APPENDIX E

FIBER OPTIC CABLE SPLICING, TESTING, AND ACCEPTANCE PROCEDURE

METROMEDIA
FIBER NETWORK

Fiber Optic Cable Splicing, Testing and Acceptance Criteria for Contractors

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This document details MFN's requirements for splicing and testing for acceptance. As MFN anticipates that this criteria will evolve, it is considered the contractor's responsibility to verify that the version number and date of this document corresponds to the most recent version of this criteria. This verification should be made via the primary interface between the contractor and MFN (typically the project engineer/manager). If the contractor encounters a situation which does not permit the following of these specifications, written authorization must be obtained from MFN prior to the commencement of work.

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1.0 General Requirements and Procedures

1.1 Equipment

MFN expects that all equipment in use by the contractor is in good working condition and that all of the manufacturer's recommendations for maintenance are followed. MFN will require contractors to submit copies of certificates of calibration for the appropriate equipment (OTDRs, fusion splicers, power meters, etc..) and may ask for verification that components such as cleaving wheels, electrodes, etc.. are replaced at the appropriate intervals. Note that rental equipment must not be used without prior authorization from MFN.

MFN has standardized to GN Nettest (Laser Precision) format OTDR traces and therefore, requires the use of GN Nettest OTDRs for testing (the CMA4000, in particular, is recommended). Recent model GN Nettest OTDRs comply with Bellcore's GR-196 file format. The contractor must ensure that the GN Nettest OTDR they use (depends on model number and year of manufacture) complies with this standard. The use of any other OTDR manufacturer must be approved in writing prior to testing. Only electric-arc fusion splicing is acceptable to MFN – no other types of splicing (rotary-mechanical, etc..) will be used.

1.2 Splicing

Splicing must be conducted with the procedure outlined by the manufacturer of the equipment with a particular emphasis on cleanliness. MFN requires that the contractor perform an arc-test, at a minimum, once per day at the start of work. It is critical that the contractor use the "special" or "DS" settings on the fusion splicer when splicing Dispersion-shifted fibers (True Wave™, LEAF™, etc..). The contractor should confirm, prior to splicing, that the cable composition is consistent and in the same sequence as indicated by MFN. Therefore, if the contractor is working on a 432 fiber cable with a composition of 96 Non-zero dispersion-shifted fibers (NZ-DSF) and 336 standard single-mode fibers, the contractor must confirm this composition and the sequencing (whether the NZ-DSF fibers appear as the first 96 fibers in the cable, etc…) by visual inspection prior to splicing. If a fiber ribbon must be cut as part of the work, a fiber traffic identifier must be used first to confirm that the fibers do not have any live traffic. If traffic is detected, the contractor must contact MFN immediately. No fibers should be cut without MFN direction in such a situation.

1.3 Splice Engineering Packages (SEPs)

MFN will provide a SEP (Splice Engineering Package) which details the splice(s) to be performed as well as the configuration of the existing splice(s). SEPs constitute proprietary information which may not be reproduced or disclosed in whole or in part without the prior written consent of MFN.

Upon opening an existing MFN splice enclosure, the contractor must first examine the existing splice configuration to determine that it corresponds to that indicated on the SEP. If there is any discrepancy the contractor must contact MFN immediately – no splice work should begin without the instruction of MFN in such a situation. Upon completion of the splice work, the contractor must complete the Splice Work Confirmation sheet (last page of SEP) and provide it to MFN within one day of the work.

MFN requests the contractor to replace/correct any information absent/incorrect on the SEP including, but not limited to manhole/pole locations, cable exits directions, duct positions, cable manufacturer, part #, fiber quantity, etc… These additions/corrections must be submitted to MFN with the Splice Work Confirmation Sheet.

1.4 Testing

The contractor must observe the guidelines provided by the manufacturers of the various components associated with testing. In particular :

- when testing at a termination panel, only the port corresponding to the fiber under test should be uncapped. All caps must be replaced promptly after the fiber has been tested.
- A connector is rated for upto 300 matings. Therefore, in the case of testing with a patchcord (power testing), it should be replaced after 300 matings. In the case of OTDR testing, where a launch cord is used, it should be sent to the manufacturer for re-surfacing after 300 matings.
  - •Do not "reverse" connectors such that the used connector is used at the OTDR/power meter as this may result in a poor launch level.
  - •Do not couple a patchcord to the launch cord in order to change the patch cord every 300 matings (and avoid over utilizing the launch cord connector). This creates an additional connection and it's associated loss will make the results unusable.
- All connectors must be cleaned prior to testing : both the connector that plugs into the OTDR power meter and each connector at the FDP (Fiber Distribution Panel) must be cleaned. New, factory-shipped connectors either in LGX or patch-cord form must also be cleaned prior to testing mating.
- All patch-cords must be power tested prior to installation.

1.4.1 OTDR Testing

OTDR testing must be conducted at the following wavelengths based on the fiber type :

- Standard Single Mode Fiber : testing at 1310 nm and 1550 nm.
- Non-zero Dispersion Shifted Fiber (True Wave, LEAF...) : testing at 1550 nm only

This procedure describes the parameters to be used when testing a fiber using the following model GN Nettest OTDRs : CMA4000, TD3000, TD1000 & TD1000 Wizard. Other model and manufacturer OTDRs can only be used if written permission is obtained from MFN.

1.4.1.1 Testing Method

OTDR testing must be conducted bi-directionally unless otherwise instructed by MFN.

1. A 3 (three) kilometer launch cord must be used for testing all spans. It is the contractor's responsibility to ensure that the 3 km cord has been appropriately assembled such that it does not create a high loss (due to, for example, improper winding or the use of an enclosure that is too small).
2. Use the "Auto Mode" per Table 1 depending on the OTDR model in use, to shoot one fiber of the span at 1550 nm. This will be called the "test fiber". See below for how to save this trace file.

Table 1 : OTDR Auto-mode Settings

OTDR Model	*Auto Setting*	*Trace Averaging*	*Comments*
CMA4000/TD3000	Automode	3:00 minutes timed	Less averaging at contractor's risk
TD1000/1000 Wizard	Auto LH	Use auto test setting	For fiber length greater than 20 km
TD1000/1000 Wizard	Auto HR	Use auto test setting	For fiber length less than 20 km

3. Verify the following :
   - The fiber length given by the trace corresponds to the estimated span length (per route diagram, taking into account the additional length due to the 3 km launch cord). This information should be obtained from the project engineer/manager. If there is a length mismatch, select a different fiber for the Auto Mode test.
   - No significant anomaly/loss exists on the "test fiber" that adds considerable loss to the span (greater than 1 dB). If such an anomaly/loss exists, select a different fiber for the Auto Mode test.
   - The range selected by Auto Mode is longer than the test fiber length. (If this is not the case, no end reflection will be observed on the test fiber). In this case, clean the connectors again and re-shoot in Auto Mode.
4. Once an appropriate fiber has been tested in Auto Mode, record the parameters that were selected by the OTDR : Pulse width, Range and Resolution.
5. Apply these parameters to all the other fibers in the span manually, using the Averaging setting per Table 1. Do not shoot all fibers in the span using Auto Mode. Therefore, make sure that the Auto Mode (or Auto HR or Auto LH) function is disabled before you start testing the remaining fibers.
6. This process must be repeated for testing at 1310 nm (if testing at this wavelength is required). Note that using the same settings as used at 1550 nm may result in unusable traces.

IMPORTANT : Each span MUST be tested with the same parameters (Range, Resolution, Pulse Width, Averaging) in BOTH directions.

7. The contractor must scrutinize and correct the traces (in the field) for obvious testing-related issues such as : ghost reflectances and low launch levels.

8. The Table 2 below lists the refractive index that should be used depending on the fiber type and wavelength. If the contractor is testing a fiber that does not appear on this list, contact MFN for the appropriate refractive index setting.

Table 2 : Refractive Indices for Various Fibers

Fiber Type	*1310 nm*	*1550 nm*
Lucent – Depressed Clad SM	1.466	1.467
Lucent – Matched Clad SM	1.466	1.467
Lucent – True Wave™ NZ-DSF	1.471	1.470
Corning – SMF28	1.467	1.468
Corning - LEAF™		1.469
Corning - LS	1.471	1.470

1.4.1.2 OTDR Trace File Naming

All traces MUST be named with the following methodology :

AAA BBB # W . nnn

Where :

AAA : is the location code of the "FROM" test site. For example, testing from the Philadelphia Regen site would mean the use of "PHL" in the "AAA" field. (see location code list)
Therefore, we have : PHL BBB # W. nnn

BBB : is the location of the "TO" test site. For example, testing from the Philadelphia Regen site to the Baltimore Regen site would mean the use of "BAL" in the "BBB". (see location code list)
Therefore, we have PHL BAL # W . nnn

: is the cable number. Thus if there is only one cable in the route between Philadelphia and Baltimore, this number would be "1".
Therefore, we have PHLBAL1W. nnn (If you are testing the 2nd cable, it would be PHLBAL2 W . nnn).

W : indicates the wavelength at which the trace was shot. At the present time there are three possible numbers that could be applicable :

- 3 : 1310 nm
- 5 : 1550 nm
- 6 : 1625 nm

Therefore, if the trace in question is shot at 1550 nm, we have PHLBAL15.nnn .

nnn : This indicates the *fiber number* of the span and must be three digits. When testing from a location where the entire cable is terminated, this may correspond to the port # of the LGX. However, this is not always the case – this number must represent the fiber number of span, not the Port #. Therefore, if testing a 12 fiber ribbon that are terminated at ports 37-48, the "nnn" field must range from 001-012 with the port numbers listed in the trace header information.
Therefore, if the trace in question was shot on fiber # 22, we have PHLBAL15.022.
Note that the same fiber shot in the opposite direction must have the filename : BALPHL15.022.

- A list of location codes is attached to this document. It is clear that this list will be continuously updated with new locations as they become apparent. If the contractor is testing from to a location that does not appear on this list, it is the contractor's responsibility to obtain the correct location code from the MFN project engineer/manager. The contractor must not make up their own location code.
- MFN has developed it's own header template for GN Nettest OTDRs which has fields for information that is required by MFN, such as Aisle, Bay, Shelf and Port numbers, Contractor & Operator name, etc.. This header MUST be used and can be obtained in electronic form from the project engineer/manager.
- When conducting the Auto Mode test for OTDR testing as described in (2), the trace generated by the Auto test must be saved with the same methodology but with a "aut" extension. Therefore, in the above example, it would be saved as PHLBAL15.aut. Note that the fiber that was used for this test will have to be re-tested with the appropriate fiber number extension.

1.4.2 Power (Insertion) Loss Test

Power testing must be conducted at the following wavelengths based on the fiber type :

- Standard Single Mode Fiber : testing at 1310 nm and 1550 nm.
- Non-zero Dispersion Shifted Fiber (True Wave, LEAF...) : testing at 1550 nm only

Power testing MUST be conducted bi-directionally with the average of the loss in the two directions used for the fiber span loss.

The contractor MUST use MFN's power test form, which is attached to this document and is available in electronic form from the project engineer/manager. Both paper and electronic copies of the test results are required by MFN.

All information must be filled out on the form including location of "from" and "to" test sites, customer name, reference loss at both locations, contractor & operator information.

- The contractor is responsible for calculating the net span loss of the fiber under test in the field by subtracting the reference.
- Before the contractor submits power test results and before leaving the test site(s):
  - → Verify that the absolute value of the loss of any given fiber is within a "reasonable range". A reasonable loss can be calculated as follows:

    Fiber loss (including splices) : 0.30 dB/km at 1550 nm
    0.40 dB/km at 1310 nm
    Connector loss : 0.50 dB per connection.

    Therefore, if testing a span that is 20 km long with one patch-through (via patch cords) in the span, an expected loss at 1550 nm would be:

    Fiber loss = 20 km × 0.30 dB/km = 6 dB
    Connector loss = 4 × 0.50 dB/km = 2 dB
    (one connection on each end and two connections at the patch-through)

    Therefore, a total expected loss = 8 dB. If the loss obtained is significantly higher than this, the contractor should initiate troubleshooting measures, such as cleaning connectors, etc.... ***without MFN direction.***

    Similarly, the contractor must verify that the loss is not impossibly low, indicating an error in measurement. For example, in the previous case, a loss of 5.5 dB is possible (although not probable) if the insertion loss of the connectors are near zero and the splice losses are extremely low. However, if the test yields a span loss of 3 dB, this is clearly impossible, and the cause of the erroneous reading must be investigated ***without MFN direction***.
  - → If conducting the power test on multiple fibers in the same span, the contractor must verify the consistency of the readings. Therefore, if testing 12 fibers of the same span, of which 11 fibers have a net loss of 9-10 dB and one fiber has a loss of 14 dB, this fiber should be investigated ***without MFN direction.*** As a general rule-of-thumb, the variability of power loss measurements for different fibers in the same span should be within 10% of the average.

MFN will not accept power test results if either the loss is impossibly high, low or variable as described above.

2.0 Splicing and Testing Methodology

2.1 Reel Tests

The contractor is responsible for conducting OTDR testing on each optical fiber of the cables that are delivered to them. This testing should follow the same general procedure described earlier in this document with the following exceptions:

- This testing need only be done in one direction and at 1550 nm only unless an anomaly is detected. If an anomaly is detected on a fiber during a unidirectional reel test, the contractor should test it in both directions (if possible) and at both 1310 and 1550 nm wavelengths.
- The trace names should follow the methodology : reel#.nnn, where nnn is the fiber number in the cable.

The contractor is responsible for not only conducting the OTDR tests, but also analyzing the results and determining if anomalies/broken fibers exist. If an anomaly is detected, MFN must be contacted immediately. In any case, the results (OTDR trace files) of the reel tests must be submitted to MFN as soon as the test is completed and in all cases, prior to placing the cable reel.

2.2 Construction-mode and Uni-directional Tests

MFN strongly encourages construction-mode testing in which active OTDR testing is conducted uni-directionally as a span is spliced. This method will significantly reduce the extent of re-work that will be necessary once a bi-directional test is conducted. However, it should be clear that only bi-directional OTDR testing will be permissible for MFN acceptance. In instances where a contractor is responsible for a section of a span which will does not end in a termination, field termination will have to be done in order to generate bi-directional results for acceptance.

By the way of guidance, MFN recommends the following criteria for unidirectional splice loss when in construction mode. Note that achieving this criteria in no way implies that MFN accepts these fiber splice losses. ***Only bi-directional splice loss can be used for acceptance.***

Table 3 : Uni-directional Splice Loss "Guidance" Criteria

Fiber Type	Splicing Method	Splice Loss (dB)
Standard Single Mode	Single fiber-splicing	0.20 dB
Standard Single Mode	Mass fusion splicing	0.30 dB
Non-zero Dispersion-shifted	Single fiber-splicing	0.40 dB
Non-zero Dispersion-shifted	Mass fusion splicing	0.50 dB

2.3 Fusion Splicer Loss Estimate

Any splice that exhibits an estimated loss (typically via a profile-alignment system of the fusion splicer) that exceeds 0.10 dB must be redone. Therefore, in the case of ribbon splicing, if any single fiber exhibits an estimated splice loss in excess of 0.10 dB, the entire ribbon must be re-spliced. Such a re-splice does NOT constitute an "attempt" as will be discussed further in this document. An "attempt" can only be determined when a bi-directional loss value is measured for the splice in question via an OTDR.

2.4 Acceptance Testing

Once a span is completed, including all splicing and termination (where applicable), acceptance testing begins. This procedure should conform to the following chronology :

2.4.1 Confirmation of Continuity

Continuity testing is conducted to verify that no transpositions have occurred. Each fiber must be tested for continuity. <u>This testing MUST be done and transpositions must be resolved prior to OTDR testing.</u>

2.4.2 Bi-directional OTDR Testing

Once the continuity testing is complete. OTDR traces must be shot from both directions using the method outlined earlier in this document. Again, <u>both directions MUST be shot with the same settings (Pulse width, Range, Resolution, Averaging).</u> The contractor is responsible for analyzing these results in order to generate a list that details the bi-directional splice loss for each fiber at each splice point (by taking the average of the splice loss in each direction). This list should be formatted as shown in the example below :

Table 4 : Bi-directional Splice Report : Sample

Span : PHL to Bal

	Splice number and location (from PHL)						
Fiber Number	**1 (2.8 km)**	**2 (7.2 km)**	**3 (11.0 km)**	**4 (14.3 km)**	**5 (17.1 km)**	**6 (21.8 km)**	**7→ (24.9 km)**
001							
002							
003							
004							
005							
006							
007 ↓							

The contractor must submit these traces to MFN (electronic copy) for analysis as well, indicating whether active (construction-mode) testing was used during the splice work. MFN will also analyze these results to generate our own list of unacceptable splices. The contractor should not wait for MFN's analysis prior to beginning the "clean-up" phase described below, but must be aware that any discrepancy between the lists will have to be addressed. MFN will make every attempt to make it's list available to the contractor as soon as possible.

MFN's acceptance criteria for any individual splice is detailed as follows. Note that the Loss values correspond to the maximum acceptable value.

Table 5 : Bi-directional Splice Loss Criteria

Fiber Type	Splicing Method	Splice Loss (dB)
Standard Single Mode	Single fiber-splicing	0.10 dB
Standard Single Mode	Mass fusion splicing	0.20 dB
Non-zero Dispersion-shifted	Single fiber-splicing	0.15 dB
Non-zero Dispersion-shifted	Mass fusion splicing	0.30 dB

Table 6 : Connection Criteria

Parameter	Criteria
Connector Insertion Loss	0.5 dB
Reflectance	- 50 dB

In addition to splice loss, the contractor must also take into account the insertion loss and reflectance of the connectors in the span for acceptance.

2.4.3 *Clean-Up & Re-splicing Attempts*

Having identified which splices have a loss exceeding the criteria, the next step is to re-burn these splices to reduce the loss.

→ This phase *MUST* be carried out with active OTDR testing in both directions. Therefore, as a fiber or ribbon is re-spliced in the field, OTDR traces from both ends must be used to determine the resulting loss of the splice. (These traces must be saved – see below)

→ Although the re-splice attempts and OTDR tests may be conducted with the splice enclosure removed from the manhole, pole, etc..., a final test must be conducted once the enclosure has been laid and positioned in it's final resting configuration, once the problem is resolved.

→ In the case of ribbon splicing, once the splice is re-burned, the entire ribbon must be tested for splice loss at that location since the fiber which originally had a high splice loss may have achieved a lower splice loss while making a different fiber worse.

→ A number of attempts may be necessary in order to reduce the splice loss. The Table below indicates MFN's requirements for re-splice attempts :

Table 7 : Re-splice Acceptance Criteria

Fiber Type	**Standard Single Mode**		**Non-zero Dispersion Shifted**	
Splicing Method	*Single fiber*	*Mass fusion*	*Single fiber*	*Mass fusion*
Acceptance Criteria	0.10 dB	0.20 dB	0.15 dB	0.30 dB
After 3 attempts	0.20 dB	0.30 dB	0.30 dB	-
After 2 additional attempts[1]	0.30 dB	0.40 dB	0.50 dB	0.50 dB

1 A total of five attempts.

Note : all attempts must be documented

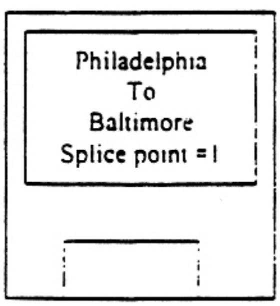
→ In the case of single-fiber splicing, each attempt corresponds to the particular fiber being re-spliced. In the case of ribbon splicing, at attempt refers to the entire ribbon being re-spliced. Therefore, a ribbon will be re-spliced upto 5 times in order to reduce the splice loss of perhaps a single fiber. This is to limit the number of times a ribbon can be re-burned since re-splicing can cause a high splice loss to move from fiber to fiber (and therefore cause upto 12 fibers × 5 re-burns = 60 re-splices per ribbon !).

While limiting the number of ribbon re-burns to five, MFN requires that the splice loss of the ribbon at the relevant location does not become "significantly" worse than the original state. For example, if the ribbon in question has one fiber (NZ-DSF) that exceeds the criteria with a bi-directional splice loss of 0.38 dB and after five attempts a different fiber in the ribbon has a loss of 0.37 dB, MFN will accept the ribbon. If, on the other hand, after five attempts one of the fibers has a splice loss of 0.55 dB. MFN will not accept since it has become "significantly" worse than it's original state.

→ The contractor MUST provide evidence of the re-splice attempts via bi-directional OTDR traces for each attempt. In the case of ribbon splicing, all 12 fibers must be shot per attempt and all traces must be saved and provided to MFN (electronic copy, GN Nettest format). MFN will not accept any other form of evidence and will not recognize any attempts for which evidence does not exist.

OTDR traces of the attempts must be named using the same methodology described earlier in this document with the following additional requirements :

- All traces related to a splice location should be on a separate diskette. If more than one diskette is needed for a given splice location, additional diskettes may be used provided they are clearly labeled.
- Each diskette MUST be set-up with folders as described in the example below:



- ➡Ribbon 3
  - ➡Attempt 1
    - ➡PhiBal15.037
    - ➡PhiBal15.038
    - ➡PhiBal15.039
    - ➡PhiBal15.040
    - ➡PhiBal15.041
    - ➡PhiBal15.042
    - ➡PhiBal15.043
    - ➡PhiBal15.044
    - ➡PhiBal15.045
    - ➡PhiBal15.046
    - ➡PhiBal15.047
    - ➡PhiBal15.048
  - ➡Attempt 2
    - ➡PhiBal15.037
    - ➡PhiBal15.038
    - ➡PhiBal15.039
    - ➡PhiBal15.040
    - ➡PhiBal15.041
    - ➡PhiBal15.042
    - ➡PhiBal15.043
    - ➡PhiBal15.044
    - ➡PhiBal15.045
    - ➡PhiBal15.046
    - ➡PhiBal15.047
    - ➡PhiBal15.048
- ➡Ribbon 8
  - ➡Attempt 1............

If MFN is unable to resolve which traces correspond to which splice point or to which attempt, those attempts will not be recognized. MFN will provide the contractor with the splice numbers for the span. The contractor must provide to MFN the sequence in which the splice locations are worked on.

2.4.4 *Final Testing*

After all re-splicing has been completed with the necessary evidence of re-burn attempts submitted and all connection issues (insertion loss, reflectance) resolved, the entire span (all fibers – not just those affected by the re-work) must be re-shot at the appropriate wavelengths (based on fiber type) and traces submitted to MFN.

At this time, power (insertion loss) testing should be conducted as described in this document and submitted to MFN in both paper and electronic form.