltage" test; however, make the following changes to the procedure in clause 6.2:

- Immerse the test sample in the salt water bath for a minimum of 10 min prior to the application of the voltage.
- Apply the 1 kV (rms) voltage for 1 min.
- Do not "ramp up" the voltage after the application of the 1 kV (rms) voltage.

8.4 Requirements:

After winding, no conductor shall be visible. During the "Withstand voltage" test, breakdown shall not occur.

TABLE 7 - Winding
(Ref. Clauses 8, 10.1, 10.2, 11.1, 11.4, and 11.5)

ISO Conductor size a mm ²	Mandrel diameter mm		Mass kg	Winding Speed s ⁻¹	Minimum number of turns
	Clauses 8, 10.2, 11.1, 11.3, 11.4	Clauses 10.1, 11.5			
a ≤ 0.75	≤ 5 X Outside cable diameter maximum	≤ 1.5 X Outside cable diameter maximum	0.5	1	3
0.75 < a ≤ 6			2.5	1	3
1.5 < a ≤ 6			5	1	2
6 < a ≤ 10			8	0.5	0.5
10 < a ≤ 25			10	0.5	0.5
25 < a ≤ 35			20	0.5	0.5
35 < a ≤ 120			30	0.2	0.5

9. RESISTANCE TO SANDPAPER ABRASION:

See ISO 6722 "Sandpaper abrasion".

9.1 Test Sample:

See ISO 6722.

9.2 Apparatus:

See ISO 6722.

9.3 Procedure:

See ISO 6722.

9.4 Requirement:

The “Resistance to sandpaper abrasion” shall meet or exceed the “Minimum length of sandpaper” requirements in Table 8.

TABLE 8 - Sandpaper Abrasion
(Ref. Clause 9)

ISO conductor size mm ²	60 V Thick wall		60 V Thin wall		60 V Ultra-thin wall		600V	
	Additional mass	Minimum length of sandpaper	Additional mass	Minimum length of sandpaper	Additional mass	Minimum length of sandpaper	Additional mass	Minimum length of sandpaper
	kg	mm	kg	mm	kg	mm	kg	mm
0.13	--	--	0.1	200	0.05	150	0.5	400
0.22	--	--	0.1	225	0.05	175	0.5	400
0.35	--	--	0.1	250	0.05	200	0.5	400
0.5	0.5	400	0.2	300	0.1	175	0.5	400
0.75	0.5	410	0.2	350	0.1	200	0.5	410
1	0.5	420	0.2	400	0.1	225	0.5	420
1.5	0.5	430	0.2	450	0.1	250	0.5	430
2	0.5	450	0.2	500	0.1	275	0.5	450
2.5	1.5	280	0.5	250	0.2	125	1.5	280
3	1.5	330	0.5	300	--	--	1.5	330
4	1.5	400	0.5	350	--	--	1.5	400
5	1.5	450	0.5	430	--	--	1.5	450
6	1.5	500	0.5	500	--	--	1.5	500

NOTE: The total vertical force exerted of the test sample will be the combination of the force exerted by the bracket, pivoting arm, support rod, and additional mass.

10. HEAT AGING:

10.1 Long Term Aging, 3000 h:

This test is intended to confirm the “Temperature class rating”.

10.1.1 Test Samples: See ISO 6722.

10.1.2 Apparatus: See ISO 6722, except use the mandrels in Table 7.

10.1.3 Procedure: See ISO 6722.

10.1.4 Requirements: See ISO 6722.

10.2 Short Term Aging, 240 h:

This test is intended to simulate thermal excursions.

10.2.1 Test Samples: See ISO 6722.