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Terminated Multi-Ribbon Cable Qualification Report

SUMITOMO

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1 Pre-Production Qualification Programme

This is an internal qualification report for the Terminated Multi-Ribbon Cables supplied by SUMITOMO. The qualification procedure consisted of a modified sequence of evaluation tests described in the CMS Tracker document "Multi-Ribbon Cable Quality Assurance Procedure" (Document ID: CMS-TK-QP-0012).

6 cables have been delivered by Sumitomo in January as part of batch CA1395955: 8-ribbon, 12-fiber optical multi-ribbon cables terminated in MPO optical connectors at both ends.

The cables are for 2 ECAL sub-projects: ECAL Endcap (EE) and ECAL Preshower (ES), with different length specifications. For this delivery, 2 of these cables were of EE type and the other 4 were of ES type even though the opposite should have been delivered (4 EE and 2 ES).

1.1 Qualification programme workflow

One ECAL preshower (ES) cable passed through the entire qualification process, while 3 others (1xES and 2xEE) passed through the lot acceptance part of the programme only.

Table 1 shows the serial numbers of the cables as well as the type (Endcap or Preshower) that passed through the tests.

The lot validation programme flow is shown in Figure 1 while the qualification programme workflow is shown in Figure 2. The figure shows the tests to be carried out as described in the test procedure for terminated multi-ribbon cables (CMS-TK-QP-0012*). For this qualification, magnetic field, irradiation and mechanical test B were not performed. The test target specifications are extracted from the technical specification for EE/ES terminated multi-ribbon cables (*MPO multi-ribbon cable technical specifications version 2.4, 12/12/2005*). All tests were carried out at room temperature.

Table 1: Cables delivered as part of batch CA1395955.

Cable ID	Cable type	MGF # number	Comment
33013066100151	ES	90-498-6443	Full Qualification
33013066100152	ES	90-498-6443	Acceptance only
33013066100154	EE	90-498-6443	Acceptance only
33013066100156	EE	90-498-6442	Acceptance only

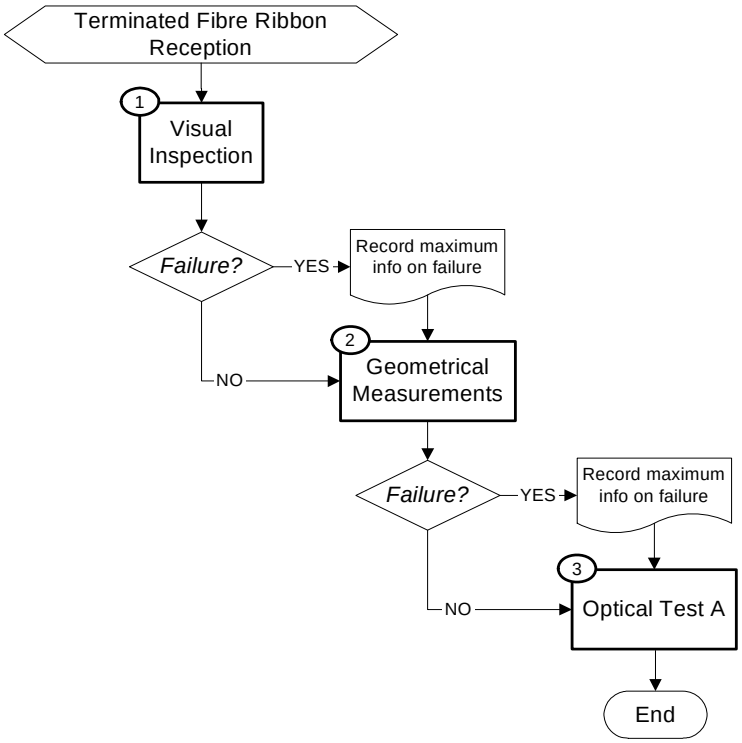

Figure 1: Flow chart of lot acceptance procedure.

* Terminated Multi-Ribbon Cable Quality Assurance Procedure, v.1.0, 2 june 2004

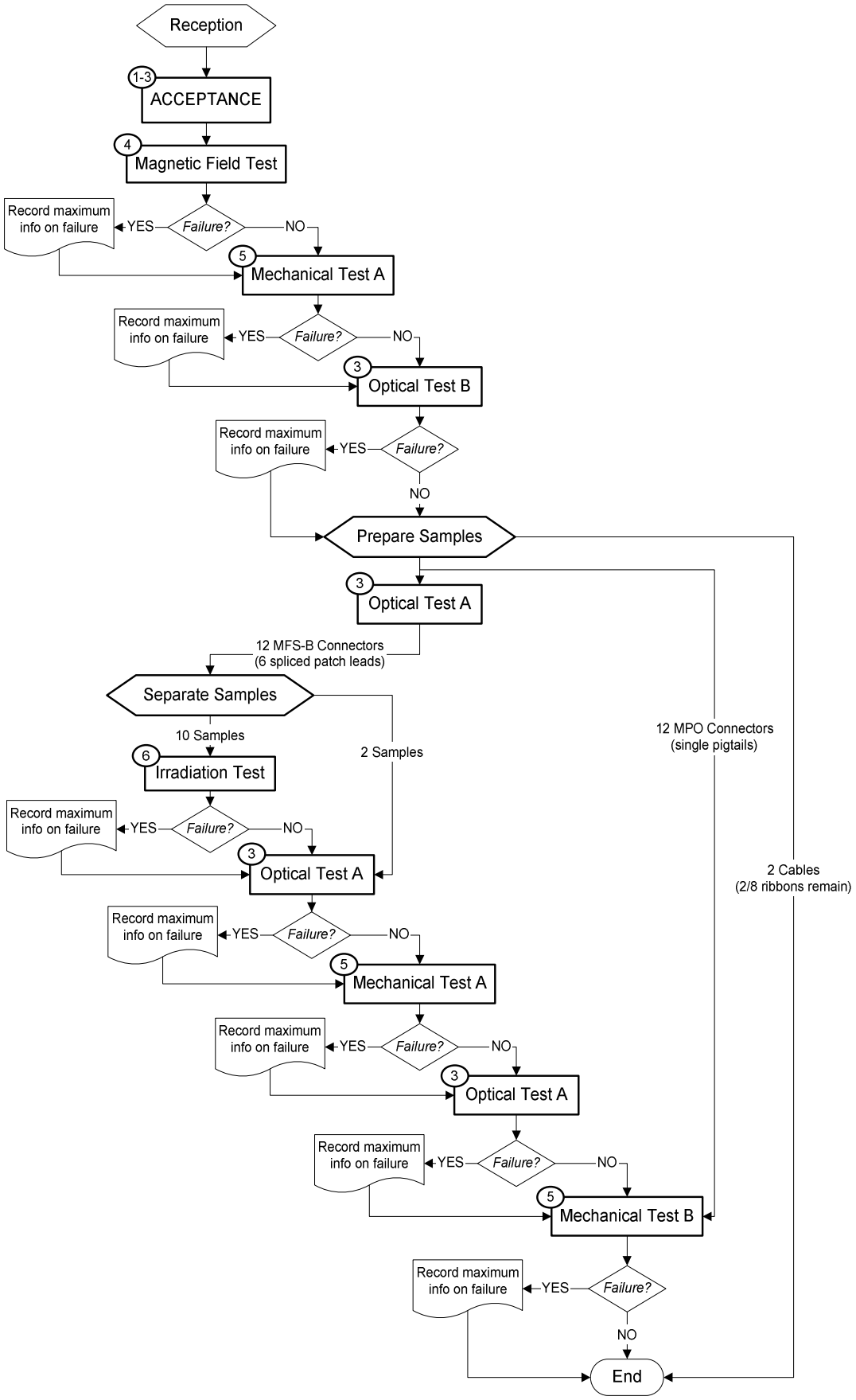

Figure 2: Full Pre-production Qualification testing flow. The Magnetic field (4), irradiation(6) and mechanical test B (5B) were not performed as part of this qualification.

2 Technical Validation

2.1 Compliance with technical requirements

Table 2 shows the specified performance of the terminated multi-ribbon cables against which the received samples were tested. The table also gives a summary of the results obtained in comparison with the specifications for the qualification cable.

Table 2: Specification test targets taken from the technical specification. Cells in gray indicate parameters not measured during qualification.

#	Specification to be tested	Test Specifications				CERN Qualification Results		
		Min	Typ	Max	Units	Min	Max	Qualified?
4.1	Number of channels		96			96	96	YES
4.2	Operation Wavelength		1310		nm			
4.3	Connector type (Inline&Back-end)		MPO12			MPO		YES
4.4	MPO12 guide pins		Non-removable, standard			Standard, fixed		YES
4.5	Number of mating cycles	100				100	Not tested	YES
4.6	Random mate insertion loss MPO			1.2	dB	0.02	0.80	YES
4.7	Random mate Return loss MPO	50			dB	63.5	>72	YES
4.8	Tensile load on connectors MPO			10	N	10	Not tested	YES
4.9	In-line ribbon section length $L_{Rinline}$		550 (±15)		mm			YES
4.10	Sheath section length L_{Sheath}		50 (±0.3) - 60 (±0.3) - 70 (±0.3)		m			YES
4.11	Flexible sleeve length L_{Sleeve}		470		mm			
4.12	Multi-ribbon cable length $L_{RBackend}$		As per drawing† (±15)		mm			**NO**
4.61	Magnetic field			4	T	Not tested		
4.62	Hadronic fluence			1×10^{12}	cm^{-2}			
4.63	Gamma radiation dose			100	Gy(Si)			
4.64	Temperature	-20		70	°C			
4.65	Operating humidity			60	%			
4.81	Material composition		Halogen-free, flame retardant material					

Legend:
① Visual Inspection ② Geometrical measurement ③ Optical Test ④ Magnetic Field Test ⑤ Mechanical Test ⑥ Radiation Hardness Test

† Diamond manufacturing drawing 1BX-284-001.

2.2 Lot Acceptance Results

A diagram of the terminated MPO multi-ribbon cable is shown in Figure 3. The entire cable specifications are on Sumitomo drawing No GE0538265B and GE0538153C.

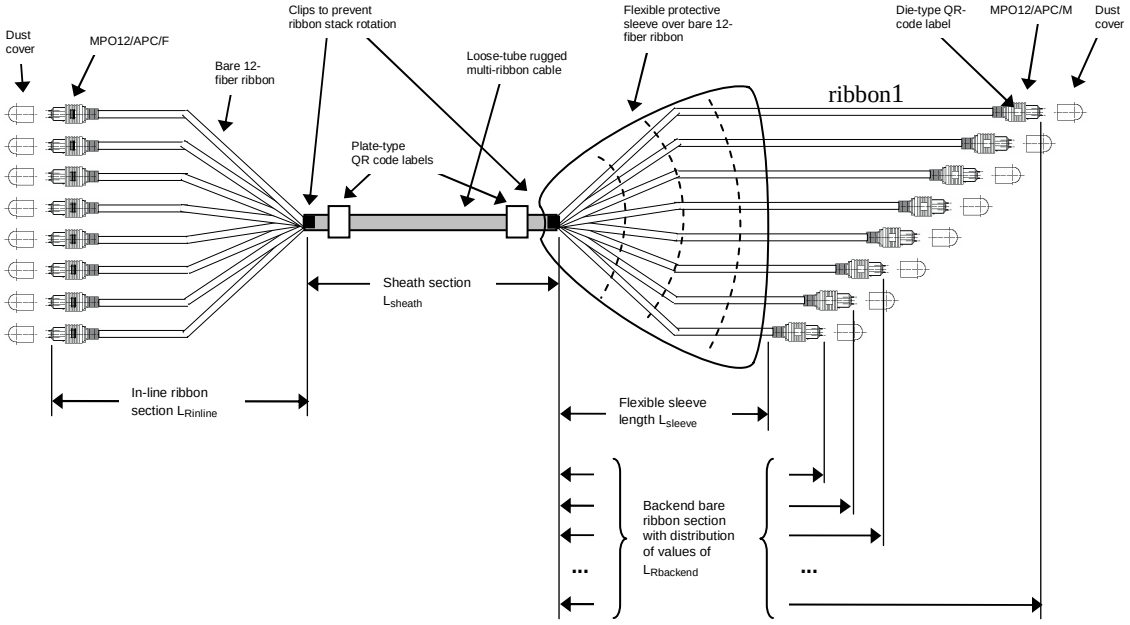

Figure 3: Diagram of the MPO multi- ribbon cable.

2.2.1 Visual Inspection

Visual inspection consists of the following sequence:

1. Unpacking the sample from its transportation container.
2. Carefully inspecting the samples for connector type, label position and legibility, colour and other macroscopic defects.

2.2.1.a Acceptance Criteria

1. All samples shall be properly packaged

   OK
2. Labels shall be legible and properly attached to the connector

   Marginal: a few labels detached after several re-mates.
3. Connector type and colour shall be as specified**.**

   BAD for EE cable: numbering of backend ribbons is inversed: ribbon1 is the shortest but should be the longest.
4. All samples shall be free from visible defects**.**

   OK

2.2.2 Geometrical Measurement

Geometry is checked in the following way:

1. The sample is laid flat with low tension (cable-end is fixed to a suitable surface to allow free ribbon-ends to lie flat).
2. The in-line ribbon length and the back-end ribbon length are measured.
3. The overall optical path length of the cable is measured using a photon-counting OTDR.

2.2.2.a Acceptance Criteria

1. The ribbon lengths must be within the specified range for the particular sample. Lengths falling outside this window will fail.

   OK: Naked ribbon lengths measured all within specifications.

   The outer diameter of the ferrule assembly is in specification (12mm).

   The length of the guide pins is <3mm.

Table 3 summarizes the different lengths: the request is 57m and 67m for ES and EE respectively. The delivered cables are 2m longer.

Table3: *summary of geometrical measurement (value in meter)*

Cable ID	**151**	**152**	**154**	**156**
INLINE				
Length marker	964	1024	1084	1321
Additional length	0.95	0.95	0.987	0.875
$L_{Rinline}$	0.56	0.565	0.562	0.565
Stack orientation	OK	OK	OK	OK
BACKEND				
Length marker	909	969	1029	1255
Additional length	0.88	0.965	0.98	0.355
$L_{Rbackend}$	2.35	2.35	2.355	As specified
L_{Sleeve}	0.475	0.47	0.48	0.47
Stack orientation	OK	OK	OK	OK
L_{sheath}	56.83	56.91	56.97	67.23
TOTAL length measured	59.74	59.83	59.88	68.40min 68.7max
OTDR measurement	59.9	59.94	59.98	68.51 min 68.8 max

2.2.3 Optical Test A and B

Optical properties are checked in the way described below. Optical Test A consists of procedures 1 and 2 while Optical Test B consists of procedures 1, 2 and 3.

Random mate insertion loss (tests A and B, all fibre channels).

The insertion loss (IL) is defined as the Log of the ratio of optical powers measured before (P0) and after (P1) insertion of the device under test (DUT). The launch patch-cord is a randomly selected fanout. The optical power (P0 and P1) is measured with a large area detector in a receptacle.

Insertion loss: $IL = 10\mathrm{Log}\frac{P_0}{P_1}$

1. Return loss (tests A and B, all fibre channels)

The return loss (RL) is defined as the Log of the ratio of the reflected optical powers measured during referencing (Pref) and after (P1) insertion of the device under test (DUT).

Return loss: $RL = \left[10\mathrm{Log}\frac{P_{ref}}{P_1}\right] + 14.7$ (1)

(1) Formula valid if using a reference with perfect glass-air interface.

2. Number of mating cycles (test B only, all fibre channels)

   The MPO connector under test and the launch connector are disconnected and re-connected 100 times. Insertion Loss is measured after the 100 mating cycles.

2.2.3.a Acceptance Criteria

Data measured on terminated fibre ribbon samples must meet the following criteria:

1. MPO connectors must have an insertion loss smaller than 1.2dB.
2. MPO connectors must have a return loss higher than 50dB.
3. The insertion loss measured before and after the repeated mating test must remain smaller than 1.2dB

If a connector doesn't meet one of the above criteria it will be re-cleaned, visually inspected and re-tested. Connectors with consistently out-of-spec performance will fail the test.

All data are in specifications.

The 100 re-mates test has been successfully passed by 2 MPO connectors (ribbon 7,8).

Figure 4 shows the optical measurement of cable ID151.

Figure 5 is the histogram of all IL measurement for the 4 cables – compared to the same data provided by Sumitomo on Figure 6.

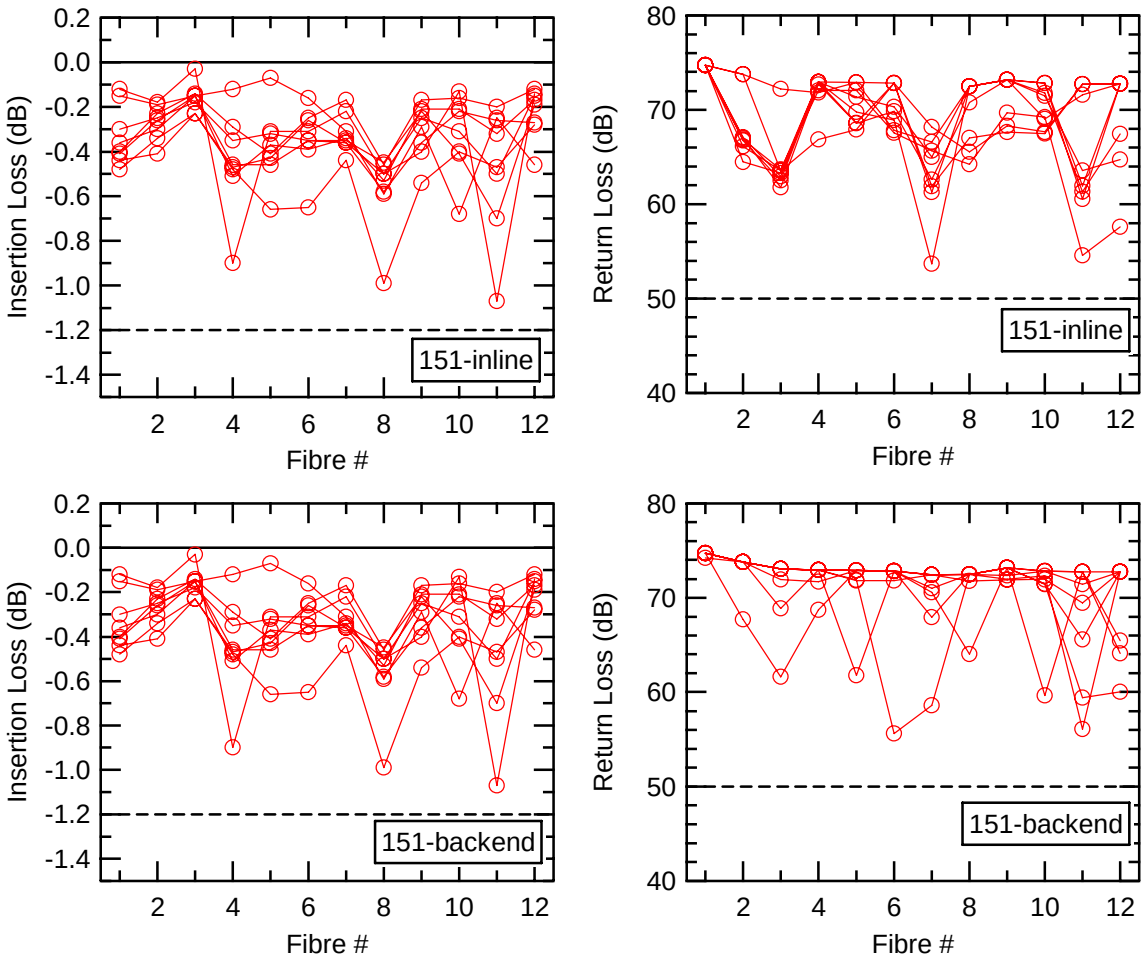

Figure 4: Insertion and Return Loss data measured on the qualification cable ID 151.

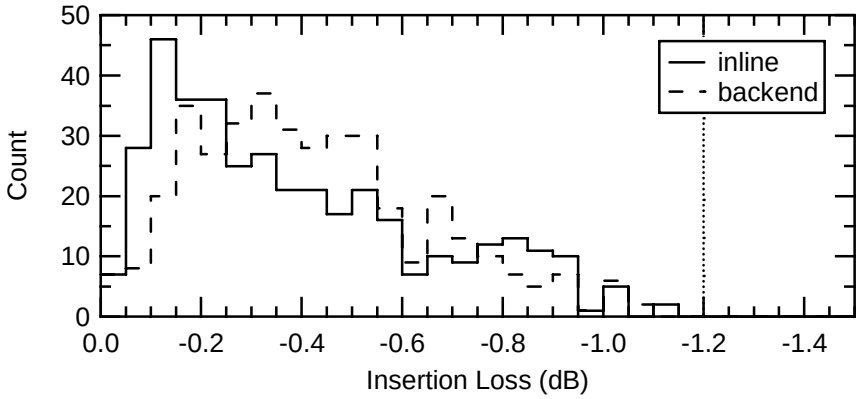

Figure 5: Insertion Loss Histogram for 4 delivered cables.

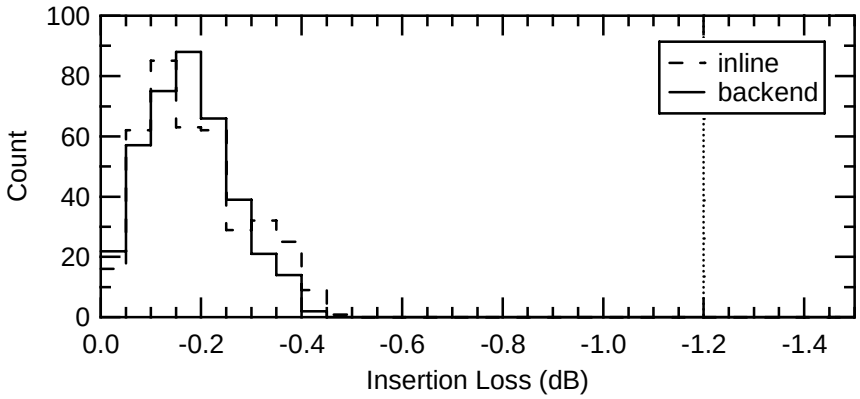

Figure 6: Sumitomo data Insertion Loss Histogram for 4 delivered cables.

As can be observed, CERN insertion loss is much higher than Sumitomo's in general. The reference fibre was replaced by a new one and all cables were tested again (remember that ribbons 7 and 8 of cable ID151 had already experienced 100 re-mate cycles). Moreover, instead of using a single-way MPO adaptor, a 4-way adaptor was used to be fully in line with the final configuration. Figure 7 shows the new results for the qualification cable and the histogram of Figure 8 is now more consistent with Sumitomo values. Nevertheless, **it should be understood wether Sumitomo performs a true random mate IL test, or uses a master launch lead.**

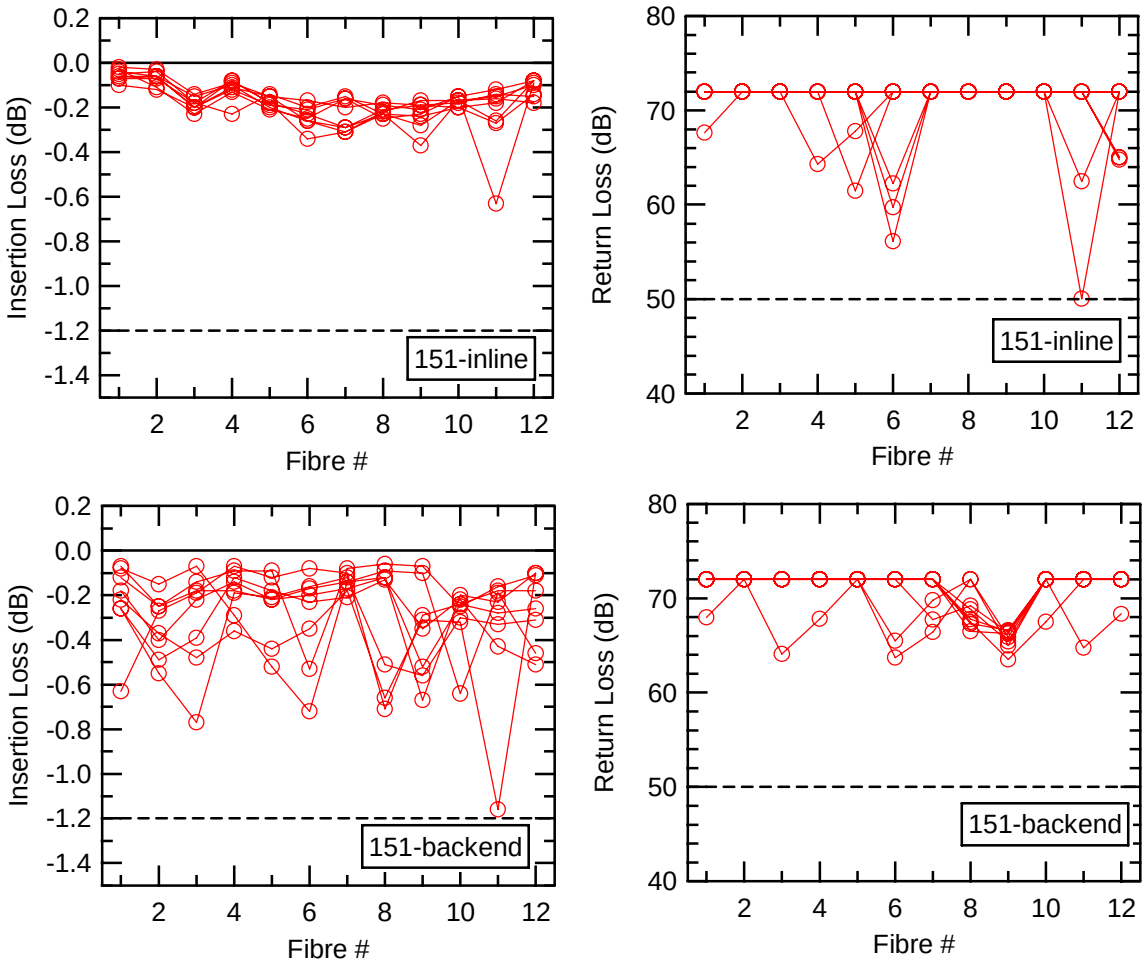

Figure 7: Insertion and Return Loss data measured on the qualification cable ID 15 with new reference fibre. Done after 100 re-mates on ribbons 7 and 8 and 10N load on all ribbons.

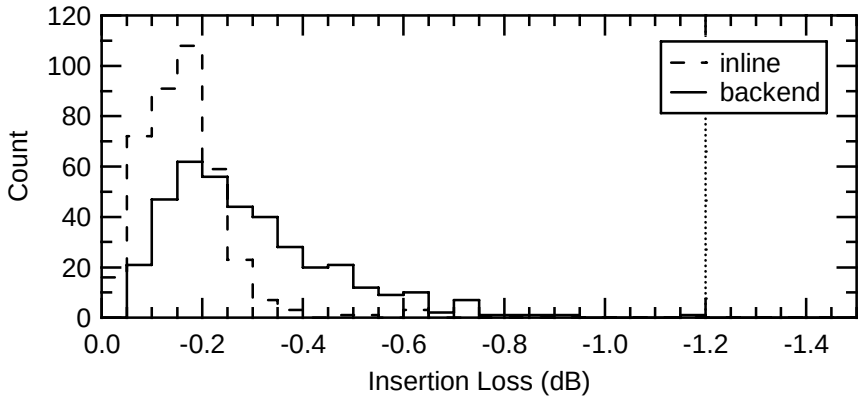

Figure 8: Insertion Loss Histogram for 4 delivered cables after new reference fibre.

2.3 Qualification Test Results

Besides the acceptance test results documented above, the following qualification tests were performed:

2.3.4 Magnetic field test

Because the cables won't be directly inside the detector, magnetic field was not tested.

2.3.5 Mechanical Test A

An increasing load is applied between ribbon and connector.

In case of Mechanical Test A, the load is increased up to a maximum value of 10N. Each connector is tested.

2.3.5.a Acceptance Criteria

Test A must not break the connector.

All parts passed test A, showing no significant change in optical properties after loading, as shown in figure 9. The connectors meet the 10N specification. Figure 10 show the same measurement with the new reference fibre as mentioned in 2.2.3.a.

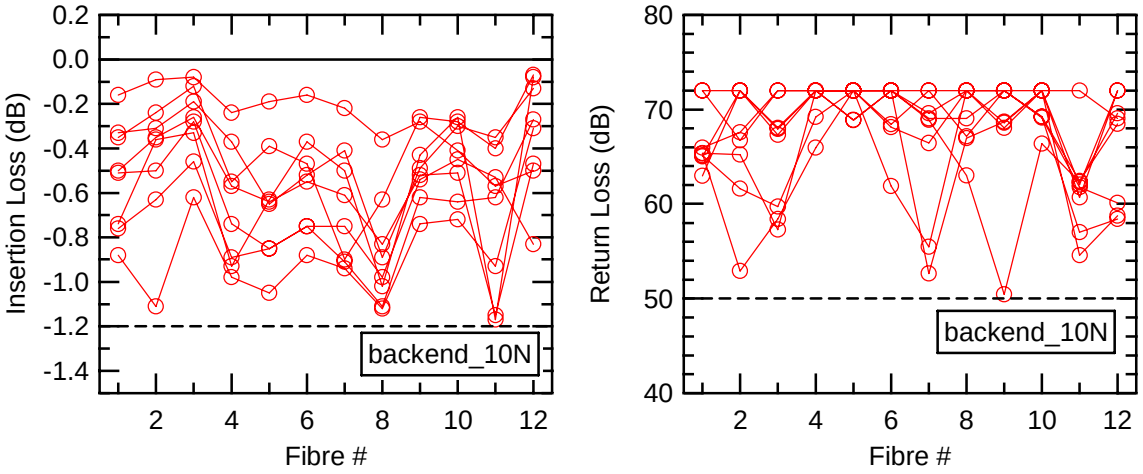

Figure 9: Insertion and return Loss after 10N loading before new reference fibre.

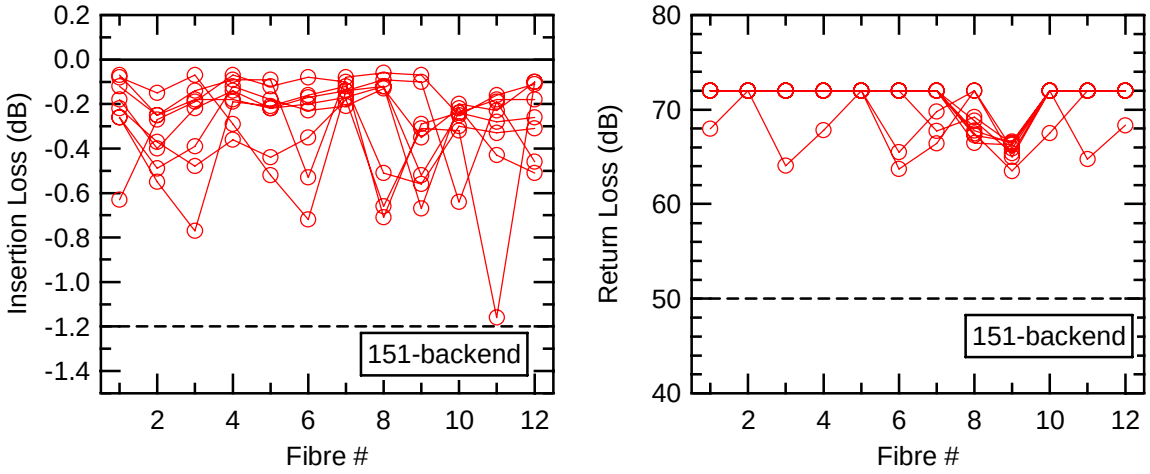

Figure 10: Insertion and return Loss after 10N loading with new reference fibre.

2.3.6 Mechanical Test B

The qualification cable was not destructively tested.

2.3.7 Irradiation test

The qualification cable was not irradiated.

3 Conclusions

The following non-compliant characteristics were noted:

1. The delivered types and quantities did not match the request.
2. The order of the staggered backend ribbons of type EE cables was inverted.
3. The label adhesion was insufficient.
4. The test files were not as requested.

The following corrective actions are requested:

1. The new delivery plan issued by CERN must be confirmed and strictly followed.
2. For EE cables, ribbon 1 should be the longest and ribbon 8 should be the shortest, as per Sumitomo engineering drawing GE0538153C.
3. Label adhesion should be reinforced.
4. Test files should include cable lot number (PxyzP), cable nominal length, lower meter mark, higher meter mark

The following questions arise:

a. Is Sumitomo measuring true random insertion loss, or is it using a master launch lead?
b. CERN free issues cables of 59m nominal length for ES-type cables. For the longest ES cable version, it requires sheath lengths of 57m, naked ribbon lengths of 0.55m and 2.35m. In total the length of 59.9m (57+.055+2.35) exceeds the raw cable length as supplied. Are the supplied cable lengths in excess of 59m? Did Sumitomo experience difficulties meeting the requested lengths?

The Sumitomo process for production of terminated multi-ribbon cables can be considered marginally qualified.

Sumitomo is requested to **replace and send to CERN by air courier the two non compliant EE cables** detailed in 2.2.1, using the spare raw cables already in Yokohama. When producing these two cables, it shall implement all corrective actions itemized above. Upon reception of the two replacement cables at CERN, CMS will carry out acceptance and will confirm the full compliance with the specification.

In addition to the above, and in order not to waste time, Sumitomo **is authorized to start production** of the terminated multi-ribbon cables (in parallel to the replacement of the 2 non-compliant cables) under the condition that all 4 corrective actions above are implemented.

Sumitomo is finally kindly requested to **answer questions** a and b above.