



## SPECIFICATION RW-2072

TE 108-121002

### 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 8. General requirements are shown 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 (-67°F) to + 105°C (221°F).

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 or HX it is also supplied as flattened spooled continuous tube as HX-CT.

The marker system comprises specific printers and ribbons. Products printed with white ribbon may not fully meet the specified print performance when exposed to some aggressive fluids detailed on page 20. 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.

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## 1 REVISION HISTORY

Revision Number	Description of change	Date	Incorporated By
1	-	14.06.2004	Paul Crofts
2	-	09.08.2004	Paul Crofts
3	-	25.05.2005	Alan Kean
4	-	02.03.2006	Paul Crofts
5	-	10.12.2010	Martyn Priddle
6	-	21.02.2011	Martyn Priddle
7	-	31.10.2011	Lee Smith
8	-	17.05.2012	Lee Smith
9	Specification rationalization	January 2013	Ewelina Mojsak
10	Flammability test method update	March 2013	Ewelina Mojsak
11	Alignment with MCD	April 2014	Steve Rowland
12	Flammability test method update	May 2014	Lee Smith
13	Flattened width modifications	October 2014	Steve Rowland
14	Dimensional corrections. Numbering alignment. Bend test method added, addition of white ribbon note	August 2022	Alan Kean
15	Local document type added in system, no change to content	May 2023	Alan Kean

## 2 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 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 their ability to highlight any changes in performance.



### 3 REQUIREMENTS

#### 3.1 Test Requirements

This specification details the requirements for the HX family of products. Table 7 lists general Identification product requirements, Table 8 lists the specific performance for HX low fire hazard.

#### 3.2 Composition, appearance, and colour

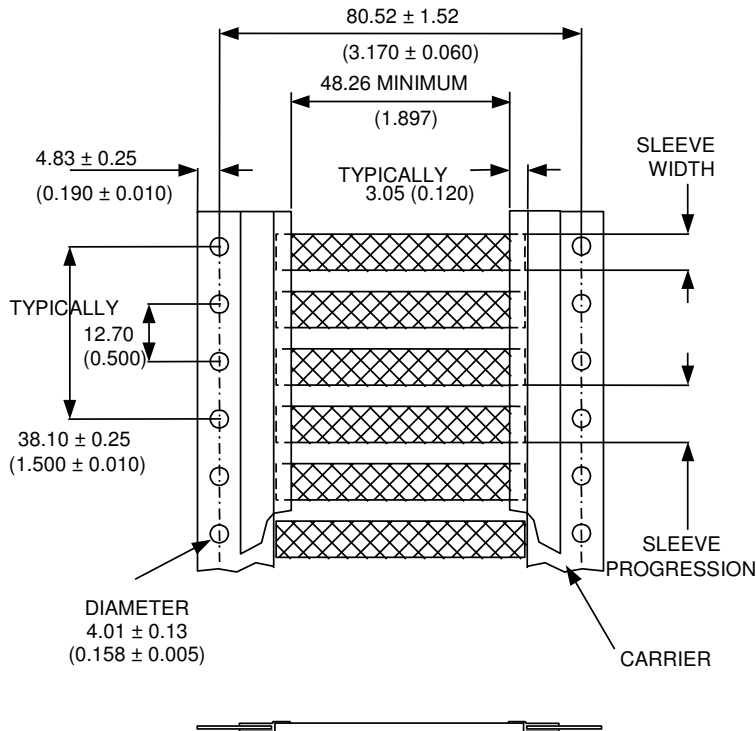
The sleeving shall be fabricated from low fire hazard (LFH), irradiated, thermally stabilized modified polyolefin compound. It shall be homogeneous and essentially free from flaws, defects, pinholes, bubbles, seams, cracks, or inclusions. Standard colours are white and yellow. Other colours are available.

#### 3.3 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
- HX-CT continuous tubing to the dimensions of Table 2
- HX as shown in figures 2 & 3 and to the dimensions of Table 3

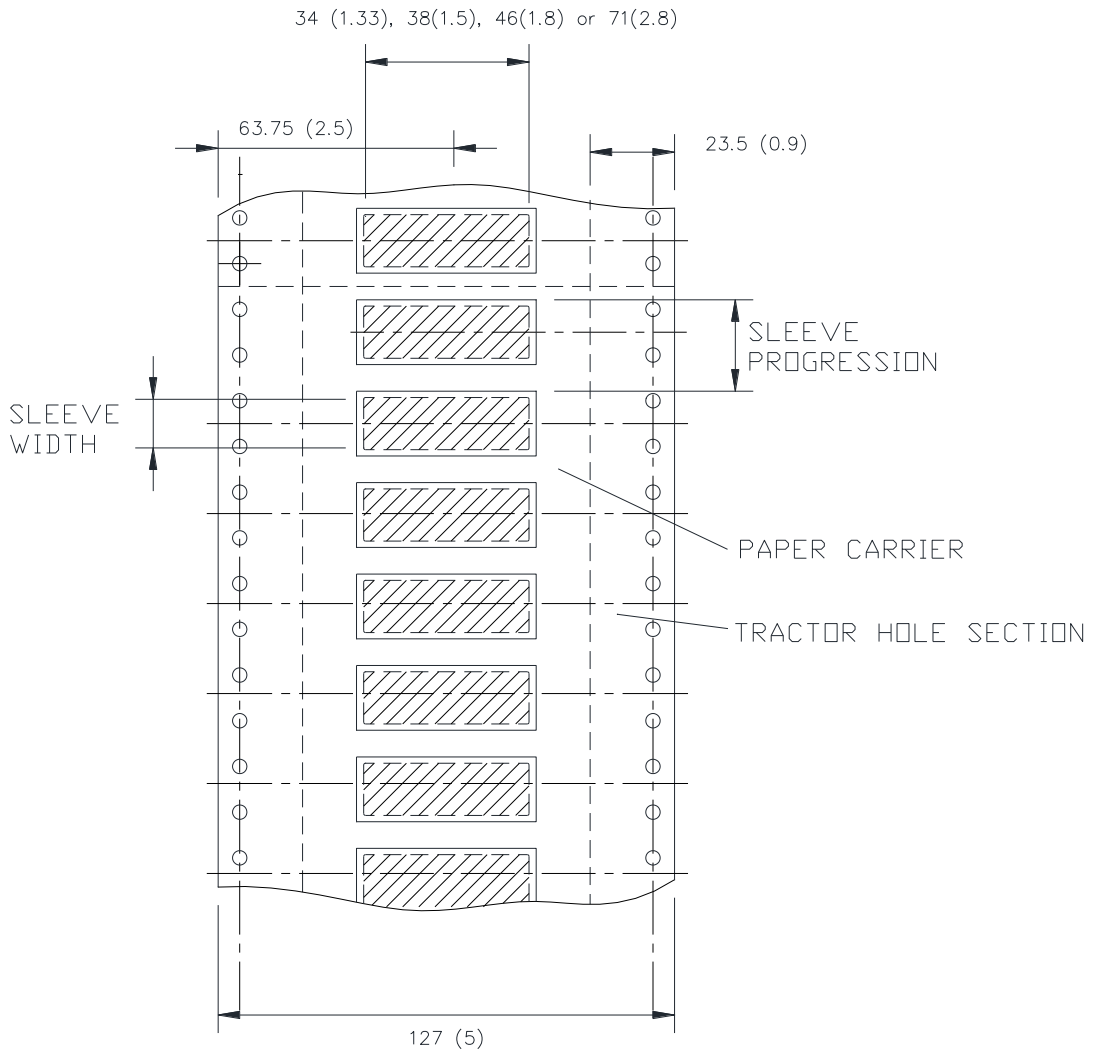
Figure 1. HX-SCE format



Dimensions in mm (inch)



**Figure 2: HX Single sided**

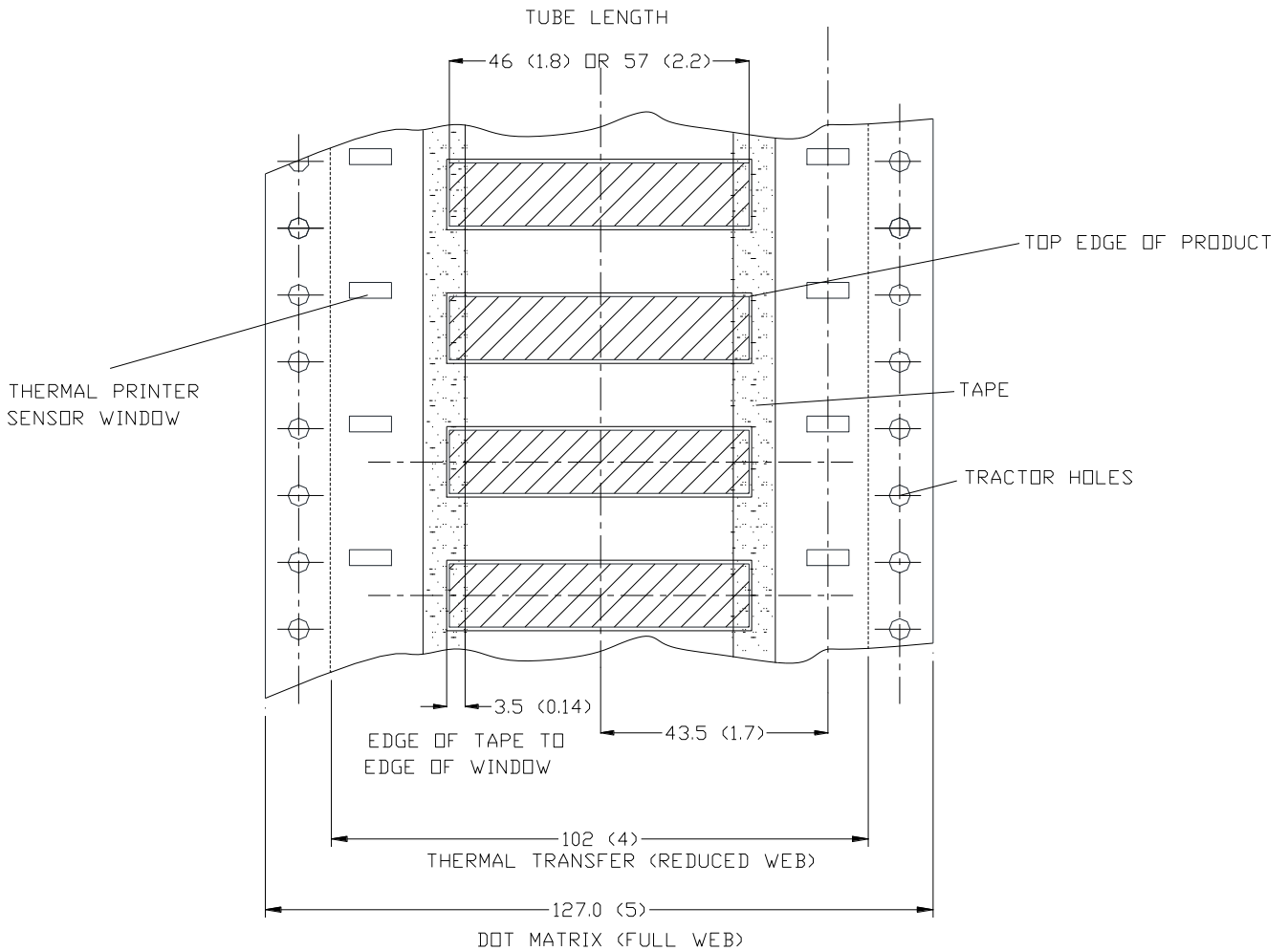


Dimensions in mm (inches).

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.



**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	2.40 (0.094)	1.19 (0.047)	0.50 ± 0.10 (0.020 ± 0.004)	4.90 (0.169)	12.70 ± 0.63 (0.500 ± 0.025)	0.21
HX-SCE-3.2	3.20 (0.126)	1.60 (0.063)	0.50 ± 0.10 (0.020 ± 0.004)	6.50 (0.256)	12.70 ± 0.63 (0.500 ± 0.025)	0.26
HX-SCE-4.8	4.80 (0.189)	2.40 (0.094)	0.51 ± 0.11 (0.020 ± 0.004)	8.90 (0.350)	12.70 ± 0.76 (0.500 ± 0.030)	0.37
HX-SCE-6.4	6.40 (0.250)	3.20 (0.126)	0.65 ± 0.15 (0.026 ± 0.006)	11.0 (0.433)	16.94 ± 0.89 (0.667 ± 0.035)	0.62
HX-SCE-9.5	9.50 (0.375)	4.80 (0.189)	0.65 ± 0.15 (0.026 ± 0.006)	15.7 (0.618)	25.40 ± 0.89 (1.000 ± 0.035)	0.87
HX-SCE-12.7	12.7 (0.500)	6.40 (0.250)	0.65 ± 0.15 (0.026 ± 0.006)	20.7 (0.815)	29.64 ± 1.02 (1.167 ± 0.040)	1.13
HX-SCE-19.0	19.0 (0.750)	9.50 (0.375)	0.75 ± 0.15 (0.030 ± 0.006)	30.7 (1.209)	42.34 ± 1.02 (1.667 ± 0.040)	1.90
HX-SCE-25.4	25.4 (1.00)	12.7 (0.50)	0.90 ± 0.15 (0.035 ± 0.006)	41.1 (1.618)	50.80 ± 1.02 (2.000 ± 0.040)	3.02
HX-SCE-38.1	38.1 (1.50)	19.1 (0.75)	1.00 ± 0.20 (0.039 ± 0.008)	61.0 (2.402)	72.00 ± 1.02 (2.833 ± 0.040)	4.96

**Table 2: HX-CT 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
HX-CT-2.4	2.40 (0.094)	1.19 (0.047)	0.50 ± 0.10 (0.020 ± 0.004)	4.90 (0.169)	0.21
HX-CT-3.2	3.20 (0.126)	1.60 (0.063)	0.50 ± 0.10 (0.020 ± 0.004)	6.50 (0.256)	0.26
HX-CT-4.8	4.80 (0.189)	2.40 (0.094)	0.51 ± 0.11 (0.020 ± 0.004)	8.90 (0.350)	0.37
HX-CT-6.4	6.40 (0.250)	3.20 (0.126)	0.65 ± 0.15 (0.026 ± 0.006)	11.0 (0.433)	0.62
HX-CT-9.5	9.50 (0.375)	4.80 (0.189)	0.65 ± 0.15 (0.026 ± 0.006)	15.7 (0.618)	0.87
HX-CT-12.7	12.7 (0.500)	6.40 (0.250)	0.65 ± 0.15 (0.06 ± 0.006)	20.7 (0.815)	1.13
HX-CT-19.0	19.0 (0.750)	9.50 (0.375)	0.75 ± 0.15 (0.030 ± 0.006)	30.7 (1.209)	1.90
HX-CT-25.4	25.4 (1.00)	12.7 (0.500)	0.90 ± 0.15 (0.035 ± 0.006)	41.1 (1.618)	3.02
HX-CT-38.1	38.1 (1.50)	19.1 (0.750)	1.00 ± 0.20 (0.039 ± 0.008)	61.0 (2.402)	4.96



**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	3.20 (0.126)	1.60 (0.063)	0.50 ± 0.1 (0.02 ± 0.004)	6.50 (0.26)	12.7 ± 0.5 (0.50 ± 0.02)	0.26
HX048	4.80 (0.189)	2.40 (0.094)	0.51 ± 0.11 (0.02 ± 0.004)	8.90 (0.32)	12.7 ± 0.5 (0.50 ± 0.02)	0.37
HX064	6.40 (0.250)	3.20 (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	9.50 (0.375)	4.80 (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)	6.40 (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)	9.50 (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 (1.00)	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 (1.50)	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

**4 TEST METHODS**

**4.1 Preparation of Test Specimens**

**4.1.1 Samples for Print Performance Test**

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 5 minutes at 150±5°C (302 ± 9°F). Specimens will be removed from the oven and allow to cool to 23±3°C (73±5°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±2°C (73±5°F)

**4.1.2 Samples for Mandrel Bend Test**

Unless specified, the recommended product size for testing is 6.4. For alternative sizes, prepare specimens as shown in sections 4.1.2.1 and 4.1.2.2





#### 4.1.2.1 For tubing sizes with recovered bore less than 6.0mm

Take three printed specimens and position them centrally onto 450mm long sections of appropriate AWG wire. Select the nearest AWG stranded wire size which is larger than the recovered ID of the specimens being tested.

*Note: Selected wire needs to be flexible at -55°C (-67°F) and remain flexible after exposure to test environment. The OD of the wire must not be greater than 15% larger than the recovered ID.*

Recover the specimens onto the wire in a fan assisted oven at 150±5°C (302±10°F) for 5 minutes. Allow the specimens to cool to room temperature (23±2°C, 73±4°F) for a minimum of 4 hours before exposure to the test environment.

#### 4.1.2.2 For tubing sizes with recovered bore of more than 6.0mm

After recovery of the printed tubing specimens at 150±5°C (302±10°F) for 5 minutes, allow to cool to room temperature (23±2°C, 73±4°F) for a minimum of 4 hours.

Cut strips longitudinally, 6.0mm wide from the printed, opened, recovered tube.

Suspend three prepared specimens for each test environment on a fine wire with spacers.

### 4.2 Print Testing

#### 4.2.1 Mark Adherence

Three sleeves shall be prepared as detailed in Clause 4.1.1 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

Twelve sleeves shall be prepared as detailed in Clause 4.1.1 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 4.1.1 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±2°C (73±7°F) for 45 ± 15min. 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 change, two gauge marks shall be positioned 100mm apart on each sleeve. The markers shall be recovered in a fan assisted air-circulating oven at 150°C (302°F) for 5 minutes 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±5mm 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 in a way to prevent trapping 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.

For HX 6.4 the mandrel diameter shall be 5.6mm. For other sizes see 109-121031.

**4.3.5 Mandrel Bend Test**

Samples shall be prepared as described in sections 4.1.2.1 or 4.1.2.2.

Bend the tubing specimens through 360° around a steel mandrel at room temperature 23±2°C (73±4°F). The diameter of the mandrel shall be as specified in Table 4. A 9.5mm diameter mandrel is used for the HX 6.4 size product.

*Note: The Low Temperature Bend Test is performed at the temperature specified. The test specimen and test mandrels must be at that specified temperature at the start of the test. The test should be conducted within the cold chamber as efficiently as possible to prevent excessive warming of the specimen or mandrel.*

The time taken to bend the specimen around the mandrel shall be approximately 10 seconds.

Unless otherwise specified this process shall be undertaken at room temperature, 23±2°C (73±4°F). Strip specimens cut from tubing greater than 6mm recovered ID shall be bent around the mandrel corresponding to the original specified diameter of the tubing from which they are cut. (See Table 4)

Visually examine the specimens for signs of cracking or damage.

If cracks are visible the test shall be recorded as FAIL.

If no cracks are visible the test shall be recorded as PASS

**Table 4 Mandrel dimensions for Bend Test**

HX sizes (Supplied ID)	Mandrel Diameter (mm)
2.4, 3.2, 4.8	7.9
6.4, 9.5, 12.7	9.5
19, 25.4, 38.1, 50.8	11.1



## 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 4.1. Specimens shall be conditioned for 168 hours at  $135\pm 2^{\circ}\text{C}$  ( $275\pm 4^{\circ}\text{F}$ ) in an air circulating oven. Markers shall be removed and allowed to cool to room temperature for a minimum of 4 hours at  $23\pm 2^{\circ}\text{C}$  ( $73\pm 4^{\circ}\text{F}$ ).

After conditioning three samples shall be tested for Mark Adherence, in accordance with section 4.2.1. 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 section 4.3.5. 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 4.1. Specimens shall be conditioned for 4 hours at  $175\pm 2^{\circ}\text{C}$  ( $347\pm 4^{\circ}\text{F}$ ) in an air circulating oven. Remove the markers and leave to cool to room temperature for a minimum of 2 hours at  $23\pm 2^{\circ}\text{C}$  ( $73\pm 4^{\circ}\text{F}$ ).

After conditioning three samples shall be tested for Mark Adherence in accordance with section 4.2.1. 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 section 4.3.5. 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 4.1. Specimens shall be conditioned for 4 cycles of 1 hour at  $-55\pm 2^{\circ}\text{C}$  ( $-67\pm 4^{\circ}\text{F}$ ) and 1 hour at  $105\pm 2^{\circ}\text{C}$  ( $221\pm 4^{\circ}\text{F}$ ) in an air circulating oven. Remove the markers and leave to cool to room temperature for a minimum of 2 hours at  $23\pm 2^{\circ}\text{C}$  ( $73\pm 7^{\circ}\text{F}$ ).

After conditioning, three samples shall be tested for Mark Adherence in accordance with section 4.2.1. 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 section 4.3.5. 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 4.1. Specimens shall be conditioned for 4 hours at  $-55\pm 2^{\circ}\text{C}$  ( $-67\pm 4^{\circ}\text{F}$ ) in a cold chamber. Half the markers shall be removed and allowed to warm to room temperature for a minimum of 2 hours at  $23\pm 2^{\circ}\text{C}$  ( $73\pm 4^{\circ}\text{F}$ ).

After conditioning three samples shall be tested for Mark Adherence in accordance with section 4.2.1. 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 section 4.3.5. The samples and mandrel shall be at low temperature when tested as in method TE 109-121006. Mandrel diameter for HX 6.4 size tubing is 9.5mm. Refer to Table 4 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 aluminium 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 150mm<sup>2</sup> 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/m<sup>2</sup>/nm irradiance.

Condition two sets of markers prepared as specified in section 4.1 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 the mandrel bend test section 4.3.5. 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 4.2.1. 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 4.1 "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 AITM 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 (1562°F). 25.4mm continuous tubing that has been printed with two lines of text is used. Product shall be printed as defined in section 4.1 "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±0.5x80±1x3±0.5mm cut from the plaques and shall be conditioned for at least 24hrs at 23±2°C (73±4°F) prior to testing. A new test piece shall be used for each determination.

### 4.7.5 Surface Flammability / 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 (73°F) before fire testing.

### 4.7.6 Specific Optical Smoke Density, D<sub>s</sub> (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 (73°F) before fire testing. Five single sheets are placed side by side vertically for each test to create the required test specimens. Testing is carried out using an NBC smoke chamber.

Smoke density (D<sub>s</sub>) is measured in flaming and non-flaming mode at 1.5 and 4 minutes.

### 4.7.7 Smoke Optical Density, D<sub>s</sub>, - 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/m<sup>2</sup> using the cone heater attachment. Test duration is 10 minutes.



#### 4.7.8 Smoke Density 3m<sup>3</sup> 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 4.1. 'Preparation of test samples. One sample is tested using a 25kW/m<sup>2</sup> 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 (D<sub>max</sub>) and rate of smoke production during the first four minutes (VOS<sub>4</sub>) are determined. This test is made in combination with NF X 70-100 section 4.7.13

#### 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±2°C (73±4°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±2°C (73±4°F) before fire testing.

Samples are tested using a 50kW/m<sup>2</sup> 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 4.1 '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 4.1. 'Preparation of test samples. 50g of material is submitted for testing. The test is conducted at 600°C (1112°F). Values of CIT (Conventional Index of Toxicity), and R (index of the weighted summation of species analysed) are determined.



**5 RELATED DOCUMENT**

**5.1 Table 5 – Related Standards**

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



**5.2 Table 6 – TE Connectivity Documents**

TE Reference	Title	Complies with
411-121002	TE Connectivity Print contrast reference scale	---
411-121005	TE Identification Printer Product Ribbon Matrix	---
109-121002	Tensile Strength and Ultimate Elongation at 23°C	ASTM D882 Method A
109-121003	Dimensions	---
109-121005	Dielectric strength	ASTM D2671 (ASTM D149)
109-121006	Low Temperature Flexibility	IEC 60684-2
109-121007	Heat Shock	AS23053
109-121008	Heat Ageing	AS23053
109-121009	Copper Mirror Corrosion	AS23053
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
109-121031	Split Testing	---
109-121054	Thermal Cycling using liquid Nitrogen	---
109-121053	Flammability testing	ASTM D2671, procedure B
109-121054	Limited Oxygen Index	BS EN ISO 4589-2

**The current document issue should be used, and reference made in the qualification report**

**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, dimensions, and longitudinal change, print quality and adherence of marking shall be carried out on every batch of sleeving.

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, colour, and batch number.

Additional information shall be supplied as specified in the contract or order





**TABLE 7: GENERAL REQUIREMENTS**

PROPERTY	TEST METHOD	UNITS	REQUIREMENTS	RW-2072 SECTION
<b>PRINT PERFORMANCE</b>				
<b>Mark Adherence</b>	TE Document 109-121012 20 rubs, 1kg load, eraser	---	Legible, minimum print contrast 3	4.2.1.
<b>Solvent Resistance</b> Solution A Solution B Solution C Solution D	TE Document 109-121014  30 strokes with toothbrush	---	Legible, minimum print contrast 3	4.2.2.
<b>Fluid Resistance</b>	24±2 hours immersion, 23±2°C (73±4°F), followed by:  TE Document 109-121012 20 rubs 1kg load	---	Legible, minimum print contrast 3	4.2.3.
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	
<b>PHYSICAL</b>				
<b>Visual Inspection</b>	In good lighting, using normal or corrected vision at a distance of 14 inches.	---	In accordance with section 3.2.	3.2
<b>Dimensions</b>	TE Document 109-121003	---	In accordance with 3.3	4.3.1.
<b>Longitudinal Change</b>	TE Document 109-121003	%	+5 to -10	4.3.1.
<b>Tensile Strength</b>	TE Document 109-121002	MPa	7 Minimum	4.3.2.
<b>Ultimate Elongation</b>	TE Document 109-121002	%	80 Minimum	4.3.2.
<b>Specific Gravity</b>	TE Document 109-121015	---	1.57 ± 0.03	4.3.3.
<b>Split testing</b>	TE Document 109-121031	%	100 pass	4.3.4.



Table 7 Continued

PROPERTY	TEST METHOD	UNITS	REQUIREMENTS	RW-2072 SECTION
<b>THERMAL</b>				
<b>Heat Ageing</b> 168 hours at 135°C (275°F), followed by: Mandrel Bend	TE 109-121008			
	360° bend around a mandrel section 4.3.5	---	No damage to the marker and print	4.4.1.
Mark Adherence	TE 109-121012 20 rubs, 1kg load, eraser	---	Legible, minimum print contrast 3	
<b>Heat Shock</b> 4 hours at 175°C (347°F), followed by: Mandrel Bend	TE 109-121007			
	360° bend around a mandrel section 4.3.5	---	No damage to the marker and print	4.4.2.
Mark Adherence	TE 109-121012 20 rubs, 1kg load, eraser	---	Legible, minimum print contrast 3	
<b>Thermal cycling</b> 4 cycles of 1hr at -55°C (-67°F) and 1hr 105°C (221°F), followed by, Mandrel Bend	TE 109-121046			4.4.3.
	360° bend around a mandrel section 4.3.5	---	No damage to the marker and print	
Mark Adherence	TE 109-121012 20 rubs, 1kg load, eraser	---	legible after 20 rubs	
<b>Low Temperature flexibility</b> 4 hours at -55°C (-67°F), followed by: Mandrel Bend	TE 109-121006			
	360° bend around a mandrel section 4.3.5	---	No damage to the marker and print	4.4.4.
Mark Adherence	TE 109-121012 20 rubs, 1kg load, eraser	---	Legible, minimum print contrast 3	
<b>ELECTRICAL</b>				
<b>Dielectric strength</b>	TE Document 109-121005	MV/m	15 minimum	4.5.1.
<b>Volume resistivity</b>	TE Document 109-121017	Ohm cm	1012	4.5.2.
<b>CHEMICAL</b>				
<b>Copper Mirror Corrosion</b>	TE Document 109-121009 16hrs at 150°C (302°F)	%	Damaged area of copper mirror, 8 maximum	4.6.1.
<b>Water Absorption</b>	TE Document 109-121016	%	1 maximum	4.6.2.
<b>ENVIRONMENTAL</b>				
<b>UV Resistance</b> followed by,  Mandrel Bend  Mark Adherence	ASTM G154 UVA and UVB (8 hours dry/4 hours wet cycle)		1000 hours at each irradiance	
	360° bend around a mandrel	---	No damage to the marker and print	4.6.3.
	TE 109-121012 20 rubs, 1kg load, eraser	---	Legible, minimum print contrast 3	



Table 7 Continued

PROPERTY	TEST METHOD	UNITS	REQUIREMENTS	RW-2072 SECTION
<b>FIRE SAFETY</b>				
<b>Fire Propagation (Aviation Method)</b>	Airbus Directive ABD0031 Issue F, Fire worthiness requirements pressured section of fuselage (Flammability of Heat Shrink tubing – AITM 2.0038)	---	Burn length Average shall not exceed 76mm  After flame time average not exceed 30s  After flame time, dripping must not exceed 3s	4.7.1.
<b>Fire Propagation</b>	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.	4.7.3.
<b>EN45545-2</b> Flammability Hazard Rating for unlimited interior mass use:  <i>Based on the following criteria:</i>  Oxygen Index (OI) Smoke Density, Ds  Toxicity	    BS EN ISO 4589-2:1999 EN ISO 5659-2  NF F 70-100 -1 NF F 70-100 -2	    % --- --- ---	<b>Requirement Set R22, Hazard Rating 3<sup>1</sup></b>  32 Minimum 150 Maximum  0.75 Maximum	    4.7.4. 4.7.7.  4.7.9. and 4.7.13.
<b>Surface Flammability, Flame Spread Index, Is</b>	ASTM E162	---	35 Maximum	4.7.5.
<b>Specific Optical Smoke Density, Ds</b>  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	    4.7.6.

<sup>1</sup> Unlimited internal use, any operating category and rail car design



**Table 7 Continued**

PROPERTY	TEST METHOD	UNITS	REQUIREMENTS	RW-2072 SECTION
<b>FIRE SAFETY Cont.</b>				
<b>Toxic Gas Generation from Material Combustion</b>  Carbon Monoxide (CO) Carbon Dioxide (CO <sub>2</sub> ) Nitrogen Oxides (NO <sub>2</sub> ) Sulphur Dioxide (SO <sub>2</sub> ) 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	4.7.10
<b>Effective Heat of Combustion<sup>2</sup></b>  Average Heat Release Rate, 3 minutes  Average Extinction area, 3 minutes	ASTM E1354 50kWm <sup>2</sup> applied heat flux with retainer frame	kW/m <sup>2</sup>  m <sup>2</sup> /kg	≤ 100  Maximum 500	4.7.11

**Table 8 – SPECIAL REQUIREMENTS FOR HX-LFH HEAT SHRINK SLEEVING**

PROPERTY	TEST METHOD	UNITS	REQUIREMENTS	RW-2072 SECTION
<b>ELECTRICAL</b>				
Volume resistivity after damp heat, 16hr at 55°C (131°F) and 95%RH	BS 4G 198-3	Ohm.cm	10 <sup>12</sup>	4.5.3
<b>FLUID RESISTANCE</b>				
1mol NaOH 1 minute immersion  1mol HCl 1 minute immersion  IRM 902 70hrs at 50°C (122°F)	TE 109-121012 20 rubs, super twill cloth, 1kg load, eraser	---	Legible, minimum print contrast 3	4.2.3.
<b>FLAMMABILITY</b>				
<b>BS6853</b> Interior minor use of materials of mass 100-500g  <i>Based on the following criteria:</i> Oxygen Index (OI) Smoke Density, Annex D.8.3, A0 Toxicity, Annex B, R	BS EN ISO 4589-2:1999 BS6853: 1999, Annex D.8.3. BS 6853: 1999, Annex B NF X 70-100	% m <sup>2</sup> /g ---	Vehicle Category 1a  34 Minimum 0.017 Maximum 1.0 Maximum	  4.7.4. 4.7.8. 4.7.13.

<sup>2</sup> 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 8 Continued**

PROPERTY	TEST METHOD	UNITS	REQUIREMENTS	RW-2072 SECTION
<b>Flammability - Continued</b>				
<b>London Underground Standard 1-085: A3</b> <b>Non-listed items</b> <i>Based on the following criteria:</i>			<b>Limited and dispersed Use</b>	
Oxygen Index (OI)	BS EN ISO 4589-2:1999	%	30 Minimum	4.7.4.
Smoke Density, Annex D.8.3, 'A0'	BS6853: 1999, Annex D.8.3	M <sup>3</sup> /g	0.02 Maximum	4.7.8.
Toxicity, Annex B (using BS6853 cat 1a requirements), 'R'	BS 6853: 1999, Annex B NF X 70-100	---	1 Maximum	4.7.13.
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)	4.7.12.
<b>AFNOR NF F 16-101</b> Category A1 Rolling Stock, 'Small dimension parts' <sup>3</sup> <i>Based on the following criteria:</i>	Use the methods below for flammability, smoke, and toxicity, determine 'I' and 'F'	---	<b>Category A1</b> NF F 16-101 Grid 10	
<b>Flammability, I (ignitability) Rating, determined with the following tests -</b> Oxygen Index (OI)	BS EN ISO 4589-2:1999	%	<b>I3</b> 28 Minimum	4.7.4.
Glow Wire test	BS EN 60695-2-11: 2001	---	Ignition does not persist at 850°C (1562°F) after glow-wire is withdrawn	4.7.2.
<b>F Rating (Smoke and toxic gas)</b>  Calculation: Conventional Toxicity Index, CIT  Maximum specific optical density of smoke, Dmax  <sup>4</sup> Rate of smoke production during first 4 minutes of test, $VOS_4 = \frac{D1+D2+D3+D4}{2}$  Smoke Index, $SI = \frac{D_{max}}{100} + \frac{VOS_4}{30} + \frac{C.I.T}{2}$	<b>Determine F rating with the following tests -</b>  NF X 70-100, Toxic gas emission, mass based method.  NFX 10-702, Determination of the opacity of smoke in a non-renewed atmosphere.		<b>F1</b>          ≤ 20	4.7.13.          4.7.9.

<sup>3</sup> Situated inside vehicles, individual parts do not exceed 100g, aggregate mass less than 200g/m. Requirements taken from grid 10 of NF 16-101

<sup>4</sup> Where D (number) is the recorded optical density at each minute.



**TABLE 9 - TEST FLUIDS DESCRIPTION**

Fluid	Description
IRM902	Reference Oil. (ASTM oil NO. 2 replacement)
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 based 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 fuel used in transportation
Propylene Glycol de-icing fluid (SAE-AMS-1424)	Aerospace De-icing fluid, 50/50 % mixture with water
Tap Water	Universal solvent
5% Sodium chloride solution	Sodium chloride is a universal compound used in many chemicals and de-icing fluids
Detergent (1% Teepol)	Commonly used industrial detergent
IPA – Isopropyl alcohol	Widely used as a solvent and cleaner

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