

Specification RW-2072

HX Low Fire Hazard Heat Shrink Sleeving

This quality assurance specification establishes the quality standard for a low fire hazard (LFH), heat-shrinkable identification sleeving for use in applications where low fire hazard characteristics are critical. These special requirements are detailed in Table 7.

HX Low Fire Hazard sleeving meets Rail Standard EN45545-2 requirement set R22/R23 Hazard rating 3. This requirement set and hazard rating allows unlimited use of this product with any rail car design and operating category in Europe.

The operating temperature for this product is -55°C to + 105°C.

This system is an automatic method of identifying items by printing a mark onto a sleeve. The mark is permanent upon printing. This system is not recommended where strain relief properties are required.

The marker shall be fabricated from cross linked polyolefin tubing, flattened and then mounted on a carrier as HX-SCE, HX or supplied as flattened spooled continuous tube as HXCT.

The marker system comprises specific printers and ribbons. Compliance to this specification can only be guaranteed if TE Connectivity approved printers and ribbons are used. This information can be found in TE document 411-121005 'Printer Product Ribbon Matrix Document'.

Unless specified, the tube size for qualification testing is 6.4mm.

Approved Signatories:

This document is electronically reviewed and approved by TE Connectivity.

TE CONNECTIVITY, SWINDON, UK

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1. SCOPE

The tests in this specification, as made on HX products, define the nature of a low fire hazard product for cable identification. Test procedures have been selected based on the ability of that test to provide key flammability data which can be used by an engineer to give a valid fire risk assessment of an installation based on actual use.

This qualification standard will establish whether fit form and function of the finished product meets product design expectations.

The flammability performance criteria has been modelled to reflect the current requirements of the global rail market. The key performance indicators of flammability, smoke and toxicity have been selected based on there ability to highlight any changes in performance.

2. REQUIREMENTS

2.1 Composition, appearance and color

The sleeving shall be fabricated from low fire hazard (LFH), irradiated, thermally stabilized modified polyolefin compound. It shall be homogeneous and essentially free from flaws, defects, pinholes, bubbles, seams, cracks or inclusions.

The markers shall be White or Yellow unless otherwise specified.

2.2 Dimensions

The product shall be supplied in one of the following formats:

- HX-SCE - as shown in figure 1 and to the dimensions of table 1.
- HXCT - continuous tubing to the dimensions of table 2
- HX - as shown in figure 2 and figure 3 and to the dimensions of table 3

Table 1: HX-SCE Dimensions

Part Description	Minimum Supplied Inside Diameter mm (inches)	Maximum Recovered Inside Diameter mm (inches)	Wall Thickness after Recovery mm (inches)	Minimum Sleeve Width mm (inches)	Sleeve Progression mm (inches)	Nominal Weight of single sleeve (~50mm long) grams
HX-SCE-2.4	2.4 (0.094)	1.19 (0.047)	0.50 ± 0.10 (0.020 ± 0.004)	4.3 (0.17)	12.70 ± 0.63 (0.500 ± 0.025)	0.21
HX-SCE-3.2	3.2 (0.126)	1.6 (0.063)	0.50 ± 0.10 (0.020 ± 0.004)	6.5 (0.26)	12.70 ± 0.63 (0.500 ± 0.025)	0.26
HX-SCE-4.8	4.8 (0.189)	2.4 (0.094)	0.51 ± 0.11 (0.020 ± 0.004)	8.9 (0.32)	12.70 ± 0.76 (0.500 ± 0.030)	0.37
HX-SCE-6.4	6.4 (0.250)	3.2 (0.126)	0.65 ± 0.15 (0.026 ± 0.006)	11.0 (0.43)	16.94 ± 0.89 (0.667 ± 0.035)	0.62
HX-SCE-9.5	9.5 (0.375)	4.8 (0.189)	0.65 ± 0.15 (0.026 ± 0.006)	15.7 (0.62)	25.40 ± 0.89 (1.000 ± 0.035)	0.87
HX-SCE-12.7	12.7 (0.500)	6.4 (0.250)	0.65 ± 0.15 (0.026 ± 0.006)	20.7 (0.81)	29.64 ± 1.02 (1.167 ± 0.040)	1.13
HX-SCE-19.0	19.0 (0.750)	9.5 (0.375)	0.75 ± 0.15 (0.030 ± 0.006)	30.7 (1.21)	42.34 ± 1.02 (1.667 ± 0.040)	1.90
HX-SCE-25.4	25.4 (1.0)	12.7 (0.50)	0.90 ± 0.15 (0.035 ± 0.006)	41.1 (1.62)	50.80 ± 1.02 (2.000 ± 0.040)	3.02
HX-SCE-38.1	38.1 (1.5)	19.1 (0.75)	1.00 ± 0.20 (0.039 ± 0.008)	61.0 (2.40)	72.00 ± 1.02 (2.833 ± 0.040)	4.96
HX-SCE-50.8	50.8 (2.0)	25.4 (1.00)	1.00 ± 0.20 (0.039 ± 0.008)	80.0 (3.15)	101.60 ± 1.02 (2.833 ± 0.040)	6.51

Table 2: HXCT Dimensions

Part Description	Minimum Supplied Inside Diameter mm (inches)	Maximum Recovered Inside Diameter mm (inches)	Wall Thickness After Recovery mm (inches)	Minimum Sleeve Width mm (inches)	Nominal Weight of single sleeve (~50mm long) grams
HXCT-2.4	2.4 (0.094)	1.19 (0.047)	0.50 ± 0.10 (0.020 ± 0.004)	4.3 (0.17)	0.21
HXCT-3.2	3.2 (0.126)	1.6 (0.063)	0.50 ± 0.10 (0.020 ± 0.004)	6.5 (0.26)	0.26
HXCT-4.8	4.8 (0.189)	2.4 (0.094)	0.51 ± 0.11 (0.020 ± 0.004)	8.9 (0.32)	0.37
HXCT-6.4	6.4 (0.250)	3.2 (0.126)	0.65 ± 0.15 (0.026 ± 0.006)	11.0 (0.43)	0.62
HXCT-9.5	9.5 (0.375)	4.8 (0.189)	0.65 ± 0.15 (0.026 ± 0.006)	15.7 (0.62)	0.87
HXCT-12.7	12.7 (0.500)	6.4 (0.250)	0.65 ± 0.15 (0.026 ± 0.006)	20.7 (0.81)	1.13
HXCT-19.0	19.0 (0.750)	9.5 (0.375)	0.75 ± 0.15 (0.030 ± 0.006)	30.7 (1.21)	1.90
HXCT-25.4	25.4 (1.0)	12.7 (0.50)	0.90 ± 0.15 (0.035 ± 0.006)	41.1 (1.62)	3.02
HXCT-38.1	38.1 (1.5)	19.1 (0.75)	1.00 ± 0.20 (0.039 ± 0.008)	61.0 (2.40)	4.96

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Table 3: HX Dimensions

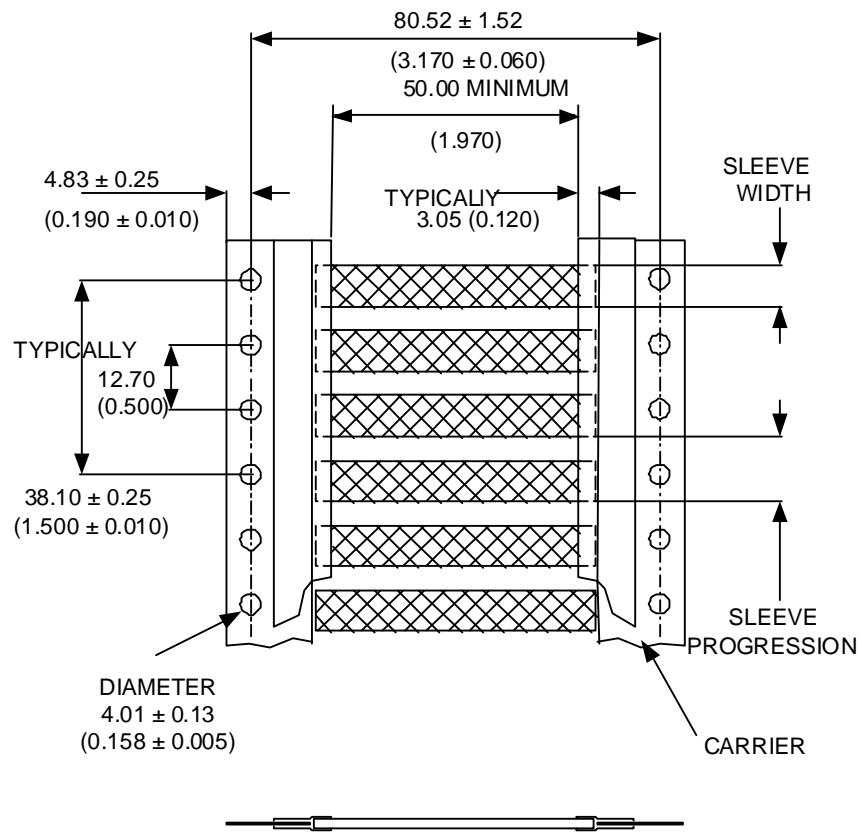
Part Description	Minimum Supplied Inside Diameter mm (inches)	Maximum Recovered Inside Diameter mm (inches)	Wall Thickness After Recovery mm (inches)	Minimum Sleeve Width mm (inches)	Sleeve Progression mm (inches)	Nominal Weight of single sleeve (~50mm long) grams
HX032	3.2 (0.126)	1.6 (0.063)	0.50 ± 0.1 (0.02 ± 0.004)	6.5 (0.26)	12.7 ± 0.5 (0.50 ± 0.02)	0.26
HX048	4.8 (0.189)	2.4 (0.094)	0.51 ± 0.11 (0.02 ± 0.004)	8.9 (0.32)	12.7 ± 0.5 (0.50 ± 0.02)	0.37
HX064	6.4 (0.250)	3.2 (0.126)	0.65 ± 0.15 (0.026 ± 0.006)	11.0 (0.43)	25.4 ± 0.5 (1.00 ± 0.02)	0.62
HX095	9.5 (0.375)	4.8 (0.189)	0.65 ± 0.15 (0.026 ± 0.006)	15.7 (0.62)	25.4 ± 0.5 (1.00 ± 0.02)	0.87
HX127	12.7 (0.500)	6.4 (0.250)	0.65 ± 0.15 (0.026 ± 0.006)	20.7 (0.81)	50.8 ± 0.5 (2.00 ± 0.02)	1.13
HX190	19.0 (0.750)	9.5 (0.375)	0.75 ± 0.15 (0.030 ± 0.006)	30.7 (1.21)	50.8 ± 0.5 (2.00 ± 0.02)	1.90
HX254	25.4 (1.0)	12.7 (0.50)	0.90 ± 0.15 (0.035 ± 0.006)	41.1 (1.62)	50.8 ± 0.5 (2.00 ± 0.02)	3.02
HX381	38.1 (1.5)	19.1 (0.75)	1.00 ± 0.20 (0.039 ± 0.008)	61.0 (2.40)	127 ± 0.5 (5.00 ± 0.02)	4.96

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Figure 1. HX-SCE format



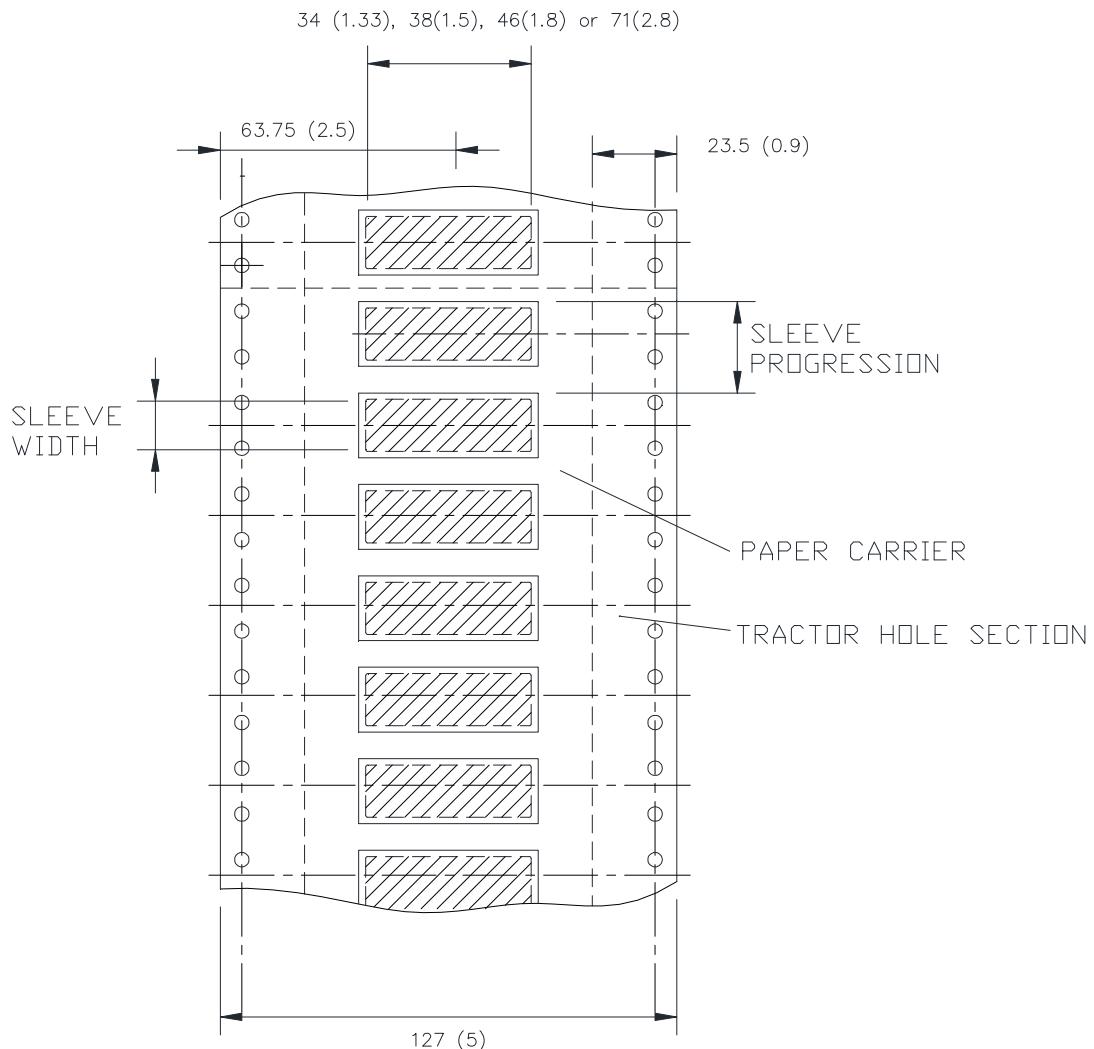
Dimensions in mm (inch).

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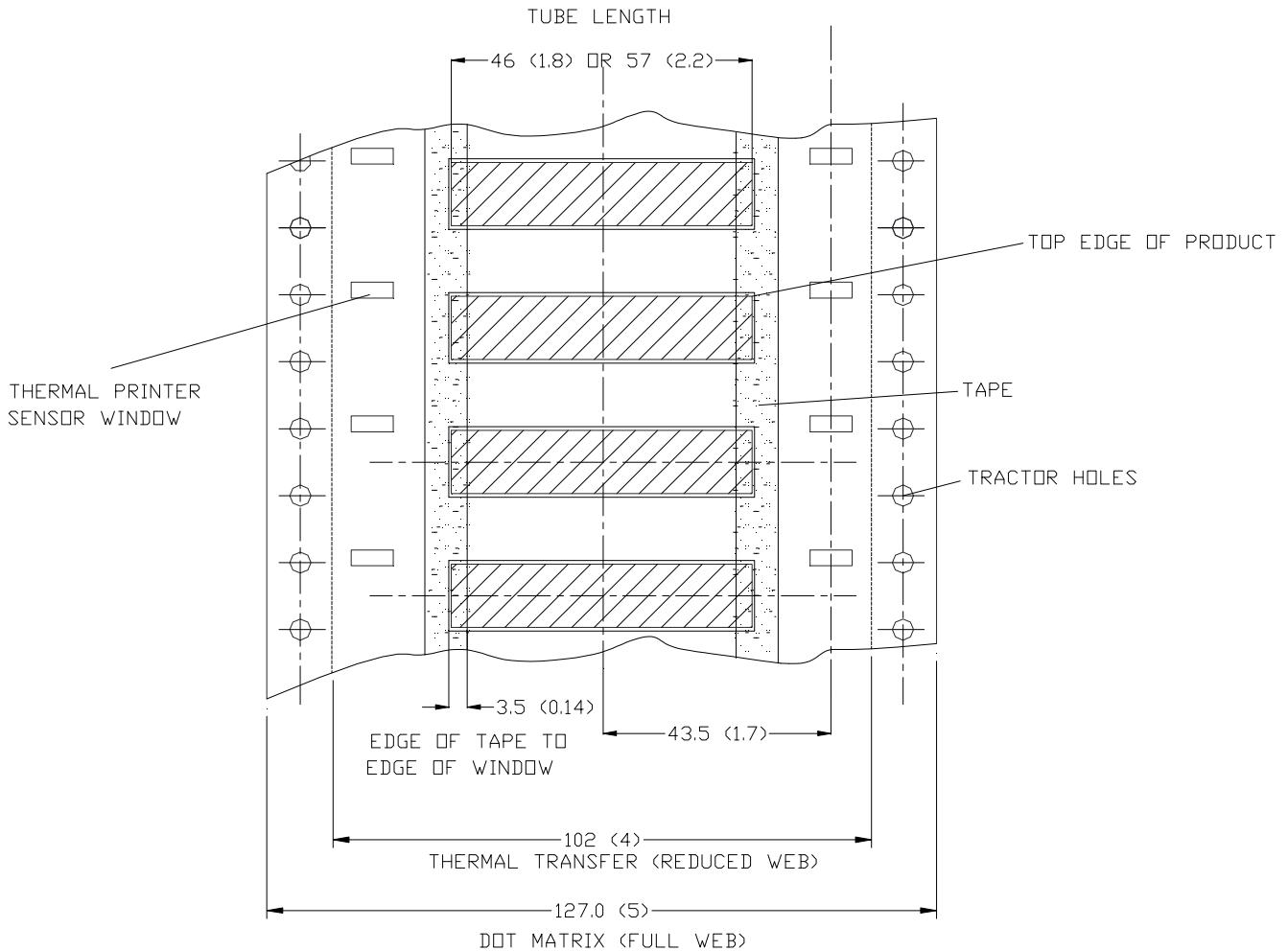
Figure 2: HX Single sided



Dimensions in mm (inches).

For thermal transfer printing, product is supplied without the tractor holes section.

Figure 3: HX - Double sided



Dimensions in mm (inches).

For thermal transfer printing, product is supplied without the tractor holes section.

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3. TEST REQUIREMENTS

This specification details the requirements for the HX family of products. Table 6 lists general Identification product requirements, Table 7 lists the specific performance for HX low fire hazard.

4. TEST METHODS

4.1 Preparation of Test Specimens

When required by the test procedure, product shall be printed using printers and ribbons specified by TE Connectivity. The full list can be found in TE document reference 411-121005 TE Identification Printer Product Ribbon Matrix.

Print random characters onto the sleeving to within approximately 6mm (1/4 inch) of both ends using font type Arial 10 bold. Remove the markers from the carrier and test in both 'as received' and 'fully recovered' form.

The marking shall be examined for legibility in accordance with TE Document 411-121002 Print Contrast Reference Scale. The initial print contrast must be 8 or above.

As required, sleeves or tubing will be recovered by placing them in a forced air oven for 3 minutes at $150 \pm 5^\circ\text{C}$ ($302 \pm 9^\circ\text{F}$). Specimens will be removed from the oven and allow to cool to $23 \pm 3^\circ\text{C}$ ($73 \pm 5^\circ\text{F}$) for at least 4 hours before continuing. Use finished markers, as supplied, for all other tests.

Unless otherwise specified, all tests shall be made at a temperature of $23 \pm 2^\circ\text{C}$ ($73 \pm 5^\circ\text{F}$)

4.2 Print Testing

4.2.1 Mark Adherence

Three sleeves shall be prepared as detailed in Clause 5.1 and tested in accordance with TE test method 109-121012. Samples shall be tested using a Crockmeter fitted with an eraser and 1kg load using the number of rubs specified in the requirement table.

After the Mark Adherence test, the marking shall be examined for legibility using normal reading vision. Print contrast shall be evaluated in accordance with TE Document 411-121002.

4.2.2 Solvent Resistance

Nine sleeves shall be prepared as detailed in Clause 5.1 and tested in accordance with TE test method 109-121014.

The marking shall be examined for legibility using normal reading vision. Print contrast shall be evaluated in accordance with TE Document 411-121002

4.2.3 Fluid Resistance

The test method shall be as specified in TE method 109-121012. Three markers as prepared as in Clause 5.1 shall be completely immersed in each of the fluids for the times and at the temperatures specified in the requirements table. The volume of the fluid shall not be less than 20 times that of the specimen. After immersion, the markers are lightly blotted with tissue paper to remove excess surface fluid and air dried at $23 \pm 2^\circ\text{C}$ ($73 \pm 7^\circ\text{F}$) for $45 \pm 15\text{min}$. Samples are tested with a Crockmeter fitted with 'Super Twill' cloth and a 1kg load.

After the print permanence test, marking shall be examined for legibility using normal reading vision. Print contrast shall be evaluated in accordance with TE Document 411-121002.

4.3 Physical Testing

4.3.1 Dimensions and Longitudinal Change

The test method shall be as specified in TE method 109-121003.

Three marker sleeves shall be tested. The inside diameter of each shall be measured. For Longitudinal changed, two gauge marks shall be positioned 100mm apart on each sleeve. The markers shall be recovered in a fan assisted air-circulating oven and the distance between gauge lengths and inside diameter of each shall be measured after cooling to room temperature. The longitudinal change shall be expressed as a percentage of the original gauge length. The minimum and maximum recovered wall thickness shall be determined.

4.3.2 Tensile Strength and Ultimate Elongation

The test method shall be as specified in TE method 109-121002. Test five recovered tubular specimens 125mm long. An initial jaw separation of 50mm with a gauge length of 20mm and rate of jaw separation of $50 \pm 5\text{mm per minute}$ shall be used.

4.3.3 Specific Gravity

Samples of un-printed product shall be tested to the procedure as specified in TE method 109-121015. Three specimens of fully recovered tubing 25mm long should be tested. Test specimens should be prepared to prevent trapping of air.

4.3.4 Split Testing

The test method shall be as specified in TE method 109-121031. Ten perforated or scored marker sleeves should be tested. Samples should be recovered, onto an ambient temperature mandrel for five minutes in the fan assisted oven at 150°C (302°F). Samples should be examined for splitting after they have been cooled down to room temperature.

4.4 Thermal Testing

4.4.1 Heat Ageing

The test method shall be as specified in TE method 109-121008. Six sleeves shall be prepared as detailed in section 5.1. Specimens shall be conditioned for 168 hours at $135\pm2^\circ\text{C}$ ($275\pm7^\circ\text{F}$) in an air circulating oven. Markers shall be removed and allowed to cool to room temperature for a minimum of 4 hours at $23\pm2^\circ\text{C}$ ($73\pm7^\circ\text{F}$).

After conditioning three samples shall be tested for Mark Adherence, in accordance with section 5.2.1. The marking shall be examined for legibility using normal reading vision. Print contrast shall be evaluated in accordance with TE Document 411-121002.

The remaining three samples shall be tested for resistance to bending. Mandrel diameter for HX 6.4 size tubing is 9.5mm.

4.4.2 Heat Shock

The test method shall be as specified in TE method 109-121007. Six sleeves shall be prepared as detailed in section 5.1. Specimens shall be conditioned for 4 hours at $175\pm2^\circ\text{C}$ ($347\pm7^\circ\text{F}$) in an air circulating oven. Remove the markers and leave to cool to room temperature for a minimum of 2 hours at $23\pm2^\circ\text{C}$ ($73\pm7^\circ\text{F}$).

After conditioning three samples shall be tested for Mark Adherence in accordance with section 5.2.1. The marking shall be examined for legibility using normal reading vision. Print contrast shall be evaluated in accordance with TE Document 411-121002.

The three remaining samples shall be tested for resistance to bending. Mandrel diameter for HX 6.4 size tubing is 9.5mm.

4.4.3 Thermal Cycling

The test method shall be as specified in TE method 109-121046. Six of each recovered and expanded samples should be prepared for testing as detailed in section 5.1. Specimens shall be conditioned for 4 cycles of 1 hour at $-55^\circ\text{C}\pm2^\circ\text{C}$ ($-67\pm7^\circ\text{F}$) and 1 hour at $105\pm2^\circ\text{C}$ ($221\pm7^\circ\text{F}$) in an air circulating oven. Remove the markers and leave to cool to room temperature for a minimum of 2 hours at $23\pm2^\circ\text{C}$ ($73\pm7^\circ\text{F}$).

After conditioning, three samples shall be tested for Mark Adherence in accordance with section 5.2.1. The marking shall be examined for legibility using normal reading vision. Print contrast shall be evaluated in accordance with TE Document 411-121002.

The three remaining samples shall be tested for resistance to bending. Mandrel diameter for HX 6.4 size tubing is 9.5mm.

4.4.4 Low Temperature Flexibility

The test method shall be as specified in TE method 109-121006. Six sleeves shall be prepared as detailed in section 5.1. Specimens shall be conditioned for 4 hours at $-55\pm2^\circ\text{C}$ ($-67\pm7^\circ\text{F}$) in a cold chamber. The markers shall be removed and allowed to cool to room temperature for a minimum of 2 hours at $23\pm2^\circ\text{C}$ ($73\pm7^\circ\text{F}$).

After conditioning three samples shall be tested for Mark Adherence in accordance with section 5.2.1. The marking shall be examined for legibility using normal reading vision. Print contrast shall be evaluated in accordance with TE Document 411-121002.

The three remaining samples shall be tested for resistance to bending. Mandrel diameter for HX 6.4 size tubing is 9.5mm. Refer to TE instruction 109-121006 if other sizes are required

4.5 Electrical Testing

4.5.1 Dielectric Strength

The test method shall be as specified in TE method 109-121005. Five printed 150mm long specimens should be recovered onto mandrels 24 hours before testing. The mandrels shall be tight fitting. A 25mm piece of aluminum self adhesive foil electrode shall be installed at the centre of each of the recovered samples. Mean average dielectric strength of five samples to be recorded as the result.

4.5.2 Volume Resistivity

The test method shall be as specified in TE method 109-121017. Three 200-250mm printed specimens are to be recovered onto clean 300mm long, steel mandrel (no larger in diameter than 15% of the fully recovered diameter of the tested tubing). Each sample should have 150mm long silver paint electrode painted a minimum 4 hours before testing. Mean average volume resistivity value should be recorded as the result

4.5.3 Volume Resistivity after Damp Heat – Specific to HX range

The test method shall be as specified in BS 4G 198: Pt 3 and TE method 109-121017. Three 150-200mm printed specimens to be recovered onto the clean 250mm long, steel mandrel (no larger in diameter than 15% of the fully recovered diameter of the tested tubing). Condition the samples as specified in BS 4G 198 Pt3 (three cycles of various levels of heat and humidity combination) and test for volume resistivity. Mean average volume resistivity value should be recorded as the result.

4.6 Environmental Testing

4.6.1 Copper Mirror Corrosion

The test method shall be as specified in TE method 109-121009. Three glass test tubes should be used. Prepare one control tube with copper mirror only, and two tubes with mirrors and printed product. Prepare samples out of recovered specimens, using at least 150mm² surface area in each tube. Use a printed sample 10mm long. After the test, mirrors should be assessed for corrosion.

4.6.2 Water Absorption

The test method shall be as specified in TE method 109-121016. Three 25mm long helical samples should be cut from recovered printed tubing specimens. Samples should be weighed after drying in the oven and after immersion in water. The mean average of three samples should be used.

4.6.3 UV Exposure

The test shall be carried out using a UV-O-meter chamber in accordance with ASTM G154. Test for 1000 hours at 1.35 W/m²/nm irradiance.

Condition two sets of markers prepared as specified in section 5.1 to the following regimes. Each set consists of three recovered and three as supplied marked sleeves for print adherence testing with three recovered and three as supplied installed on wire for bend tests:

- UVA type fluorescent bulbs, consisting of a repeating cycle of 8 hours exposure at 60°C (140°F) followed by 4 hours of condensation at 50°C (122°F) .
- UVB type fluorescent bulbs, consisting of a repeating cycle of 8 hours exposure at 60°C (140°F) followed by 4 hours of condensation at 50°C (122°F) .

After conditioning test one set for flexibility using a 90° mandrel bend test. Mandrel diameter for HX 6.4 size tubing is 9.5mm.

The second set of samples shall be tested for Mark Adherence in accordance with section 5.2.1. The marking shall be examined for legibility using normal reading vision. Print contrast shall be evaluated in accordance with TE Document 411-121002.

4.7 Flammability Testing

4.7.1 Fire Propagation (Aviation Method)

Test on 6.4mm sleeve. Continuous sleeve taken from manufacturing prior to laying onto carrier is printed as stated in section 5.1 'Preparation of test specimens', and then tested in accordance with Airbus directive ABD0031, 'Flammability of Heat Shrink tubing. The conditions used are stated in Airbus specification AIMT 2.0038.

Burn length, glowing (after flame time) and time of dripping after removal of flame shall be recorded.

4.7.2 Glow Wire Test – Specific to HX range (HX-254 only)

This test is performed on HX sleeve in accordance with BS EN 60695-2-10: 2001 using a glow wire at 850°C. 25.4mm continuous tubing that has been printed with two lines of text is used. Product shall be printed as defined in section 5.1 'Preparation of test specimens'.

4.7.3 Fire Propagation

6.4mm sleeve shall be tested to ASTM D2671 procedure B. Five printed samples shall be prepared and tested in accordance with TE method 109-121053. 460mm long samples should be installed onto 530mm long mandrels. Each sample should have a paper flag indicator 250mm above the flame impingement point. The flame should be applied to the sample at a 70° angle. The flame should be applied five times, each application is 15s on and 15s off.

The duration of burning and percentage of the burnt area shall be recorded.

4.7.4 Limited Oxygen Index

The test method shall be as specified in TE method 109-121054. Tests shall be carried out on 3mm plaques of the material from which the sleeving is fabricated. The plaque will be irradiation cross-linked to the same degree as the sleeving. Test piece dimensions shall be $6.5 \pm 0.5\text{mm} \times 80 \pm 1\text{mm} \times 3 \pm 0.5\text{mm}$ cut from the plaques and shall be conditioned for at least 24hrs at $23 \pm 2^\circ\text{C}$ prior to testing. A new test piece shall be used for each determination.

4.7.5 Flame Spread Index, (HX-254 only)

This test is performed in accordance with ASTM E162, with the following modification: Instead of testing a moulded plaque, 25.4mm continuous tubing which has been printed with two lines of text is used.

To arrange the samples to form the specified exposed area, 13mm wide cement board fingers are cut from a single board. Six 75mm lengths are cut from the tube, which is then recovered over the fingers. The cement board fingers are butted together to form a single sheet. Samples are allowed to condition for at least 24 hours at 23°C before fire testing.

4.7.6 Smoke Optical Density, Ds (HX-254 only)

The test is performed in accordance with ASTM E662 with the following modification: Instead of testing moulded plaques, 25.4mm continuous tubing which has been printed with two lines of text is used.

To arrange the samples to form the specified exposed area, 13mm wide cement board fingers are cut from a single board. Six 75mm lengths are cut from the tube, which is then recovered over the fingers. The cement board fingers are butted together to form a single sheet. Samples are allowed to condition for at least 24 hours at 23°C before fire testing. Five single sheets are placed side by side vertically for each test in order to create the required test specimens. Testing is carried out using an NBC smoke chamber.

Smoke density (Ds) is measured in flaming and non-flaming mode at 1.5 and 4 minutes.

4.7.7 Smoke Optical Density, Ds, - Specific to HX range

The test is performed in accordance with EN ISO 5659-2. Evaluation is carried out on 75x75mm x 1mm plaques of material using an irradiance of 25kW/m² using the cone heater attachment. Test duration is 10 minutes.

4.7.8 Smoke Density 3m³ BS 6853 (Annex D) – Specific to HX range

The test method shall be as specified in BS 6853:1999 Annex D.8.3. Tests shall be carried out on 3mm thick plaques of the material from which the sleeving is fabricated. The plaques will be irradiation cross-linked to the same degree as the sleeving.

4.7.9 Smoke Density NF X 10-702

The test is performed in accordance with NF X 10-702 on continuous sleeving taken from manufacturing prior to assembly. All samples tested are printed using the standard TE Identification printing system as stated in section 5.1.'Preparation of test samples'. One sample is tested using a 25kW/m² radiant heat with and with a pilot flame. Two further samples are tested in the mode which ever gives the worst overall result. Values of maximum specific density of smoke (Dmax) and rate of smoke production during the first four minutes (VOS₄) are determined. This test is made in combination with NF X 70-100 section 5.7.13.

4.7.10 Flammability Toxicity (HX-254 Only)

This test is performed in accordance with BSS 7239, with the following modification: Instead of testing moulded plaques, 25.4mm continuous tubing that has been printed with two lines of text is used.

To arrange the samples to form the specified exposed area, 13mm wide cement board fingers are cut from a single board. Six 75mm lengths of sleeve are cut from the tube and then placed and recovered over the fingers. The cement board fingers are butted together to form a single sheet. Samples are allowed to condition for at least 24 hours at 23°C (73 ± 7°F) before fire testing. Five single sheets are placed together side by side for each test to create the required test specimens.

BSS 7239 is carried out during the ASTM E662 test.

Gases are extracted and analyzed using the techniques described in BSS 7239.

4.7.11 Effective Heat of Combustion (HX-254 Only)

This test is performed in accordance with ASTM E1354, with the following modification: Instead of testing moulded plaques, 25.4mm continuous tubing which has been printed with two lines of text is used.

To arrange the samples to form the specified exposed area, 13mm wide cement board fingers are cut from a single board. Six 75mm lengths are cut from the tube, which is then recovered over the fingers. The cement board fingers are butted together to form a single sheet. Samples are allowed to condition for at least 24 hours at 23°C (73 ± 7° F) before fire testing.

Samples are tested using a 50kW/m² heat flux. Average Heat Release Rate and Average Specific Extinction Area at 3 minutes is measured.

4.7.12 Toxic Fume, Elemental Analysis – Specific to HX range

This test is performed in accordance with London Underground Standard 1-085 A3 Fire safety performance of materials. Tests are to be carried out on printed product. A 250mm length of continuous product shall be printed as defined in clause 5.1 'Preparation of samples'. Testing shall be carried out using qualitative analysis using x-ray fluorescence spectroscopy.

4.7.13 Toxic Gas Emission

The test shall be carried out as specified in NF X 70-100. The mass based method is used. Testing is carried out on 6.4mm sleeving. All samples tested are printed using the standard TE Identification printing system as stated in section 5.1.'Preparation of test samples'. 50g of material is submitted for testing. The test is conducted at 600°C. Values of CIT (Conventional Index of Toxicity), and R (index of the weighted summation of species analysed) are determined.

5. RELATED DOCUMENTS

5.1 Table: 4 Related Standards and Issue

Document, Revision	Description
ABD0031 ISSUE F	FIREWORTHINESS REQUIREMENTS PRESSURIZED SECTION OF FUSELAGE
AFNOR NF FR 16-101: 1988	ROLLING STOCK. FIRE BEHAVIOUR. CHOICE OF MATERIALS
AITM 2.0038: 1996	FLAMMABILITY OF NON METALLIC HEAT SHRINKABLE TUBINGS – SMALL BURNER TEST, 60°
ASTM E 162-13	STANDARD TEST METHOD FOR SURFACE FLAMMABILITY OF MATERIALS USING A RADIANT HEAT ENERGY SOURCE
ASTM E 662-13D	STANDARD TEST METHOD FOR SPECIFIC OPTICAL DENSITY OF SMOKE GENERATED BY SOLID MATERIALS
ASTM D882 METHOD A	STANDARD TEST METHOD FOR TENSILE PROPERTIES OF THIN PLASTIC SHEETING
ASTM D792 METHOD A	STANDARD TEST METHODS FOR SPECIFIC GRAVITY (RELATIVE DENSITY) AND DENSITY OF PLASTICS BY DISPLACEMENT
ASTM E 1354-13	STANDARD TEST METHOD FOR HEAT AND VISIBLE SMOKE RELEASE RATES FOR MATERIALS AND PRODUCTS USING AN OXYGEN CONSUMPTION CALORIMETER
ASTM G154-06	STANDARD PRACTICE FOR OPERATING FLUORESCENT LIGHT APPARATUS FOR UV EXPOSURE OF NONMETALLIC MATERIALS
EN 45545-2: MARCH 2013	RAILWAY APPLICATIONS – FIRE PROTECTION ON RAILWAY VEHICLES – PART 2: REQUIREMENTS FOR FIRE BEHAVIOUR OF MATERIALS AND COMPONENTS
BS 6853:1999	CODE OF PRACTICE FOR FIRE PRECAUTIONS IN THE DESIGN AND CONSTRUCTION OF PASSENGER CARRYING TRAINS
BS EN 60695-2-10: 2013	FIRE HAZARD TESTING GLOWING/HOT-WIRE BASED TEST METHODS. GLOW-WIRE APPARATUS AND COMMON TEST PROCEDURE
BS EN ISO 4589-2	PLASTICS – DETERMINATION OF BURNING BEHAVIOR BY OXYGEN INDEX – PART 2: AMBIENT TEMPERATURE TEST
NF X 70 – 100:1986	FIRE TESTS ANALYSIS OF PYROLYSIS AND COMBUSTION GASES, TUBE FURNACE METHOD
MIL STD 202 METHOD 215	TEST METHODS FOR ELECTRONIC AND ELECTRICAL COMPONENT PARTS. RESISTANCE OF SOLVENTS.
SAE AS5942	MARKING OF ELECTRICAL INSULATING MATERIALS
LONDON UNDERGROUND STANDARD 1-085	REVISION A3, FIRE SAFETY PERFORMANCE OF MATERIALS.
IEC 60212 ED3.0	STANDARD CONDITIONS FOR USE PRIOR TO AND DURING THE TESTING OF SOLID ELECTRICAL INSULATING MATERIALS

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5.2 Table 5: TE Connectivity Documents

TE Reference	Title	Complies with
109-121002	Tensile Strength and Ultimate Elongation at 23°C	ASTM D882 Method A
109-121003	Dimensions	---
109-121006	Low Temperature Flexibility	IEC 60684-2
109-121007	Heat Shock	AMS DTL 23053
109-121008	Heat Ageing	AMS DTL 23053
109-121009	Copper Mirror Corrosion	AMS DTL 23053
109-121012	Print Permanence testing using the Mechanical Crockmeter	SAE AS5942
109-121014	Resistance to Solvents	MIL 202 Method 215
109-121015	Specific Gravity	ASTM D792 Method A
109-121016	Water Absorption	ASTM D570
109-121017	Volume Resistivity	BS 4G198:Pt3
109-121053	Flammability testing	ASTM D2671, procedure B
109-121054	Limited Oxygen Index	BS EN ISO 4589-2

6. Sampling

Tests shall be carried out on a sample taken at random from a batch. A batch is defined as that quantity of product extruded at any one time.

Testing frequency shall be Production Routine or Qualification.

Production Routine tests consisting of Visual Examination and Dimensions shall be carried out on every batch of product.

Qualification tests shall be carried out to the requirements of the Design Authority.

7. Storage Conditions

Cable Markers should be stored in a clean dry location. Maximum storage temperature is 40°C (104°F).

8. Packaging

Packaging shall be in accordance with good commercial practice. Each package shall bear an identification label showing material quantity, description, size, color and batch number. Additional information shall be supplied as specified in the contract or order

TABLE: 6 GENERAL REQUIREMENTS

PROPERTY	TEST METHOD	UNITS	REQUIREMENTS	RW-2072 SECTION
PRINT PERFORMANCE				
Mark Adherence	TE 109-121012 20 rubs, 1kg load, eraser	---	Legible, minimum print contrast 3	5.2.1.
Solvent Resistance Solution A Solution B Solution C	TE Document 109-121014 30 strokes, tooth brush	---	Legible, minimum print contrast 3	5.2.2.
Fluid Resistance	24 ± 2 hours immersion, 23 ± 2°C, followed by TE 109-121012, 20 rubs 1kg load	---	Legible, minimum print contrast 3	5.2.3.
Diesel Fuel				
Propylene Glycol de-icing fluid 50/50				
Tap Water				
5% Sodium chloride solution				
Detergent, 1% Teepol				
Reference test oil IRM 902				
Aircraft Gas Turbine Lubricant MIL-PRF-23699				
Fire Resistant Hydraulic Fluid Skydrol LD-4				
Synthetic hydrocarbon base hydraulic fluid MIL-H-83282				
Isopropyl alcohol	TE 109-121012, 20 rubs 1kg load, Soaked "Super Twill" cloth	---	Legible, minimum print contrast 3	

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PROPERTY	TEST METHOD	UNITS	REQUIREMENTS	RW-2072 SECTION
PHYSICAL				
Visual Inspection	In good lighting, using normal or corrected vision at a distance of 14 inches.	---	In accordance with section 3.1.	3.1
Dimensions	TE 109-121003	---	In accordance with table 1, 2 or 3.	5.3.1.
Longitudinal Change	TE 109-121003	%	+5 to -10	5.3.1.
Tensile Strength	TE 109-121002	MPa	7 Minimum	5.3.2.
Ultimate Elongation	TE 109-121002	%	80 Minimum	5.3.2.
Specific Gravity	TE 109-121015	---	1.57 ± 0.03	5.3.3.
Split testing	TE 109-121031	%	100 pass	5.3.4.
THERMAL				
Heat Ageing 168 hours at 135°C, followed by: Mandrel Bend Mark Adherence	TE 109-121008 360°bend around a mandrel (10 x thickness) TE 109-121012 20 rubs, 1kg load, eraser	---	No damage to the marker and print Legible, minimum print contrast 3	5.4.1.
Heat Shock 4 hours at 175°C, followed by: Mandrel Bend Mark Adherence	TE 109-121007 360°bend around a mandrel (10 x thickness) TE 109-121012 20 rubs, 1kg load, eraser	---	No damage to the marker and print Legible, minimum print contrast 3	5.4.2.
Thermal cycling 4 cycles of 1hr at -55°C and 1hr 105°C, followed by, Mandrel Bend Mark Adherence	TE 109-121046 360°bend around a mandrel (10 x thickness) TE 109-121012 20 rubs, 1kg load, eraser	---	No damage to the marker and print legible after 20 rubs	5.4.3.
Low Temperature flexibility 4 hours at -55°C, followed by: Mandrel Bend Mark Adherence	TE 109-121006 360°bend around a mandrel (10 x thickness) TE 109-121012 20 rubs, 1kg load, eraser	---	No damage to the marker and print Legible, minimum print contrast 3	5.4.4.

ELECTRICAL				
Dielectric strength	TE 109-121005	MV/m	15 minimum	5.5.1.
Volume resistivity	TE 109-121017	Ohm cm	10^{12}	5.5.2.
CHEMICAL				
Copper Mirror Corrosion	TE 109-121009 16hrs at 150°C	%	Damaged area of copper mirror, 8 maximum	5.6.1.
Water Absorption	TE 109-121016	%	1 maximum	5.6.2.
ENVIRONMENTAL				
UV Resistance followed by,	ASTM G154 UVA and UVB (8 hours dry/4 hours wet cycle)		1000 hours at each irradiance	
Mandrel Bend	360°bend around a mandrel (10 x thickness)	---	No damage to the marker and print	5.6.3.
Mark Adherence	TE 109-121012 20 rubs, 1kg load, eraser	---	Legible, minimum print contrast 3	

PROPERTY	TEST METHOD	UNITS	REQUIREMENTS	RW-2072 SECTION
FIRE SAFETY				
Fire Propagation (Aviation Method)	Airbus Directive ABD0031 Issue F, Fire worthiness requirements pressured section of fuselage (Flammability of Heat Shrink tubing – AIM 2.0038)	---	Burn length Average shall not exceed 76mm After flame time average not exceed 30s After flame time, dripping must not exceed 3s	5.7.1.
Fire Propagation	ASTM D2671 procedure B		Burn time shall not exceed one minute, and not more than 25% of indicator flag shall be burned or charred. No dripping or flowing. No burning of cotton.	5.7.3.
EN45545-2 Flammability Hazard Rating for unlimited interior mass use: <i>Based on the following criteria:</i>			Requirement Set R22, Hazard Rating 3ⁱ	
Oxygen Index (OI) Smoke Density, Ds	BS EN ISO 4589-2:1999 EN ISO 5659-2	% ---	32 Minimum 150 Maximum	5.7.4. 5.7.7.
Toxicity	NF F 70-100 -1 NF F 70-100 -2	--- ---	0.75 Maximum	5.7.9. and 5.7.13.
Surface Flammability, Flame Spread Index, Is	ASTM E162	---	35 Maximum	5.7.5.
Specific Optical Smoke Density, Ds Flaming Mode Specific Optical Density 1.5 minutes 4 minutes Non Flaming Mode 1.5 minutes 4 minutes	ASTM E 662	--- --- --- ---	100 Maximum 200 Maximum 100 Maximum 200 Maximum	5.7.6.

ⁱ Unlimited internal use, any operating category and rail car design

PROPERTY	TEST METHOD	UNITS	REQUIREMENTS	RW-2072 SECTION
FIRE SAFETY				
Toxic Gas Generation from Material Combustion	Carbon Monoxide (CO) Carbon Dioxide (CO ₂) Nitrogen Oxides (NO ₂) Sulphur Dioxide (SO ₂) Hydrogen Chloride (HCl) Hydrogen Fluoride (HF) Hydrogen Bromide (HBr) Hydrogen Cyanide (HCN)	BSS 7239 Measured at maximum smoke density. Flaming mode and non-flaming mode assessed, worst case reported.	ppm	Maxima: 3500 90000 100 100 500 100 100 100
Effective Heat of Combustionⁱⁱ	Average Heat Release Rate, 3 minutes Average Extinction area, 3 minutes	ASTM E1354 50kW/m ² applied heat flux with retainer frame	kW/m ² m ² /kg	≤ 100 Maximum 500

ⁱⁱ NFPA 130 does not specify a requirement for small electrical components, the figures stated are based on current best practices for US federal rail administration and national fire protection association.

TABLE: 7 Special Requirements for HX-LFH Heat Shrink Sleeving

PROPERTY	TEST METHOD	UNITS	REQUIREMENTS	RW-2072 SECTION
London Underground Standard 1-085: A3 Non-listed items <i>Based on the following criteria:</i>			Limited and dispersed Use	
Oxygen Index (OI)	BS EN ISO 4589-2:1999	%	30 Minimum	5.7.4.
Smoke Density, Annex D.8.3, 'A0'	BS6853: 1999, Annex D.8.3	M ³ /g	0.02 Maximum	5.7.8.
Toxicity, Annex B (using BS6853 cat 1a requirements), 'R'	BS 6853: 1999, Annex B NF X 70-100	---	1 Maximum	5.7.13.
Toxic Fume, Elemental Analysis	Use printed product, London Underground Standard 1-085 A3 Fire safety performance of materials.	---	Halogen, Phosphorus, Silicone or Nitrogen shall not be intentionally added or be present at greater than trace amounts (300ppm maximum)	5.7.12.
BS6853 Interior minor use of materials of mass 100-500g <i>Based on the following criteria:</i>			Vehicle Category 1a	
Oxygen Index (OI)	BS EN ISO 4589-2:1999	%	34 Minimum	5.7.4.
Smoke Density, Annex D.8.3, A0	BS6853: 1999, Annex D.8.3.)	M ² /g	0.017 Maximum	5.7.8.
Toxicity, Annex B, R	BS 6853: 1999, Annex B NF X 70-100	---	1.0 Maximum	5.7.13.

PROPERTY	TEST METHOD	UNITS	REQUIREMENTS	RW-2072 SECTION
AFNOR NF F 16-101 Category A1 Rolling Stock, 'Small dimension parts' ⁱⁱⁱ <i>Based on the following criteria:</i>	Use the methods below for flammability, smoke and toxicity, determine 'I' and 'F'	---	Category A1 NF F 16-101 Grid 10	
Flammability, I Rating (ignitability)	Determine I rating with the following tests -		I3	
Oxygen Index (OI)	BS EN ISO 4589-2:1999	%	28 Minimum	5.7.4.
Glow Wire test	BS EN 60695-2-11: 2001	---	Ignition does not persist at 850°C afterglow wire is withdrawn	5.7.2.
F Rating (Smoke and toxic gas)	Determine F rating with the following tests -		F1	
Calculation: Conventional Toxicity Index, CIT	NF X 70-100, Toxic gas emission, mass based method.			5.7.13.
Maximum specific optical density of smoke, Dmax	NFX 10-702, Determination of the opacity of smoke in a non- renewed atmosphere.			5.7.9.
^{iv} Rate of smoke production during first 4 minutes of test, VOS ₄ = <u>D1+D2+D3+D4</u> 2				
Smoke Index, SI= <u>Dmax + VOS4 + C.I.T</u> 100 30 2			≤ 20	

ⁱⁱⁱ Situated inside vehicles, individual parts do not exceed 100g, aggregate mass less than 200g/m. Requirements taken from grid 10 of NF 16-101

^{iv} Where D (number) is the recorded optical density at each minute.

PROPERTY	TEST METHOD	UNITS	REQUIREMENTS	RW-2072 SECTION
ELECTRICAL				
Volume resistivity after damp heat, 16hr at 55°C and 95%RH	BS 4G 198-3	Ohm cm	10 ¹² Minimum	5.7.3.
FLUID RESISTANCE				
1mol NaOH 1 minute immersion 1mol HCl 1 minute immersion IRM 902 70hrs at 50°C	TE 109-121012 20 rubs, super twill cloth, 1kg load, eraser	---	Legible, minimum print contrast 3	5.2.3.

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TABLE: 8 Test fluids description

Fluid	Description
IRM902	Reference Oil
MIL-PRF-23699	Synthetic lubricating oil STD class (NATO Code 0-156). Has replaced MIL-L-7808 oil at temperatures above 25°C.
Skydrol LD-4	Widely used aviation phosphate ester hydraulic fluid.
MIL-H-83282	The principal hydraulic fluid used in military aircraft. It replaces MIL-H-5606.
JP-8	Kerosene based jet fuel, replacement for JP-4. NATO code is F-34. It's specified by MIL-DTL-83133 and British Defence Standard 91-87.
Diesel Fuel (BS EN 590:2009+A1)	General automotive fuel
Propylene Glycol de-icing fluid (SAE-AMS-1424)	50 / 50 % mixture with water
Tap Water	Universal solvent
5% Sodium chloride solution	Sodium chloride is a universal component of many chemicals and deicing fluids
Detergent (1% Teepol)	Commonly used detergent
IPA - Isopropyl alcohol	Widely used as a solvent and cleaner

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