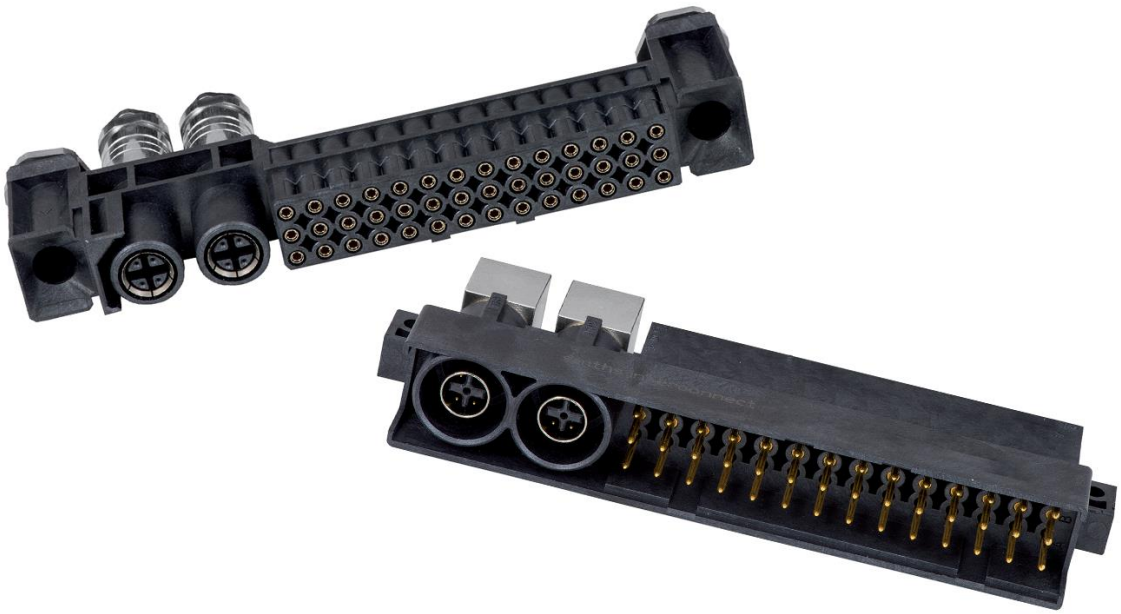
smiths interconnect

Qualification Test Report

INTERCOMPACT Series

42-way Signal & 2-way Ethernet PCB Connectors
60-way Signal PCB Connectors

June 30, 2021
Revision - C



1. Scope

The purpose of this report is to summarize the samples, test sequence, test methods, and test data gathered during the Qualification activity of Smiths Interconnect, E471i 60-way Signal PCB Connector and the 42-way Ethernet PCB connector, built using E471i insulator material for the male connectors and E130i insulator material for female connectors, and labelled as "E471i Signal connector" or "E471i Ethernet connector" throughout this report.

2. Standard ambient test conditions

All tests and examinations specified by this Qualification test procedure will be continued under any combination of conditions within the ranges stated in this paragraph, unless specified otherwise.

Temperature: 22°C ± 3°C Relative
Humidity: 30-60% Max
Pressure: 970 -1020 mBarG

GOVERNMENT DOCUMENTS
Military

MIL-C-28748	Connector, plug and receptacle, rectangular,rack and panel solder type and crimp type contacts general specification
MIL-STD-202-301	Department of Defense Test MethodStandard Method 301, Dielectric Withstanding Voltage

NON-GOVERNMENT DOCUMENTS
European Standard

EN50155:2017 Railway applications – Electronic equipmentused on rolling stock

EN61373:2010 Railway applications – Rolling stock equipment – Shock and vibration tests

EN 60068-2-30:2005 Environmental testing – Part 2-30: Tests –Test Db: Damp heat, cyclic (12h + 12 h cycle)

EN45545-2 Fire Protection on Railway Vehicles

STM-S-001ind.D Fire Protection on Railway Vehicles

Association Française de Normalisation

NF C93-426 Electronic components. Connecting devices. Multiple rectangular connectors without shell. General requirements.

NF F61-030 Railway rolling stock. Electrical connectors. Generalities.

Electronic Industries Alliance (EIA)

EIA 364-23C Low Level Contact Resistance Test Procedure for Electrical Connectors and Sockets

EIA/TIA 568 C

International Electrotechnical Commission (IEC)

IEC 60068-2-30:2005 Environmental testing – Part 2-30: Tests –Test Db: Damp heat, cyclic (12h + 12 h cycle)

Smiths Interconnect

ANSI/NCSL Z540-1-1994 Calibration System Requirements

QMM 400A Smiths Interconnect Quality AssuranceManual

IEEE 802.3-2008

3. Test procedures

Marking Check, Dimension and Weight

Requirements: Visual examination with the naked eye shall show that the markingsmeeting the drawing requirements. All measurements, dimension and weight, shall meeting the drawing requirements. No parts will show any sign of defect.

Marking checks performed are in addition to First Article Inspection (FAI) of components prior to submission for Qualification testing, and will focus on the followingsubset of marking features only:

- Male and female part marking per the component packing label
- Provision of date code
- Pin identification legible (for pin row and column identifiers used to select specific pins for tests including Contact Resistance and Contact Retention)

Contact Resistance (CR)

Requirements: The contact resistance of contacts of the connectors shall comply with Table 5 below. This shall be proven by the measurement of the contact resistance on mated connectors, as specified by EIA 364-23C. Minimum of 10% of the total contacts shall be tested, with a minimum of 5 contacts tested, and covering all pin diameters of theconnector.

Table 5: Contact Resistance Requirements

Setup	Contact Resistance
Signal and Ethernet contacts	<4.5mΩ for contact under low and servicecurrent, after value adjustment to account for pin length. < 15 mΩ for unadjusted values.
Crimping of a female contact	< 0.5 mΩ

Method for final calculation of Contact Resistance:
Due to the variation of the male pin length resistance (RC1) and the major influence on the raw value of the measured contact resistance, the following methodology to adjust forpin length has been agreed for both the Signal and Ethernet connectors:

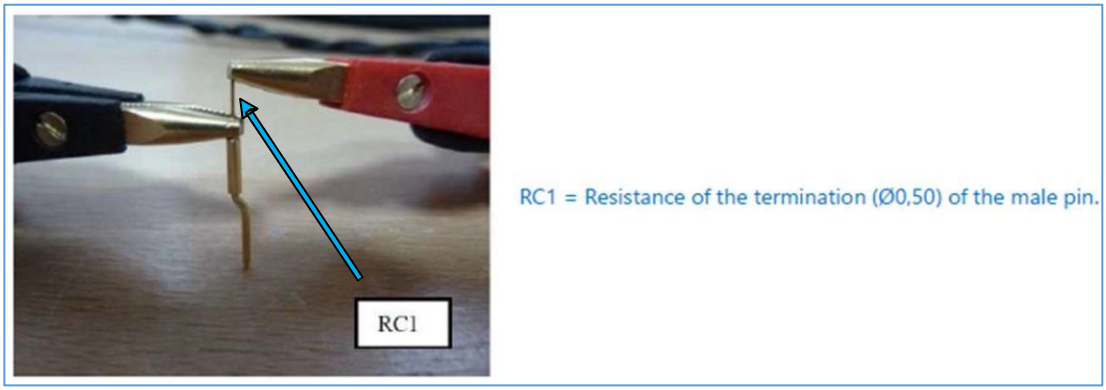


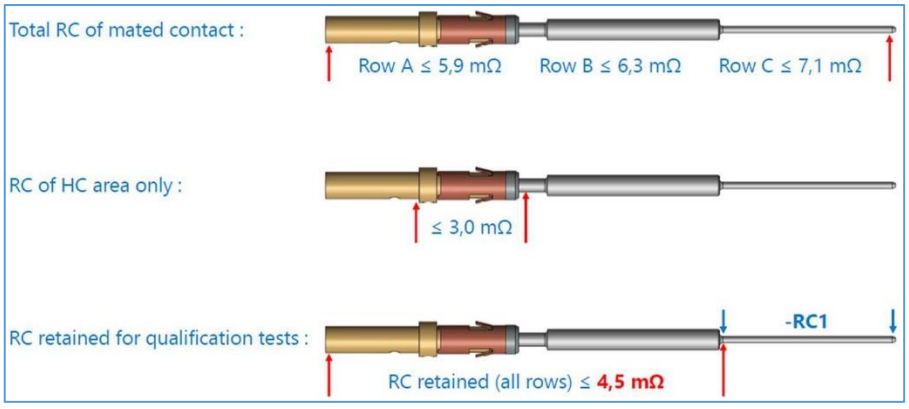
Figure 1: RC1 pin resistance illustration

Based on characterization and statistical worst case analysis of the pins from Rows A, Band C of the connectors, it has been determined that the as-measured Contact Resistancecan be adjusted by the following amounts for each row contact type as follows:

- **Row A** type contacts: **Subtract 1.8 mΩ**
- **Row B** type contacts: **Subtract 1.9 mΩ**
- **Row C** type contacts: **Subtract 3.1 mΩ**

The resultant final values for Row A, B and C contacts will then be compared against the < 4.5 mΩ spec value. This is further illustrated in the diagram below:

Figure 2: Contact resistance - Measurement component for Qualification test



A further set of unadjusted contact resistance data for rows A, B and C contacts will be compared against a < 15 mΩ spec value.

Insulation Resistance (IR)

Requirements: The connectors shall provide insulation resistance between pins as specified in the Table 6 below.

Table 6: Insulation Resistance Requirement

Applied Voltage	Minimum Insulation Resistance
500VDC +/-50V DC	>100GΩ, Characterise to 1TΩ
100VDC +/-50V DC (Quadrax)	>100GΩ, Characterise to 1TΩ

Insulation resistance shall be measured at points A and B for a minimum time of 60 seconds, as defined:

- 1 – Between A and B
- 2 – Between A and B together and the "test panel".

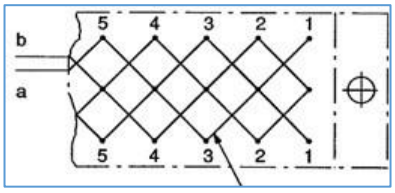


Figure 3: Measurement points, alternate pins connected together (A & B).

The connection to the "test panel" shall be made generally as follows (this applies to both Insulation Resistance and Dielectric Withstand Voltage tests):

For standard contacts on both Signal and Ethernet connectors:

- For mated connector tests and male-only connector tests, the "test panel" connection will be made to the Alstom fitted metal work.
- For female-only connector tests, the "test panel" connection will be made to the metal spacer nut.

For Quadrax contacts on the Ethernet connector module:

- For mated connector tests, male-only connector tests and female-only connector tests, the "test panel" connection will be made to the Quadrax module metal work.

After damp heat test and salt spray, the connectors shall provide insulation resistance between pins as specified in **Table 7.**

Table 7: Insulation Resistance after Damp Heat /Salt Spray

Applied Voltage	Minimum Insulation Resistance
500VDC +/- 50V DC	>1GΩ, Characterise to 10GΩ
100VDC +/- 50V DC (Quadrax)	>1GΩ, Characterise to 10GΩ

Dielectric Withstanding Voltage (DWV)

Requirements: Any contact of the Flat Floating Connectors shall be insulated from othercontacts and from connector body. Insulation level shall be such that the application of the test voltages specified in Table 8 below will not produce breakdown or flashover.

Table 8: Dielectric Test Voltages

Contacts	DC Voltage (V)
Standard pins (Signal and Ethernetconnectors)	1500

Electrical insulation test shall be passed at points A and B, as defined (**see Figure 3**):

- 1 – Between A and B
- 2 – Between A and B and the test panel

Note: See also details in section 9.1.3 regarding "test panel" connection definition.

Test procedure and results to be obtained shall be based on MTL-STD-202, Method 301in particular:

- Ramp Rate: 500 V/s
- Dwell: 60 s
- Leakage Current: < 2mA (with no breakdown or flashover)

Quadrax Electrical Characterization

DC Resistance

Requirements: The mated contacts shall be tested according to IEC 60512-2-1.

The following measuring parameters apply to this 4-wire, DC, contact resistance test:

- Applied test voltage: 20mV
- Compliance test current: ≤100mA
- Total number of mated contacts: 8
- The forward and reverse current and voltage shall be measured tocalculate the resistance
- Calculated resistance ≤ 0.2Ω
- Input to output resistance <200mΩ
- Input to output resistance unbalance <50mΩ
- Current carrying capacity >0.75 A
- Dielectric Strength 1500 VDC conductor to conductor, 1000 VDCconductor to test panel (shell).

The measuring points shall be:

- on the signal pin (Qty 4) of the PCB side of the male connector (Qty 2)
- on the rear of the signal, socket contact (Qty 4) before assembly of the S-67635-99 socket Quadrax (Qty 2)

Additional female contacts (Qty 8) soldered to wire will need to be used for these measurements.

RF Measurement Note: For all RF measurements the following shall be done:

- The male and female Quadrax connectors and Filotex 2PK319 cable shall be attached to fixtures, at the discretion of the RF engineer, specifically for RF measurement. This shall be done to minimize reflections and skew that may affect the transmitted signal. The Quadrax connectors on the PCB shall be connected to differential traces and terminate at SMA connectors. The female connector shall be assembled with a *minimum* of 200mm of Filotex 2PK319 cable and may be terminated with a PCB and/or SMA connectors.
- 2 differential pairs (Qty 4) of each Quadrax (Qty 2) mated connector shall be measured. For cross talk measurements, there shall be one set of measurementsper Quadrax.
- A 4-port network analyzer (VNA) shall be used to make differentialmeasurements. All four ports will be used.
- The VNA shall be calibrated with a 4-port E-Cal device.
- De-embedding, fixture removal, and gating techniques may be used to isolate the mated connector with its cable to make accurate measurements.

- The system rise time shall be 1000 ps.
- Differential assignments are as follows per Figure 4.
  - Pair 1 shall be: 1 (Yellow) & 3 (Orange)
  - Pair 2 shall be: 4 (Blue) & 2 (White)
  - Ground shall include the braid

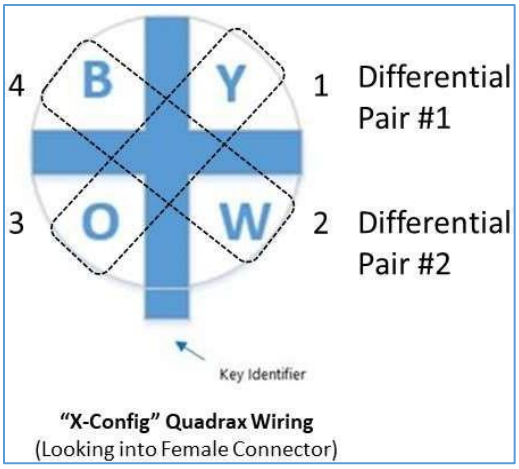


Figure 4: "X-Configuration" Quadrax Wiring Scheme

- Adjacent lines shall be terminated with 50 Ohms loads at both ends. There shall beat least 200 frequency points in the measurement. The frequency of interest shall be 10MHz to 100MHz. Two measurements shall be made and shall include RF fixtures with and without the DUT.

Return Loss (RL)

Requirements: The mated connectors shall be tested in accordance to IEC60512-25-5.

See RF Measurement Note.

Return loss (-20 log10 |SDD11|) shall be measured and the value shall be ≤ -20dB at 100 MHz. As stated within the IEC spec:

"The fixture loss shall be measured separately so that it can be removedfrom and compared to the specimen measurement."

The plot shall be 10 dB per division on the vertical scale and log frequency sweep for the horizontal scale.

Insertion Loss (IL)

Requirements: The mated connectors shall be tested in accordance to IEC60512-25-2.

See RF Measurement Note.

Attenuation (SDD21) shall be measured and the value shall be greater than -0.4dB and less than 0.0 dB at 100MHz. As stated within the IEC spec:

"The fixture attenuation shall be measured separately so that it can be removed from and compared to the specimen measurement."

The plot shall be 1 dB per division on the vertical scale and log frequency sweepfor the horizontal scale.

Near End Cross Talk (NEXT)

Requirements: The mated connectors shall be tested in accordance to IEC60512-25-1. The following exception applies to the spec:

- Baluns are not going to be used because a 4-port VNA is being used.Measurement techniques for this type of VNA shall be used.

See RF Measurement Note. As stated within the IEC spec:
"Unless otherwise specified, for differential measurements one signal pair
to one ground ratio shall be used and the crosstalk shall be measured on the closest (adjacent) or the most closely coupled quiet lines to the drivenline."

50 Ohms loads shall be at the far end of the driven and quiet lines. On the near endside of the connectors, logical Port 2 shall be connected to Pair 2 and logical port 1 shall be connected to Pair 1. Cross talk (SDD21) of the DUT shall be measuredand the value shall be less than -43dB at 100 MHz.

The plot shall be 10dB per division on the vertical scale and log frequency sweep for the horizontal scale.

Far End Cross Talk (FEXT)

Requirements: The mated connectors shall be tested in accordance to IEC60512-25-1.
The following exception applies to the spec:

- Baluns are not going to be used because a 4-port VNA is being used.Measurement techniques for this type of VNA shall be used.

See RF Measurement Note. As stated within the IEC spec:
"Unless otherwise specified, for differential measurements one signal pair
to one ground ratio shall be used and the crosstalk shall be measured on the closest (adjacent) or the most closely coupled quiet lines to the drivenline."

50 Ohms loads shall be at the far end of the driven line and at the near end of thequiet line. On the near end side of the connectors, logical port 1 shall be connected to Pair 1. On the far end side of the connectors, logical port 2 shall be connected to Pair 2. Cross talk (SDD21) of the DUT shall be measured and thevalue shall be less than -35.1 dB at 100 MHz.

The plot shall be 10dB per division on the vertical scale and log frequency sweep for the horizontal scale.

Propagation Delay

Requirements: The mated connectors shall be tested in accordance to IEC60512-25-4.

See RF Measurement Note.

Time delay (SDD21) shall be measured and the value shall be less than 2.5ns. It shall be measured at the 10% and 50% amplitudes of the signal.

Inter-pair Skew

Requirements: The mated connectors shall be tested in accordance to IEC 60512-25-4. As stated within the spec for propagation delay measurements: "Specimen induced skew should not be compensated. When skew is observed, a waveform plot should be provided."The inter-pair skew shall be less than 1.25ns.

Retention of Gauge

Requirements: Per NFF 61-030, section 11.5.6

Preparation of the test specimen
The connectors fitted with female contacts shall be fixed, face pointing downwards following the vertical axis.

Procedure
An individual gauge with maximum dimension defined on the drawing preparedby the supplier, shall be inserted three consecutive times in 10% of the female contacts and withdrawn.

An individual gauge with the minimum size and known mass, defined on thedrawing prepared by the supplier shall then be introduced in the contacts previously used with the gauge of maximum dimension.

Check and result to be obtained.
The gauge of minimum size, stressed by its own weight, shall be retained by each female contact tested.

Result:
An individual gauge with the minimum diameter and a mass is then introduced in the contacts previously used with the gauge of maximum dimension.

Insertion/Extraction Force

Requirements: The connector will be placed on a support in such a way that the connector cannot move during test. A gauge will measure the force. The insertion and extraction speed will not exceed 5 mm/second.

Note that these forces are measured on fully accessorized connectors and as such, includeforce contributions from both the standard contacts (Signal and Ethernet connectors) andalso from the Quadrax contacts where applicable (Ethernet connector only).

The maximum insertion/extraction forces shall be 122N.

Damp Heat Cycling

Requirements: The temperature and humidity of the air in the test chamber shall be controllable and means shall be provided for on-going recording of these values. The lab will be maintained at a humidity of <50% RH.

The water from moisture condensation shall be extracted from the test chamber and shallnot be reused.

If the air is humidified by the spraying of water, the spray water shall have a minimum resistivity of 500 Ω · m.

The climatic conditions in the test chamber shall be kept as uniform as possible (if necessary by circulation) and the equipment under test (EUT) shall not alter such conditions (through heat dissipation, adsorption of humidity or otherwise) beyond thespecified tolerances.

No condensate water shall be allowed to drip on the EUT.

This test is carried out in accordance with EN 60068-2-30, test Db as shown below in **Figure 5** and **Figure 6**.

Temperatures: + 55 °C and + 25 °C Variant 2Number of cycles: 2 (respiration effect) Time: 2 x 24 hours

If condensation has not occurred by the beginning of the second cycle, (low thermal inertia of test piece), speed of temperature variation can be increased (but not exceed 1
°C/min, and with a maintained relative humidity).

Temperature and humidity will be monitored during test to target the following profiles(per HwRS) shown in **Figure 5**, but using the Temperature and Humidity minimum andmaximum levels defined per EN 60068-2-30, test DB, variant 2.

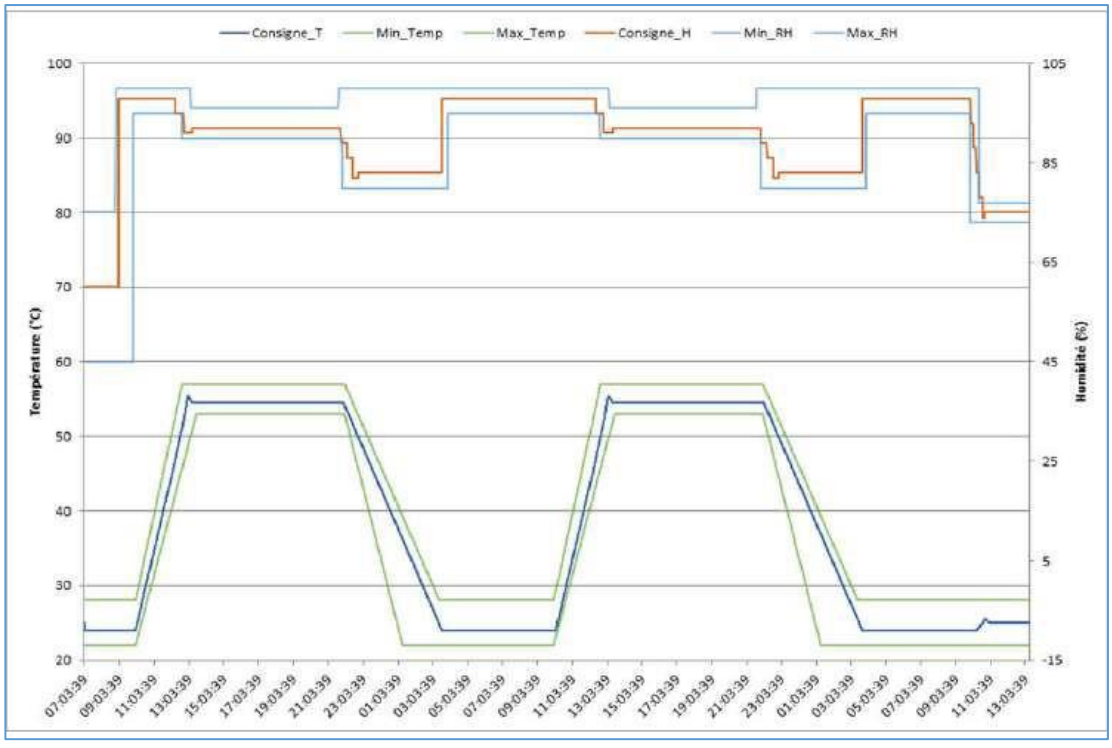


Figure 5: Cyclic Damp Heat Temperature and Humidity Profile

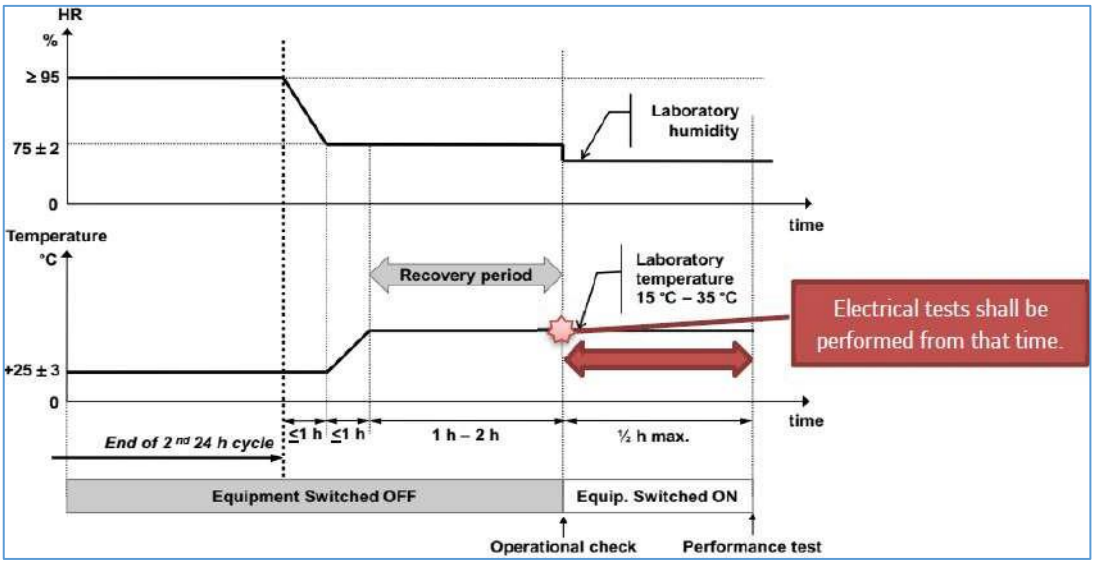


Figure 6: Cyclic Damp Heat Recovery Period

Return to ambient temperature is carried out under controlled recovery conditions as shown in **Figure 6**. Post Damp Heat electrical testing will be performed within half an hour at the end of the recovery period (but as soon as practical) and within laboratory conditions that are < 50% RH maximum, but will target <= 40% RH if possible. All times of electrical measurements shall be recorded.

Electrical measurements shall be performed on:

- Mated connectors
- Male connector alone
- Female connector alone

2 Groups shall be defined to perform electrical tests. Wiring arrangement for IR and DWV measurements shall be compliant with the following test setups shown in **Figure 7** and **Figure 8**

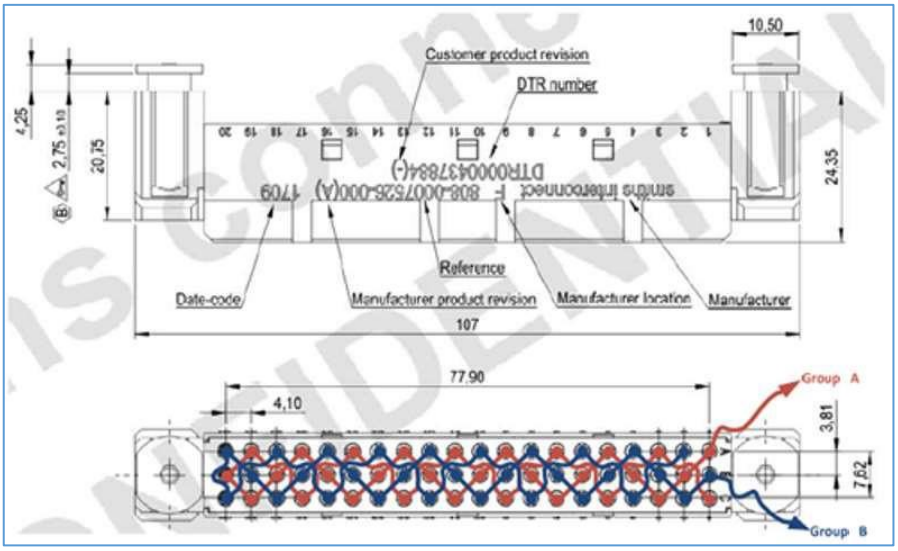


Figure 7: IR and DWV wiring arrangement details – Female signal connector

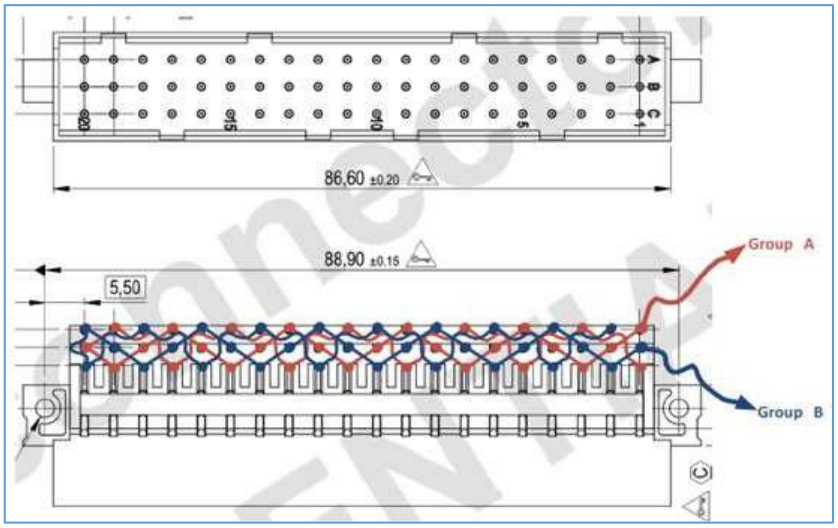
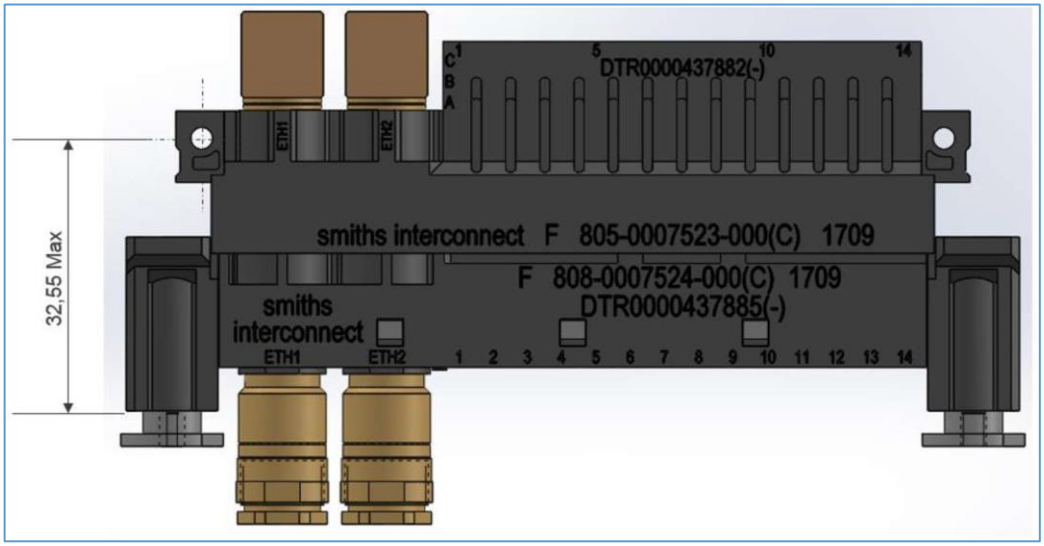


Figure 8: IR and DWV wiring arrangement details – Male signal connector

A similar IR and DWV wiring arrangement will be used for the male and female Ethernet connector.

Random Vibration (RV)

Requirements: The Flat Floating connectors shall be able to withstand vibrations for Category 1, Class B devices as defined per EN 61373 as listed below in **Figure 9** (per theapproved HwRS) and using Vertical axis limits for all axis, and will be followed by a further assessment to Category 2 as listed below in **Figure 10**, also per EN 61373, again using the Vertical axis limits for all axis. Connectors will be connected at the maximum unmated length of 32.55mm.



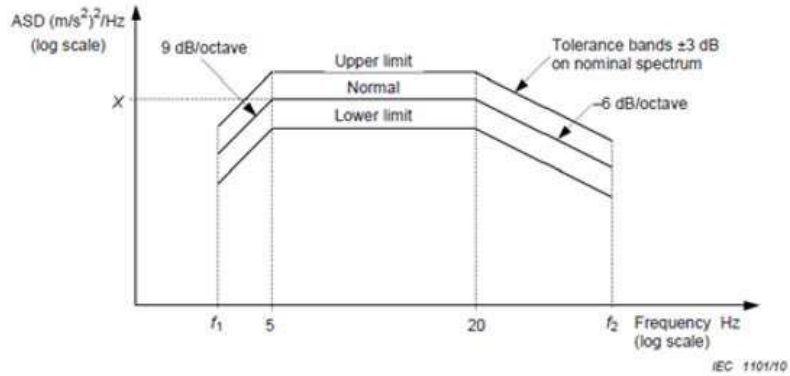
Compliance to requirement FFC_AC4_HwRS_0212 as stated in the TRV9088000227 shall be proven during qualifications by a mechanical endurance test, as specified per EN61373, with 5 hours test duration per axis (3 axis; 15 hours test duration total) as follows:

Procedure:

- **Levels**: Setup for Random Vibration per condition EN 61373 – Category1, Class B, then followed by a separate Random Vibration test to EN 61373 - Category 2, using the "Vertical" limit levels stated in Figure 9 and Figure 10 for all 3 axis;
5.72 m/s^2 rms for Category 1, Class B, and 30.6 m/s^2 RMS for Category 2
- **Frequency Sweep**: 5 Hz to 150 Hz for Category 1, Class B; 5 Hz to 250 Hz forCategory 2.
- **Duration:** The frequency range will be swept in 1 cycle, up and back in 5 hours; Each axis will be swept 1 time in each of the 3 axis, and for a total exposure timeof 15 hours per connector and per Vibration test.
- **Measurement**: In addition to acceptance criteria defined by EN 61373, it shall beverified that the electrical continuity is kept on all contacts during these Vibration tests, including the Quadrax contacts for the Ethernet connector. The connector will be monitored for any disconnects > 0.1usec during the Random Vibration. Via pencil marks or similar, no rotation of connector screws and nuts

will also be verified, post Vibration testing. The appearance of the connectors shall be without damage, and markings shall be readable at the end of the test.

- **Documentation:** Charts will be taken at the completion of the Random Vibrationtests (both for Category 1, Class B, and Category 2, and for both connector types) and will be included in the final Qualification report.



when mass	≤500 kg:	f_1 = 5 Hz	f_2 = 150 Hz
when mass	>500 kg≤1 250 kg:	$f_1 = \frac{1250}{\text{mass}} \times 2\,\text{Hz}$	$f_2 = \frac{1250}{\text{mass}} \times 60\,\text{Hz}$
when mass	>1 250 kg:	f_1 = 2 Hz	f_2 = 60 Hz

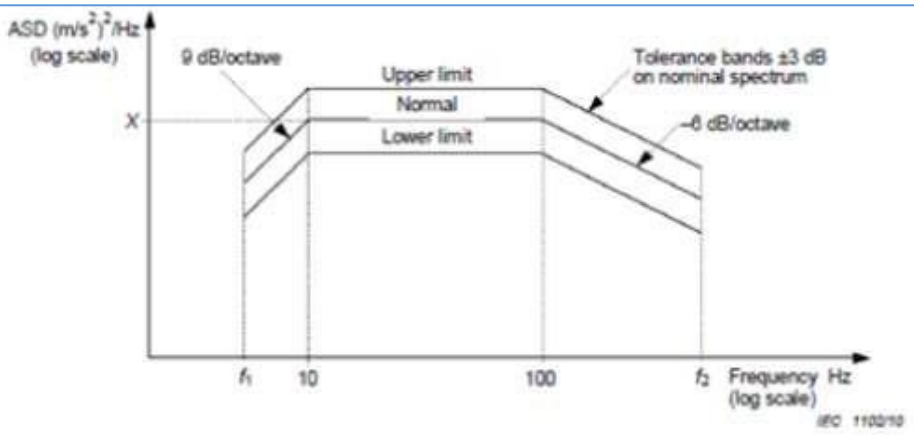
	Vertical	Transverse	Longitudinal
Long-life test ASD level $(m/s^2)^2/Hz$	0,964	0,192	0,461
RMS value m/s^2 2 Hz to 150 Hz	5,72	2,55	3,96

NOTE 1 For items with test frequencies over than 2 Hz the r.m.s. levels shall be lower than those quoted above.

NOTE 2 For items with test frequencies less than 150 Hz the r.m.s. levels shall be lower than those quoted above.

NOTE 3 If frequencies above f_2 are known to exist they may be included, the amplitude being established by extending the 6 dB/octave decay line until it intersects the maximum frequency required. In such cases the r.m.s. levels shall be increased.

Figure 9 : Category 1, Class B – Body Mounted, ASD Spectrum



when mass	≤100 kg:	f_1 = 5 Hz	f_2 = 250 Hz
when mass	>100 kg≤250 kg:	$f_1 = \frac{250}{\text{mass}} \times 2$ Hz	$f_2 = \frac{250}{\text{mass}} \times 100$ Hz
when mass	>250 kg:	f_1 = 2 Hz	f_2 = 100 Hz

	Vertical	Transverse	Longitudinal
Long-life test ASD level $(m/s^2)^2/Hz$	6,12	4,62	1,32
RMS value m/s^2 2 Hz to 250 Hz	30,6	26,6	14,2

NOTE 1 For items with test frequencies over than 2 Hz the r.m.s. levels shall be lower than those quoted above.

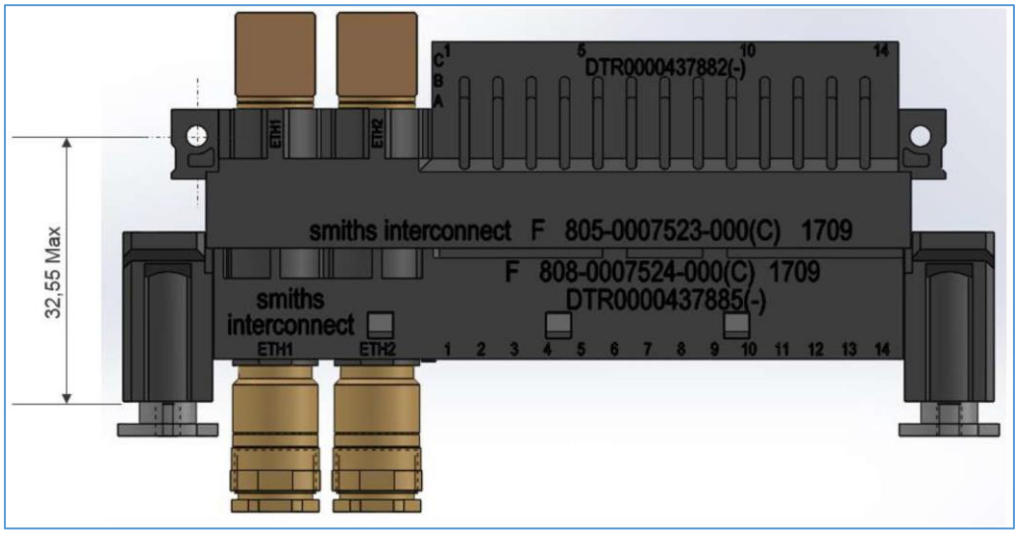
NOTE 2 For items with test frequencies less than 250 Hz the r.m.s. levels shall be lower than those quoted above.

NOTE 3 If frequencies above f_2 are known to exist they may be included, the amplitude being established by extending the 6 dB/octave decay line until it intersects the maximum frequency required. In such cases the r.m.s. levels shall be increased.

Figure 10: Category 2 – Bogie mounted – ASD spectrum

Half Sine Shocks (HSS)

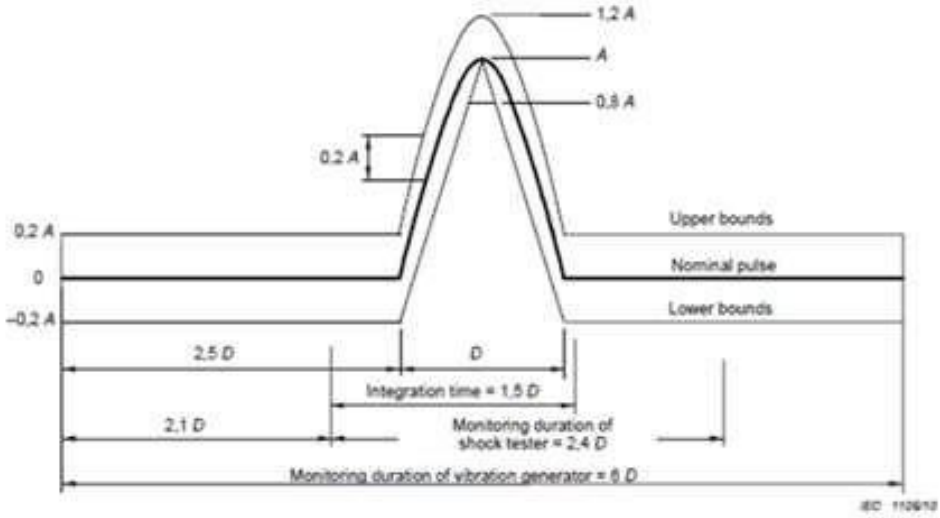
Requirements: The Flat Floating connectors shall be able to withstand half sine shocks for Category 1, Class B, with all axis tested per Longitudinal levels (per the approved HwRS), and will be further assessed to Category 2 half sine shocks, as defined per EN 61373 and as highlighted below in Figure 11. Connectors will be connected at the maximum unmated length of 32.55mm.



Procedure:

- **Levels:** Setup for half Sine Shock per condition EN 61373 – Category1, Class B then followed by a separate half Sine Shock test to EN 61373 - Category 2, usingthe "Longitudinal" limit levels stated in Figure 11 for all 3 axis; 50 m/s^2 peak acceleration for Category 1, Class B and 300 m/s^2 peak acceleration for Category2.
- **Nominal Pulse Width**: 30ms for Category 1, Class B test; 18ms for Category 2 test.
- **Duration:** 18 pulses total per Shock test – 3 positive and 3 negative pulses in each of the 3 orthogonal axis.
- **Measurement:** In addition to acceptance criteria defined by EN 61373, it shall beverified that the electrical continuity is kept on all contacts during these Shock tests, including the Quadrax contacts for the Ethernet connector. The connector will be monitored for any disconnects > 0.1usec during the Shock test. Via pencil marks or similar, no rotation of connector screws and nuts will also be verified, post Shock testing. The appearance of the connectors shall be without damage, and markings shall be readable at the end of the test.

- **Documentation:** Charts will be taken at the completion of the half Sine Shock tests (both for Category 1, Class B and Category 2, and for both connector types) and will be included in the final Qualification report.



Category	Orientation	Peak acceleration A m/s²	Nominal duration D ms
1			
Class A and class B	Vertical	30	30
Body mounted	Transverse	30	30
	Longitudinal	50	30
2			
Bogie mounted	All	300	18
3			
Axle mounted	All	1 000	6

NOTE Some category 1 equipment intended for specific applications may require additional shock testing with peak accelerations A of 30 m/s² and duration D of 100 ms. In such cases these test levels should be requested and agreed prior to testing.

Figure 11: Pulse shape and limits of tolerance for half sine pulse

Quadrax Measurements

Please see Section "Quadrax Electrical Characterization"

Resistance to Fluids

Resistance to Gas Oil

Per NFF 61-030, Section 4.4.1

Procedure

A single connector (1 male part, 1 female part) assembled, cabled (appendices for the insulated conductors) and not mated shall be totally immersed for 5 minutes ±30 seconds in fuel for diesel powered vehicles (gas oil), kept at the temperature of (50±2) °C.

They shall then be mated for at least 24 hours, at the ambient temperature of +15°C to +30°C with a relative humidity of between 30 and 70%.

The test consists of 3 cycles. Checks **and final measurements**

Without carrying out any clean or wiping
Marking: As specified in clause 11.1.2.2 of NFF 61-030
On the unmated assembly after 4 hours of storing at temperature of 70°C ±2.

Results to be obtained

- Appearance: as specified in clause 11.1.1 of the NFF 61-030 standard.
- Dielectric Withstand voltage; Should meet the following:
  - Standard (signal) pins on both the Signal and Ethernet connectors:1000 VDC, per setup in **para Dielectric Withstanding Voltage.**
  - Quadrax pins, conductor to conductor: 1000 VDC, per setup in **para Quadrax Electrical Characterization.**
  - Quadrax pins, conductor to test panel (shell): 667 VDC, per setup in **para Quadrax Electrical Characterization.**
  - **Note:** The Quadrax DWV voltage levels for post fluids tests are defined by SINT Design team and are scaled at 0.667x the default value of Quadrax DWV voltage levels defined in section **Quadrax Electrical Characterization**, and are not referenced directly from the French rail standard NFF 61-030.
- Insulation resistance: Should meet > 400 MΩ; characterize to 1 GΩ, andfollow the general setup described in **para Insulation Resistance**

Resistance to Mineral Oil Per NFF 61-030, Section 4.4.2

Procedure

A single connector (1 male part, 1 female part) assembled, cabled (appendices for the insulated conductors) and not mated shall be totally immersed for 5 minutes ±30 seconds in Mineral Oil No 2 at the temperature of 50°C ±2.

The oil shall have the following characteristics:

- Aniline point : 93°C ±3
- Kinematic viscosity at 100°C: 20 mm^2/s ±1
- Ignition point: 245°C ±6

The connectors shall then be unmated for 24 hours at least, at the ambient temperatures of +15°C to 30°C and with a relative humidity of betwwen 30% and 70%. The rest consits of 3 cycles.

Final checks and measurements

Without carrying out any cleaning or wiping
Appearance: There should be no crack or dissolution of the insulation or he sealing system.

On the unmated assembly after 4 hours of storing at temperature of 70°C ±2.

Results to be obtained

- Appearance: as specified in clause 11.1.1 of the NFF 61-030 standard
- Dielectric Withstand voltage; Should meet the following:
  - Standard (signal) pins on both the Signal and Ethernet connectors:1000 VDC, per setup in **para Dielectric Withstanding Voltage.**
  - Quadrax pins, conductor to conductor: 1000 VDC, per setup in **para Quadrax Electrical Characterization**
  - Quadrax pins, conductor to test panel (shell): 667 VDC, per setup in **para Quadrax Electrical Characterization.**
  - **Note:** The Quadrax DWV voltage levels for post fluids tests are defined by SINT Design team and are scaled at 0.667x the default value of Quadrax DWV voltage levels defined in section 9.1.5, and are not referenced directly from the French rail standard NFF 61-030.
- Insulation resistance: Should meet > 400 MΩ; characterize to 1 GΩ, and follow the general setup described in **para Insulation Resistance**

Resistance to Hydrochloric Acid and Base Per NFF 61-030, Section 4.4.3

Procedure

A different test specimen shall be used for each type of bath.

A single connector (1 male part, 1 female part) fitted, cabled (see appendices for insulated conductors) and not mated shall be totally immersed for 5 minutes ±30 seconds in acid and base baths, kept at a temperature of 23°C ±2 which shall havethe following characteristics :

- Acid bath: normal solution of hydrochloric acid
- Base bath: normal solution of sodium hydroxide

Note: A normal solution is a concentration that has one mole of product per liter.

Two rinses shall be carried out. The connectors shall then be mated for 24 hours at anambient temperature of +15°C to +30°C with a relative humidity of between 30 and70%.

The test consists of 3 cycles.

Final checks and measurements

Without carrying out any cleaning or wiping
Appearance: There should be no crack or dissolution of the insulation or the sealingsystem.

On the unmated assembly after 4 hours of storing at temperature of 70°C ± 2.

Results to be obtained

- Appearance: as specified in clause 11.1.1 of the NFF 61-030 standard
- Dielectric Withstand voltage; Should meet the following:
  - Standard (signal) pins on both the Signal and Ethernet connectors:1000 VDC, per setup in **para Insulation Resistance.**
  - Quadrax pins, conductor to conductor: 1000 VDC, per setup in **para Quadrax Electrical Characterization.**
  - Quadrax pins, conductor to test panel (shell): 667 VDC, per setup in **para Quadrax Electrical Characterization**
  - **Note:** The Quadrax DWV voltage levels for post fluids tests are defined by SINT Design team and are scaled at 0.667x the default value of Quadrax DWV voltage levels defined in section Quadrax Electrical Characterization, and are not referenced directly from the French rail standard NFF 61-030.

- Insulation resistance: Should meet > 400 MΩ; characterize to 1 GΩ, and follow the general setup described in **para Insulation Resistance.**

Thermal Shock

Requirements: The mated connectors shall endure Thermal Shocks and maintain continuity for the following temperatures (See Table 9) and durations for 120 cycles: as per NF F 61-030, para Endurance Test Results.

Table 9: Thermal Shock/Rapid Variation of Temperature Test Requirements

Temperature (°C)	Duration (minutes)
-50	30
+85	30

Results to be obtained:
There shall be no visible or physical damage.
After thermal shock, repeat IR measurement according to **para Insulation Resistance**.
Continuity will be continuously monitored across the series wired contacts with a "daisy chain". Starting daisy chains should be < 3 Ohms or broken into small daisy chains, and Maximum daisy chain resistance during Thermal Shock shall be **< 5 Ohms**.

Quadrax Mechanical Protection

Requirements: The connectors shall mate with no interference or deterioration of the contacts, following the Thermal Shock cycles.

Endurance Cycles

Requirements: The contacts shall be able to withstand 500 mating cycles. The mating speed shall not exceed 5 mates per minute. The contact resistance after endurance cycles shall be <4.5mΩ for contact under low and service current, after value adjustment to account for pin length, and < 15 mΩ for unadjusted values. See also test details in **para Contact Resistance**. Perform a detailed visual inspection of the contact surface (as per NF F 61-030 para 11.6.1).

Contact Retention

Requirements: The connector shall be supported so as not to allow movement.

For the standard contacts on both the Signal and Ethernet connectors, a force of > 40N (Characterize to 70N) shall be applied at a maximum speed of 10 N/s along the longitudinal axis of the contact, as per NF F 61-030 paragraph 11.5.5. At the end of the test, and after the force has been removed, check appearance of the contacts and ensure the displacement of the contact in the insulator is <= 0.3mm.

For the Ethernet connector, an additional retention test will be performed on the Quadrax module. Given how the contacts are held by the Quadrax module design as shown in Figure 12, a more useful test to be performed will be an Insert Retention test to determine the strength of the Quadrax module retaining clip system as highlighted in Figure 12.

For this test, an initial small force (in 5-10N range) will be applied to the female Quadrax connector front face (via the insert retention tool) to take up any initial float/slack of the module within the Ethernet female connector insulator. This will be followed by applying a 40N force that will be applied for 5s. After the force has been removed, the Quadrax module displacement shall be <= 0.3mm. This test will be repeated to characterize the force versus displacement level up to a maximum force level of 100N.

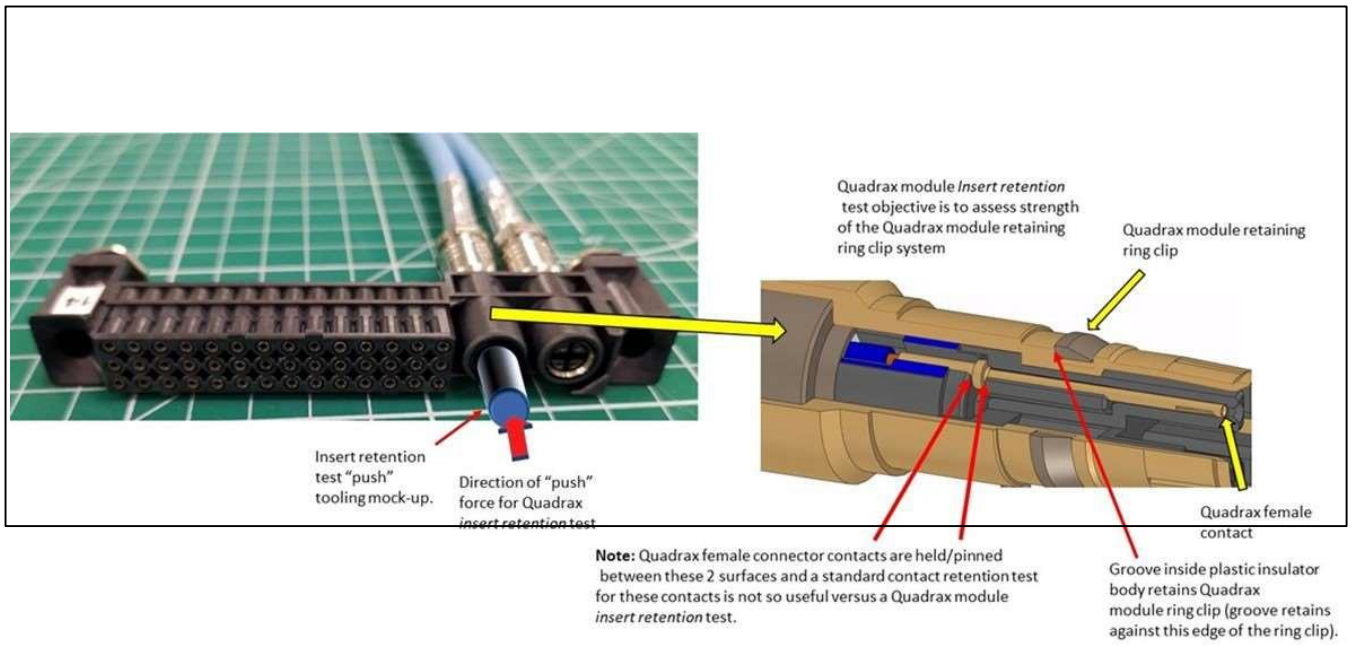


Figure 12: Ethernet Connector Quadrax

Insert Retention Test

Objective Results to be obtained:

- Standard contacts displacement, post 40N force applied: 0.3mm Max (characterize displacement to 70N)
- Female Quadrax module displacement, post 40N force applied: 0.3mm Max (characterize displacement to 100N).

Quadrax Measurements

Please see Section "Quadrax Electrical Characterization"

Temperature Rise

Requirements: The testing on both the Signal and Ethernet connectors will be comprised of 2 separate tests as follows, and will be based on a nominal starting ambienttemperature of +23°C:

- Single contact test: mated contact should withstand a 3A current and display a max temperature rise of +20°C; data will be gathered to 5A levels.

- Connector level test: all mated contacts daisy chained together should withstand a 3A current and display a max temperature rise of +30°C; data will be gathered to 5A levels.

Salt Spray

Requirements: The solution for producing the salt mist shall be prepared by dissolving 50g ±1 sodium chloride (NaCl) analytical reagent quality, in distilled or demineralized water to make up1 L ±0.02 of final solution at 20°C; if the pH does not lie between 6.5 and 7.2, the solution shall be rejected.
During the test, the temperature in the test chamber shall be maintained at 35°C ±2.The solution and the air used to produce the salt mist shall have a temperature equal tothat of the test chamber.

The equipment should be tested in the manner in which they are expected to be used i.e. the connectors shall be placed flat/horizontal in the salt spray chamber.

The test chamber shall be kept closed and spraying of the salt solution shall continue without interruption during the whole conditioning period.

The period shall be for class ST4: 96 hours.

At the end of the test, the equipment shall be washed in running tap water for 5 min, rinsed in distilled or demineralized water, then dried to remove droplets of water and stored under standard atmospheric conditions of the testing area for not less than 1 hour, no more than 2 hours.

After that, the equipment is subjected to a visual examination. After salt spray, repeat IR measurement according to **para "Insulator Resistance"**

Dry Heat Test

Requirements: The plug and socket shall be cabled with insulated conductors suitable to the connector's use. The connector shall be coupled, locked and placed in the test chamber in such a manner that their principal axis is horizontal. The mated connectors will be preconditioned for 1hr. The chamber will be raised to 100°C ±2 at a rate not to exceed 1°C per minute. The temperature will be held for 96hrs. During the bake and after 24 hours minimum, the insulation resistance shall be measured while at temperature. After the full test period of 96 hours, the connectors will be allowed to cool to room temperature at a rate of 1°C per minute. The final measurements shall be carried out after a period of 24 hours at room temperature. Appearance, Insulation Resistance and Contact Resistance shall be measured.

Insulation Resistance shall be recorded with an applied voltage of 500 VDC (for standard signal contacts) or 100VDC (for Ethernet Quadrax contacts) - **See also Insulation Resistance** for general setup for Insulation Resistance test:

Measure during the test (after 24h minimum):

- The value of the insulation resistance shall be > 10 GOhms; characterize to100 GOhms

Final checks and measurements shall be done after a period of 96 hours at bake temperature (+ 24 hrs cooling at room temperature):

- The appearance shall be without deterioration at the end of the test **per para Marking Check, Dimension and Weight.**
- The value of the insulation resistance shall be > 10 GOhms; characterize to100 GOhms
- The value of the contact resistance shall be **per para Contact Resistance.**

Quadrax Measurements

Please see Section "Quadrax Electrical Characterization"

Crimping DDP Measurement

Requirements: The contact pair shall be crimped on a conducting core of the smallest section allowable. The voltage drop shall be measured as specified in **Figure 13**. Note that the formula used to calculate DPP levels differs from the French Rail standard NFF 61-030 and reflects only 1 crimp in the actual product setup and a reduced wire length in the DPP test setup per the amended test setup diagram shown in Figure 13.

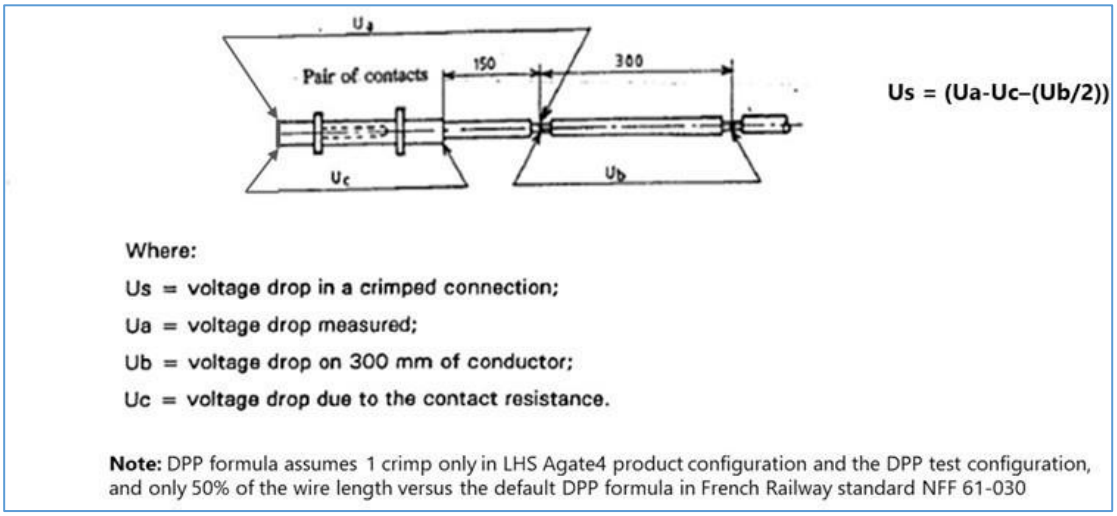


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Figure 13: Assembly for the measurement of the voltage drop in a crimped connector

The following crimp setup shall be applied:

Standard Contacts:
Crimping Tool: DMC FT8
Locator: M22520/1-05 (manually adjusted locator tool, providing equivalent position tofixed location Production tool TP 1848)
Position 4 for 0.5mm^2 conductor
Cable UL for 0.5mm^2: EN 50306-2-300V 1 x 0.5-M-10

Ethernet Quadrax Contacts:
Crimping Tool: M22520/2-01 (DMC AFM8 equivalent)
Locator: S_129
Position 4 for 0.25mm^2 conductor
Cable UL for 0.25mm^2: DTREN150007-300V-4 x 0.25mm^2 FILOTEX P EDE 2PK319

The crimp voltage drop values shall meet the following values:

- Standard contacts; 2A rated, 0.5mm^2: Us < 0.mV
- Ethernet connector Quadrax contacts; 0.75A rated, 0.25mm^2: Us < 0.7mV

Crimp Tensile Strength

Requirements: 10 standard contacts shall be tested, 5 with the maximum section (1mm^2) of conductor that can be joined and 5 with the minimum section (0.5mm^2) that can be joined. For Ethernet connector Quadrax contacts only, 0.25mm^2 conductor shall be used and 5 contacts tested. The conductor shall be pulled at a constant speed between 25mm/min and 50mm/min.

The following shall apply to the crimp tensile test setup:

Standard Contacts:
Crimping Tool: DMC FT8
Locator: M22520/1-05 (manually adjusted locator tool, providing equivalent position to fixed location Production tool TP 1848)
Position 4 for 0.5mm^2 conductor Position 5 for 1.0mm^2 conductor
Cable UL for 0.5mm^2: EN 50306-2-300V 1 x 0.5-M-10 Cable UL for 1.0mm^2: EN 50306-2-300V 1 x 1.0-M-44

Ethernet Quadrax Contacts:
Crimping Tool: M22520/2-01 (DMC AFM8 equivalent)
Locator: S_129
Position 4 for 0.25mm^2 conductor
Cable UL for 0.25mm^2: DTREN150007-300V-4 x 0.25mm^2 FILOTEX P EDE 2PK319

The crimp tensile strength shall meet the following values:

- Standard contacts; 2A rated, 0.5mm^2: 100N (Min)
- Standard contacts; 2A rated, 1mm^2: 160N (Min)
- Quadrax contacts; 0.75A rated, 0.25mm^2: 32N (Min)

4. LHS E471i Signal Connector Qualification Results

The Qualification result summary for LHS E471i Signal Connector Qualification isshown in Table 10.

Table 10: E471i Signal Connector Qualification Result Summary

Test Procedure				Para Ref	Pass/Fail Criteria	Test Date	Qual Result
Group 0	**Sample**	**Specification**	**Method**	9.1	**Pass/Fail Criteria**	**Date**	**Pass/Fail**
Marking, Dimension andWeight	A to H			9.1.1		18 Nov – 2 Dec 2020	**Pass**
Contact Resistance	A to H	NFF 61-030		9.1.2	<4.5 mΩ. < 15 mΩ unadjusted < 0.5 mΩ for crimp		**Pass**
Insulation Resistance	A to H	HwRS	HwRS	9.1.3	> 100 GΩ		**Pass**
Dielectric WithstandingVoltage	A to H	HwRS	HwRS	9.1.4	Pass/Fail – *see 9.1.4		**Pass**
Retention of gauge	A to H	NFF 61-030		9.1.6	10% of female contacts.		**Pass**
Insertion/Extraction Force	A to H	HwRS	HwRS	9.1.7	122N Max		**Pass**
Group 1	**Sample**	**Specification**	**Method**	9.2	**Pass/Fail Criteria**	**Date**	**Pass/Fail**
Damp Heat Cycling	A	EN50155 ; HwRS	EN 60068-2-30, DB	9.2.1	Pass/Fail – *see 9.2.1	5 – 7 Jan 2021	**Pass**
Random Vibration	B	EN61373	Cat1B (per HwRS) +Cat 2	9.2.2	No discontinuity > 0.1µs, or physical damage	15 – 21 Dec 2020	**Pass**
Half Sine Shock	B	EN61373	Cat 1B (Per HwRS) +Cat 2	9.2.3	No physical damage	16 – 21 Dec 2020	**Pass**
Resistance to fluids	B,C,D & E	NFF 61-030		9.2.5	IR > 400 MΩ; DWV pass to 1000V.	11 - 21 Jan 2021	**Pass**

Group 2	**Sample**	**Specification**	**Method**	9.3	**Pass/Fail Criteria**	**Date**	**Pass/Fail**
Thermal Shock	F	NFF61-030	NF C 20-714	9.3.1	Pass/Fail -*see 9.3.1	8 Jan -19 Jan 2021	**Pass**
Endurance 500 cycles	F	NFF61-030	NF-C 93 400	9.3.3	<4.5 mΩ < 15 mΩ unadjusted <0.5 mΩ for Crimp.		**Pass**
Contact Retention	F	NFF61-030	NF-C 93 400	9.3.4	>40N; Characterize to 70N		**Pass**
Group 3	**Sample**	**Specification**	**Method**	9.4	**Pass/Fail Criteria**	Date	**Pass/Fail**
Temperature Rise	G	NFF61-030	NF-C 93 400	9.4.1	3A; 20°C /30°C max rise	5 Jan 2021	**Pass**
Salt Spray	G	NFF61-030	NF-C 93 400	9.4.2	IR > 1 GΩ *see 9.4.2	7 – 11 Jan 2021	**Pass**
Group 4	**Sample**	**Specification**	**Method**		**Pass/Fail Criteria**	Date	**Pass/Fail**
Dry Heat bake	H	EN50155 + HwRS		9.5.1	*see 9.5.1	30 Nov- 4 Dec 2021	**Pass**
Insulation Resistance	H	HwRS	HwRS	9.1.3	>10 GΩ, Characterize to100 GΩ	4 Dec 2021	**Pass**
Contact Resistance	H	NFF 61-030		9.1.2	<4.5 mΩ. < 15 mΩ unadjusted <0.5 mΩ for Crimp.	18 Dec 2020 – 7 Jan 2021	**Pass**
Visual Inspection	H			9.1.1		18 Dec 2020 – 7 Jan 2021	**Pass**
Crimping DDP measurement		NFF 61-030		9.5.3	0.6 mV max for standardcontacts	24 Sep- 15 Oct 2020	**Pass**
Group 5	**Sample**	**Specification**	**Method**	9.6	**Pass/Fail Criteria**	**Date**	**Pass/Fail**

Crimp tensile strength	10 contacts	NFF 61-030		9.6.1	160 N (1mm^2) 100 N (0.5mm^2)	24 Sep – 15 Oct 2020	**Pass**
Fire Behavior	Specific plates	EN 45545-2 & STM-S-001 ind. D			R22 – HL3	19 Dec 2019 – 30 Oct 2020	**Pass**

E471i Signal Connector Qualification Conclusion

All Intercompact E471i 60-way Signal Connector Qualification tests have completed and passed successfully.

6.0 LHS E471i Ethernet Connector Qualification Results

Table 50: E471i Ethernet Connector Qualification Summary

Quadrax Mechanical Protection	M			9.3.2	Mate with no interference orcontact deterioration.		Pass
Endurance 500 cycles	M	NFF61-030	NF-C 93 400	9.3.3	<4.5 mΩ. < 15mΩ unadjusted <0.5 mΩ for Crimp		Pass
Contact Retention	M	NFF61-030	NF-C 93 400	9.3.4	>40 N, Characterize to >=70N		Pass
Quadrax Electrical Characterization	M	IEC 60512-2-1		9.1.5	*see also 9.1.5	19 Mar 2021	Pass
Return Loss	M	IEC60512-25-5		9.1.5	>20dB @ 100 MHz	19 Mar 2021	Pass
Insertion Loss	M	IEC60512-25-2		9.1.5	< 0.4dB @ 100MHz		Pass
NEXT	M	IEC60512-25-1		9.1.5	>43dB @ 100 MHz		Non-Compliant
FEXT	M	IEC60512-25-1	HwRS	9.1.5	>35dB@ 100 MHz		Pass
Propagation Delay	M	IEC60512-25-4		9.1.5	< 2.5ns		Pass
Inter-Pair Skew	M	IEC60512-25-4		9.1.5	< 1.25ns		Pass
Group 3	**Sample**	**Specification**	**Method**	9.4	**Pass/Fail Criteria**	**Date**	**Pass/Fail**
Temperature Rise	N	NFF61-030	NF-C 93 400	9.4.1	3A; 20C/30C maxrise	16 Mar – 2021	Pass
Salt Spray	N	NFF61-030	NF-C 93 400	9.4.2	IR > 1 GΩ; *see also 9.4.2	19 Mar-23 Mar 2021	Pass
Group 4	**Sample**	**Specification**	**Method**		**Pass/Fail Criteria**	**Date**	**Pass/Fail**
Dry Heat bake	O	EN50155 + HwRS		9.5.1	*see 9.5.1	15 Mar - 22 Mar 2021	Pass
Insulation Resistance	O			9.1.3	>10 GΩ, Characterise to100 GΩ	22 Mar 2021	Pass
Contact Resistance	O	IEC60512-2-1		9.1.2	<4.5 mΩ < 15mΩ unadjusted < 0.5 mΩ for crimp	22 Mar-23 Mar 2021	Pass
Visual Inspection	O			9.1.1		22 Mar-23 Mar 2021	Pass
Quadrax Electrical Characterization	O	IEC 60512-2-1		9.5.2	*see also 9.1.5	22 Mar-23 Mar 2021	Pass
Return Loss	O	IEC60512-25-5		9.5.2	>20dB @ 100 MHz	22 Mar-23 Mar 2021	Pass
Insertion Loss	O	IEC60512-25-2		9.5.2	< 0.4dB @ 100MHz		Pass
NEXT	O	IEC60512-25-1		9.5.2	>43dB @ 100 MHz		Non-Compliant
FEXT	O	IEC60512-25-1	HwRS	9.5.2	>35dB@ 100 MHz		Pass
Propagation Delay	O	IEC60512-25-4		9.5.2	< 2.5ns		Pass
Inter-Pair Skew	O	IEC60512-25-4		9.5.2	< 1.25ns		Pass

Crimping DDP measurement (Quadrax contact pair + re-use data from Signal connector for standard contacts)	5 Contacts	NFF61-030		9.5.3	Standard contacts:0.6mV max Quadrax contacts: 0.7mV max	24 Sep 2020- 12 Feb 2021	Pass
Group 5 (10 Crimped Contacts)	**Sample**	**Specification**	**Method**	9.6	**Pass/Fail Criteria**	**Date**	**Pass/Fail**
Crimp tensile strength (Quadrax contacts + re-use data from Signal connector forstandard contacts)	5 Contacts	NFF 61-030		9.6.1	160 N (1mm^2) 100 N (0.5mm^2); 32 N (0.25mm^2)	24 Sep 2020- 3 Feb 2021	Pass
Fire Behavior	Specific plates	EN 45545-2 & STM-S-001 ind.D			R22 – HL3	19 Dec 2019 to 30 Oct 2020	Pass

E471i Ethernet Connector Qualification Conclusion

All Intercompact E471i 42-Way Ethernet Connector Qualification tests have completed and passed successfully with exception of Quadrax Rf NEXT testing.
The E471i Ethernet connector Rf NEXT testing was conducted with the Quadrax in "X Configuration" rather than the recommended "Parallel Configuration". It has been shownin the previous E130i Ethernet connector Qualification (TML_Qual_116, Rev B) and in standalone studies, that the Intercompact Ethernet connector NEXT testing can be compliant with good margins to minimum NEXT spec levels of 43dB @100 MHz (typically in 49-50dB range for practical test cable lengths) by adopting the recommended Quadrax "Parallel configuration". Please see further details and example data towards the end of section.

Note: Per E130i Qualification report (TML_Qual_116, Rev B) an extra step was inserted to ensure compliant IR and DWV results post Hydrochloric Acid Fluids exposure, giventhese PCB connectors are not IP level sealed – the Ethernet connector male Quadrax inserts plus female Quadrax outer casings + inserts were removed, to allow improved cleaning/rinsing access following acid exposure, then replaced prior to final electrical testing.

7.0 E471i Signal Connector + E471i Ethernet Connector Qualification Conclusion

All Intercompact E471i 60-way Signal Connector Qualification tests and LHS E471i Ethernet Connector 42-way Qualification tests have completed and passed successfully with exception of Quadrax Rf NEXT testing on the Ethernet connector.
The E471i Ethernet connector Rf NEXT testing was conducted with the Quadrax in "X Configuration" rather than the recommended "Parallel Configuration". It has been shownin the previous E130i Ethernet connector Qualification (TML_Qual_116, Rev B) and in standalone studies, that the Intercompact Ethernet connector NEXT testing can be compliant with good margins to minimum NEXT spec levels of 43dB @100 MHz (typically in 49-50dB range for practical test cable lengths) by adopting the recommended Quadrax "Parallel configuration".