# Gigaclear Documentation
# Optical Build and Testing Standard

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# 2. Scope and Purpose

This document sets out the requirements for contractors and operatives who perform optical establishment (splicing, patching) and testing work on the Gigaclear network. It is a general guide to fibre working on Gigaclear's network. It does not contain specific procedures or processes.

Gigaclear's optical network is the company's key asset, and so construction of the network must be done consistently and to a good standard. When performing work such as construction of new network sections, repair of existing infrastructure or changes to existing assets, testing is required to ensure that works have been completed properly and produced a network asset that can be used in the way it has been designed. Testing also provides evidence to authorise financial release for completed works.

This document explains Gigaclear's optical build, test, and measurement principles, the range of activities that that Gigaclear requires contractors and operatives to be able to perform, as well as the equipment required to correctly perform these works. The standards to which we hold works performed are also to be found in this document.

# 3. Risks and Safety

Working on Gigaclear's network generally involves outdoor work at the roadside. **Risks, hazards, required personal protective equipment (PPE) and safe working practices are covered in Gigaclear's civils documentation and this document should be read alongside the civils documentation for a full view of the risks**. This document will only discuss hazards specific to fibre optic working.

Additional risks encountered while cleaving, splicing, cleaning and testing fibre include:

- Risk of fibre shards and sharps contaminating clothing or coming into contact with skin
- Risk of fibre shards or sharps being ingested, causing internal damage
- Solvent risks from the use of isopropyl alcohol and similar chemicals
- Optical risks from the use of test equipment or active equipment connected to fibre
- Risk of gas near ducts and buried assets

Gigaclear recommends contractors conduct a risk assessment for all activities; at a minimum the following PPE is required, in addition to civils PPE appropriate to the site:

- Safety goggles or glasses with side shields to be used when cleaving or splicing fibre
- Gloves (latex or nitrile) to be worn when cleaving or splicing fibre
- Sharps bins must be used for disposal of waste when cleaving or splicing fibre
- Overalls or disposable aprons used to minimise risk of fibre sharps contaminating clothing
- Laser safety glasses when working on live fibre that may carry high power

Whenever work is being done on a fibre, no matter when the work is done, fibres **must be treated as live**, and therefore unsafe to observe. This must be strictly enforced by contractors to ensure the safety of operatives working on the network. The ends of fibres must always be kept at least 30cm from the eye to avoid eye damage from live fibre.

Gigaclear generally uses low-power (<3dBm), short-range optical transceivers. These have few safety implications in and of themselves. However, Gigaclear also operates high power (~24-30dBm, Raman amplified) transmission systems. These systems are equipped with safety cut-out devices, but these must not be relied upon to ensure the safety of operatives, as automated restart procedures can still result in short pulses (eye-safe without magnification or focusing). These systems are used across Gigaclear's network, including access segments, so **all fibres must be treated as if they were carrying high power transmission systems. Optical microscopes must never be used anywhere in the network, and direct viewing of fibre ends must never be performed.**

The highest moments of risk are when cutting, stripping, cleaving, and splicing fibre, as well as when inspecting connectors. During these phases, care should be taken to keep fibres well away from the eyes, so that reflected or emitted light remains at a safe level and sharps are kept away from the face. Indirect viewing, such as using the screen on an automated inspection microscope, or the alignment microscope in a fusion splicer, should be used to inspect fibres when needed.

**Always treat fibres as live!**

*Never* view the end of a fibre or connector endface directly – use an automated inspection microscope with a camera to check connector cleanliness safely

# 4. Fibre Hygiene and Cleanliness

The most important thing to ensure throughout any works conducted on fibre is cleanliness, both of tools and the fibre plant itself. Dirt, bacterial contamination, and other contamination of fibre or tools can adversely affect splices and connectors. This can cause faults in service, additional loss in splicing, and require expensive remedial works before the works are accepted into service.

Dirt and contamination on connectors can easily cause permanent damage when connectors are mated, and testing – where connections are made between a test instrument and many ports – presents an ideal opportunity to systematically cross-contaminate and damage the network if not conducted with cleanliness in mind.

Basic levels of fibre hygiene are achieved by systematically following a process of inspecting connectors before making connections using an automated inspection microscope. If the check fails, cleaning must then be performed, and the inspection repeated. Only once both sides of a link are clean may connections be made. Test launch/receive leads should be inspected frequently, even if being connected to clean and inspected connectors. Test launch/receive cross contamination is the leading cause of damage to fibre networks.

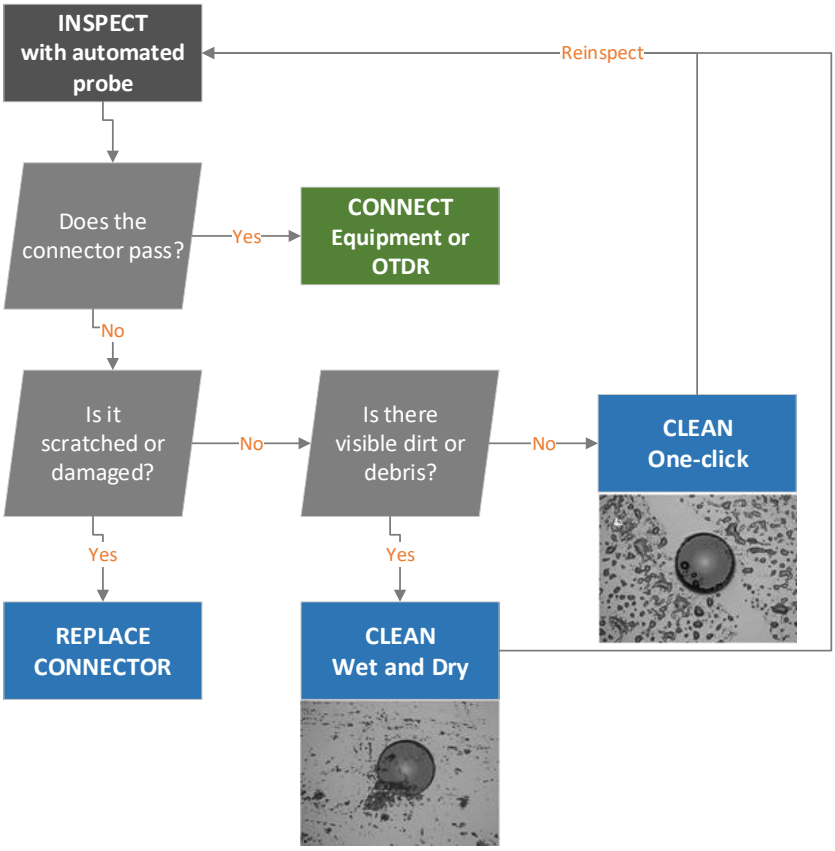



*Figure 1 Process for connecting equipment*

Cleaning processes related to fibre cleaving, splicing and splice protector installation are described in detail in the associated documents for those processes.

**ALWAYS INSPECT BOTH SIDES BEFORE CONNECTING**
Don't damage the network as you install/test it – follow best practice for fibre hygiene

# 5. Network Topology

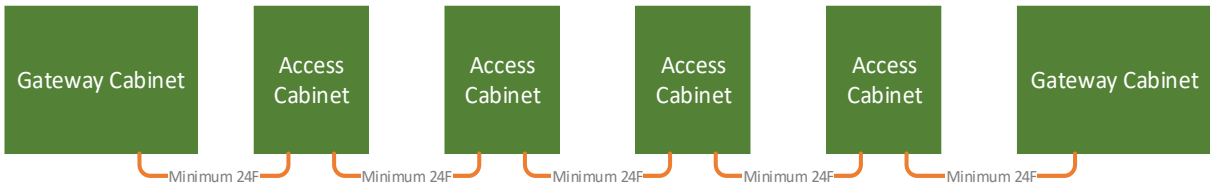
Gigaclear operates a point-to-point network, where all customer premises are connected directly to the equipment that serves them by a continuous strand of glass. This differs from PON/GPON networks ("passive optical network" technologies) where splitters are used to share fibres between properties.

Gigaclear has no "exchange" buildings and instead operates exclusively from street cabinets. There are different types of cabinets, and they can serve different functions:

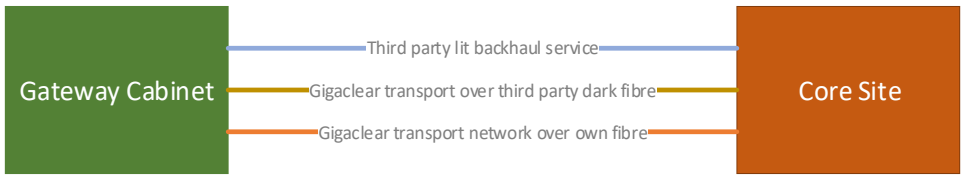
- Gateway cabinets, typically a large, two-rack cabinet, form the backbone of Gigaclear's network and contain transport and backhaul equipment to connect back to the core
- Access or Active cabinets, typically a small, one-rack cabinet, act as a hub in each community and are the sites where we aggregate around 450 customers to serving equipment
- Customer drop or passive cabinets, commonly known as CDCs, typically small cabinets or connectorized closures, serve around 48 properties

## 5.1. Backhaul and aggregation topology

Mostly, Gigaclear designs networks to be highly resilient against loss of a single link; this implies that any access cabinet can reach at least two gateway cabinets. Access cabinets are typically not connected directly to a gateway cabinet but are connected to adjacent access cabinets. This section of the network is known as the aggregation network.

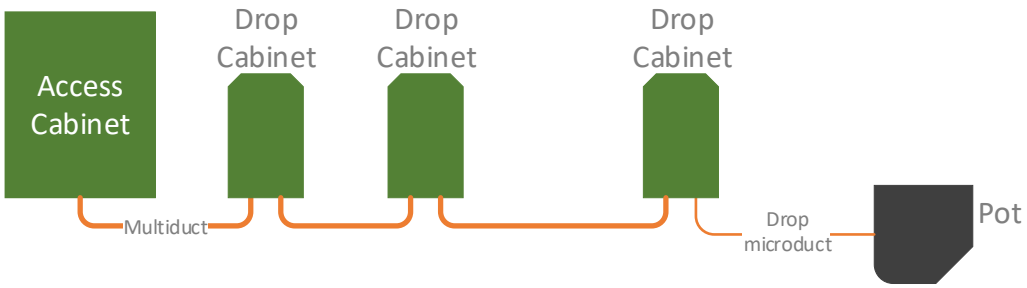



Once a gateway cabinet is reached, either Gigaclear's own fibre or third-party dark or lit backhaul services are used to connect back to one of Gigaclear's core sites or third-party core sites to provide internet services. These are known as the backhaul network. Gigaclear's own dark fibre network and lit services using third party dark fibre networks are typically referred to as the transmission or transport network.



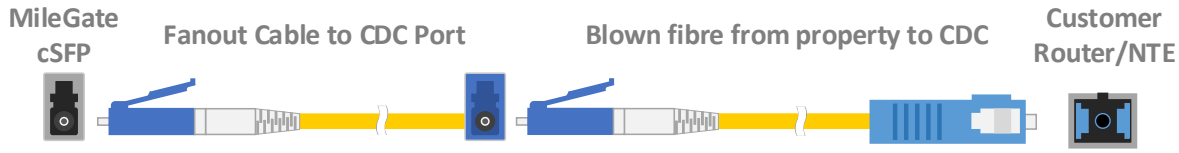

## 5.2. Blown fibre networks (current build standard)

Our current network build standard comprises a chain of drop cabinets, linked by microducts. At each drop cabinet, a window cut is made to access the fibres that are needed at that drop cabinet, allowing other tubes to pass through without interruption.




Each drop cabinet contains a small patch panel and splice trays to accommodate the fibre. The pigtails from the patch panel are spliced onto the incoming fibres. To connect a property, a drop microduct is installed between the pot and its assigned drop cabinet.

Once a service is ordered, a pre-terminated cable is blown through this duct to the drop cabinet and connected in the drop cabinet's patch panel. As there is no fibre in the pot, the test path runs from the active cabinet to the drop cabinet patch panel.

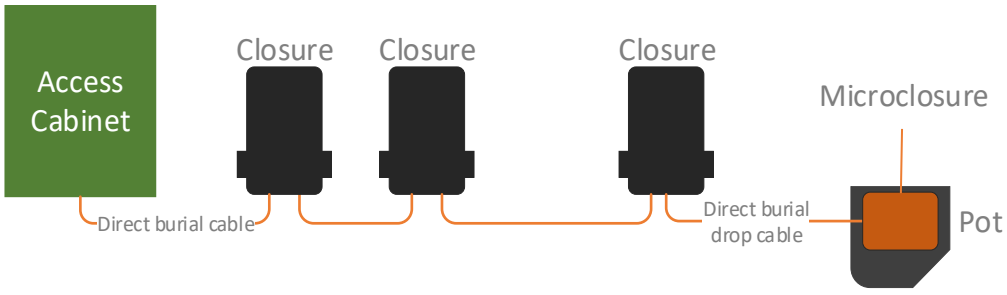



In some areas it may not be possible to install a drop cabinet for aesthetic or practical reasons, and so instead a connectorized closure may be used. This is a standard closure with a small patch panel on the rear of the splice tray backplate; the topology and connections are identical.

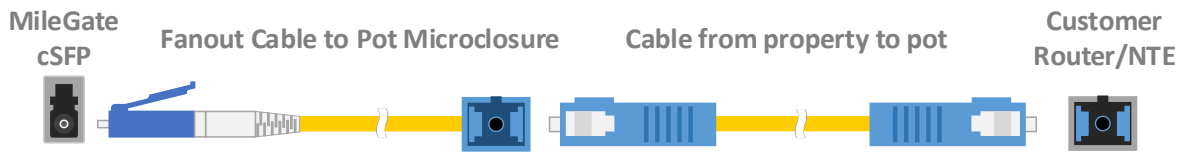
## 5.3. Direct burial networks (legacy areas)

In older areas of the network, direct burial is used; in these cases, the topology is very similar but uses an underground closure as the aggregation point. In the pot, a fibre connector is left in a microclosure (often referred to as a customer connection point or CCP) as opposed to a duct cap or coupler.

In these networks, cables are broken at each closure and re-spliced. This introduced a huge amount of additional splicing that was not actually needed, which lead to increased fault rates and cost of build. Therefore in our current build standard we keep splicing to a minimum and use window cuts to avoid breaking any fibres that do not need to be accessed in a joint.




Properties are connected by a direct burial cable from the assigned closure. This cable contains two fibres to allow for some expansion without further civil engineering works; only one fibre from each cable is connected on day one. The property end of this cable terminates in a microclosure, which can hold two splices and two SC/UPC connectors; as with the closure end, only one connector is spliced and tested on day one.


MileGate
cSFP
Fanout Cable to Pot Microclosure
Cable from property to pot
Customer
Router/NTE

# 6. Required Equipment

Gigaclear requires all contractors to provide their operators with a basic set of equipment that will be required to properly conduct basic work on the network; this document provides a list which is not comprehensive but should be used as a minimal starting point.

Gigaclear has previously not required the use of specific equipment for test and measurement purposes. This standard requires the use of specific equipment models and software options, both to aid in consistent measurement across the network and to improve ease of use in the field. Equipment such as splicers and cutting tools may cite recommended brands, but Gigaclear does not mandate specific suppliers.

It is a requirement that, for any testing which is being performed in order to provide evidence of completion to Gigaclear, the test equipment and processes described are adhered to. Gigaclear will not accept test results performed outside of this regime as evidence.

Personal protective equipment for site safety and operative safety is also required; this is discussed in section 3.

Personal protective equipment (PPE) is also required for safe working at the roadside. You must refer to Gigaclear's HSE policy for information on safe working and required safety equipment

## 6.1. Fibre access

For accessing cable interiors and retrieving fibre for splicing without damaging other fibres in the cable, the following tools are required:

- Cable ringing and slitting tools for 4-25mm cables, e.g. Ripley ACS, Ripley ACS-2, Mills MasterClass Cable Ringing tool – preferably with a rounded blade rather than a diagonal blade, able to be used longitudinally as well as for ringing cuts
- Kevlar scissors, e.g. Mills Kevlar snips
- Buffer tube cutter/stripping tool, e.g. IDEAL Fibre 1A "clothes peg" stripper
- Tri-hole fibre stripper or strippers for 2mm, 900µm and 250µm diameters (jacket, buffer, coating strippers), e.g. Miller Tri-hole Stripper, Mills Masterclass 3-way strippers, or thermal strippers
- Diamond cutters (sidecutters) for cutting strength members
- Screwdriver or similar rounded tool for pulling ripcords

Cable ringing/cutting tools and mid-span access tools must have cut depth limiters to prevent nicking of fibres or tubes.

Armour cutting and stripping tools may be useful to aid clean removal of sheaths from direct burial or steel tape armoured cable.

A pair of narrow-nosed pliers and gripping pliers will also be useful in constructing closures, though closures typically have other tooling requirements specific to the closure.

Cleaning of fibres is required before splicing and cleaving; see section 6.3 for more detail on recommended cleaning supplies.

## 6.2. Splicing and cleaving

Fusion splicers must meet the following criteria:

- Core alignment type
- Typical loss <0.03dB in G.657.A1
- Typical return loss >60dB in G.657.A1
- Support for protection sleeves from 40-60mm
- Support for cables with 125µm cladding
- Tension test ~2N

The Fujikura 70S+ is generally recommended, however the Sumitomo Quantum Q102-CA or Inno View 7 splicers are also suitable.

The manufacturer's recommended spares and cleaning kits should also accompany fusion splicers, so that field technicians can correctly clean their splicers prior to work commencing and replace any parts as required (such as electrodes). Cleaning and servicing of fusion splicers must be conducted in line with the manufacturer's guidance, and evidence of this activity should be kept (particularly servicing).

Cleavers must meet the following criteria:

- Accepts fibre with a cladding diameter of 125µm
- Accepts coating diameters from 160µm to 900µm
- Has a cleaving length adjustable from 5mm to at least 10mm
- Typical cleaving angle < 0.5 degrees or better
- Performs automatic collection of sharps after cleaving operations

The Fujikura CT-08 or CT-50 cleavers are recommended, however the Sumitomo FC-8R or Inno V8 cleavers are also suitable.

### 6.2.1. Ribbon Splicing and Cleaving

Ribbon splicers and cleavers may deviate from the above specifications on the basis of individual model approval conducted by Gigaclear.

Gigaclear does not routinely use ribbon cables in its network, but this may change in future.

## 6.3. Inspection and cleaning

Connector inspection for reportable testing must be performed with an EXFO FIP-430B series automated inspection microscope. No other vendors' inspection probes will be accepted for reportable tests.

The FIP-435B model is strongly recommended, as it features wireless connectivity which enables the use of a mobile phone app for testing where an OTDR is not required; this is commonly required for the connection of receive leads for end-to-end iOLM tests. The FIP-410 and FIP-420 models are not permitted as they do not feature fully automatic acquisition, leaving room for operator error in focusing the microscope or aligning the fibre.

The following tip model numbers are also required for typical use on our network and should be ordered alongside:

- FIPT-400-LC – LC/UPC bulkhead
- FIPT-400-U12M – 1.25mm patchcord tip for UPC (LC)

- FIPT-400-U25M – 2.5mm patchcord tip for UPC (SC)
- FIPT-400-SC-UPC – SC/UPC bulkhead

Gigaclear also uses APC connectors in some portions of the network, so the following APC tips should form part of your kits:

- FIPT-400-LC-APC – LC/APC bulkhead
- FIPT-400-U12MA – 1.25mm patchcord tip for APC (LC)
- FIPT-400-U25MA – 1.25mm patchcord tip for APC (SC)
- FIPT-400-SC-APC – SC/APC bulkhead

Any tips supplied by EXFO for the microscope that match the physical connector or cable being inspected may be used. Long-reach LC/UPC bulkhead tips may be advantageous for some testing procedures.

The operative performing inspection and cleaning must have a TestFlow license so that tests can be issued to the operative and sent back to Gigaclear automatically.

Cleaning should be performed, where needed, with the following supplies:

- Sticklers fibre optic cleaning fluid or similar isopropyl alcohol based cleaning solvent, of at least 99.9% isopropyl alcohol content
- Sticklers CleanWipes (singles recommended over benchtop packs) or similar lint-free fibre cleaning wipes for connector and fibre splice cleaning
- Sticklers CleanStixx fibre cleaning swabs for bulkhead cleaning
- Fujikura One-Click or Sticklers CleanClicker one-click cleaners

Other cleaning products are permitted so long as the cleaning performance is adequate, but the above list is strongly recommended. However, any operative who needs to perform cleaning of cables or connectors must have at least: cleaning fluid, wipes, swabs, and a one-click cleaner for the relevant connector type.

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Optical microscopes that permit the direct viewing of a connector endface should not be allowed on Gigaclear work sites due to the danger of eye damage if live fibres are observed.
Use only automated inspection probes that indirectly view the fibre with a camera.

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## 6.4. Fibre identification

Identifying fibres from end to end requires the use of either a light source/power meter pair, a live fibre detector, or a red light source.

Red light sources are only suitable for use for short links due to the power limits on visible light sources; beyond 10km, red lights will become hard to see. For this reason, their use is only recommended on short links within cabinet areas. Use of “high power” red light sources exceeding class 2M safety levels (1mW between 400-700nm) is not permitted on the network.

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**Do not use red light sources with an optical power in excess of 1mW/class 2M**
There is a high risk of permanent eye damage when using more powerful sources! Use a light source and power meter if you need to confirm continuity or identity at long distances.

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The following tools are recommended for fibre identification:

- EXFO FLS-240 visual fault locator (red light)
- EXFO FLS-300 light source and FPM-300 or PPM-350D power meter
- EXFO LFD-300B/TG-300B dark/live fibre identifier set

## 6.5. Fibre path testing via OTDR (optical time domain reflectometry)

OTDR testing must be performed with an EXFO iOLM instrument, specifically from the MaxTester range. The use of the FTB-1 and other EXFO modular platforms is not currently permitted, due to availability of TestFlow on these platforms; once TestFlow is available on these platforms, equivalent OTDR modules (FTBx-735C) may also be used in FTB platforms.

The MaxTester 730C OTDR is required for performing OTDR tests on the network. The following device configuration is required:

- SM8 – 1310/1550nm singlemode fibre configuration with filtered 1650nm port (PON compatible configuration) OR SM1 or SM3 1310/1550nm singlemode fibre configuration without 1650nm filtered port (discouraged)
- iOLM – iOLM base software, optionally Oi software package for raw OTDR support (iOLM is required in either case – devices MUST NOT be ordered with OTDR support only)
- EA-EUI-91 – SC/APC connector
- RF – WiFi/Bluetooth support

The MaxTester 720C is also permitted for contractors that already have the device. However, due to the limited dynamic range available this is discouraged for new purchases. Gigaclear suggests that contractors may find the SM8 configuration preferable as it is standardised by other network operators in the UK and supports more common passive optical network (PON) deployments which may in future be used by Gigaclear in some areas; as such this is the instrument currently recommended. FTB-1/2/4 units with OTDR modules are not currently recommended due to the lack of TestFlow support.

Optionally the iOLM Advanced option may be purchased for real-time averaging, or the Oi option selected to additionally enable a traditional OTDR mode for technicians more familiar with OTDRs. However, Gigaclear will not accept OTDR results produced outside of the iOLM mode as evidence of completion.

Launch cables of 150-300m length must be used (eg EXFO part SPSB-B-150-88-91-A for LC/UPC, or EXFO part SPSB-B-150-88-101-A for SC/UPC). Gigaclear test configurations will require a launch lead of at least 150m to pass the test.

Receive cables of at least 1km length must be used, with 2.2km length strongly recommended (EXFO part PSB-B-2200-101-101-A for LC/UPC). Gigaclear test configurations will verify the presence of a receive cable and require that a receive cable of at least 1km length be present to pass the test.

A complete kit of parts for fibre testing is available from EXFO as a Gigaclear standard package with an agreed discount rate.

## 6.6. Fibre path testing via ILM (insertion loss measurement)

Gigaclear does not generally require the use of insertion loss measurement testing, as it is difficult to document automatically and iOLM based OTDR results are typically within 0.5dB of ILM measurements.

However, if ILM tests are required for specific segments, then EXFO MaxTester 940 loss test sets or the FTBx-940 module should be used. TestFlow does not, at time of writing, support ILM tests and so tests must be correctly labelled and run with Gigaclear provided pass/fail thresholds. Deliverables shall be EXFO ILM result files, optionally with a PDF report.

For ad-hoc testing, FLS-300 light sources and EXFO FPM-300 power meters are recommended. ILM testers from other vendors may be used for ad-hoc tests so long as wavelength auto-detection is used to avoid wavelength mismatch errors.

## 6.7. Fibre testing via CD/PMD (Chromatic Dispersion/Polarisation Mode Dispersion)

As with ILM, CD/PMD testing is not generally performed on the network. However, where it is performed, the following equipment may be used:

- EXFO FLS-5800A polarised light source
- EXFO FTB-5800 chromatic dispersion analyser
- EXFO FTB-5600 PMD analyser
- EXFO FTB-5700 single-ended CD/PMD analyser

The single-ended analyser is not recommended for links longer than 100km or on links where mode field diameter mismatch has been identified. When used on longer links or links where high reflectance events occur, a single mode retroreflector at the far end should be used in addition to the receive cable.

## 6.8. Test equipment calibration and servicing

Generally, test equipment from reputable vendors does not require frequent recalibration to produce consistent results. For this reason, Gigaclear does not mandate the calibration of devices by the original manufacturer on an annual basis.

However, Gigaclear does put the onus of proving accuracy of measurements performed on the contractor; if tests are audited by Gigaclear and discrepancies are found that take the test result out of specification then the contractor may be held liable for remedial works to bring fibres back into specification.

For iOLM/OTDR, ILM, and CD/PMD testing equipment Gigaclear suggests at minimum an annual bench test using a suitable test or fault simulation fibre, along with a detailed inspection of the launch connector and bench cleaning of the connector in accordance with the manufacturer's guidance. If any damage has occurred to the instrument's connector or there is concern about the result of bench testing, the instrument should be returned to the manufacturer for connector replacement, calibration and any remedial work required.

Where in-house testing is performed in lieu of manufacturer-performed calibration, in-house test results must be maintained by contractors and associated with a unit or module serial number; Gigaclear may request to see these results at any time, including result files for the launch connector and test fibre iOLM/ILM/CD/PMD result.

Gigaclear recommends that test equipment should be returned to the manufacturer for calibration a minimum of once every three years, regardless of in-house test capability, to ensure proper functioning of test equipment in accordance with the manufacturer's specification. Calibration certificates should be retained by contractors to prove that a calibration has been performed.

# 7. Test management and transfer

*EXFO TestFlow is being trialled at time of writing; anticipated general launch is early 2020.*

Test configurations for tests to evidence completion of build shall generally be issued through EXFO's TestFlow system, since EXFO equipment is required. This system allows Gigaclear to issue the tests required to evidence a specific work package or cabinet area, and to automatically capture the results of tests. Test configuration is automatically specified, reducing the chance of errors occurring.

TestFlow is a new product and there will undoubtedly be a period of acclimatisation and development to enable all parties to use TestFlow. Gigaclear will work with contractors to enable this over the months after the introduction of this standard.

Gigaclear aims not to accept any results performed outside of TestFlow, to reduce the possibility of error. Tests performed outside of TestFlow must be clearly labelled as per section 10.6 of this document if they are intended to be shared with Gigaclear. Tests that are not correctly labelled or which are ambiguously labelled will not be accepted.

Tests performed outside of TestFlow should be shared with Gigaclear as EXFO result files, openable with FastReporter 2 or 3. PDF reports must be provided *only* as a supplement to the files; the test files themselves are considered the deliverables, as these files contain more detail and can be automatically analysed. These files should be transferred to Gigaclear's Sharepoint or submitted to the requestor of the work at Gigaclear by some other manner.

Tests performed outside of TestFlow must use the appropriate configuration file for the link or connector being tested, to ensure that appropriate pass/fail thresholds are observed. The applied thresholds must be verifiable, hence the requirement that iOLM files are provided. Reports must also state the pass/fail thresholds used. Tests that do not use the correct pass/fail thresholds or testing configuration will be rejected.

When using TestFlow, no reports are required; Gigaclear will accept a TestFlow result alone, with no generated report, as evidence of completion. TestFlow enforces the correct pass/fail criteria and identifiers. If additional tests are added manually to a TestFlow job the identifiers must be consistent with the existing tests and the labelling scheme used.

# 8. Required As-Built Tests

In testing the network Gigaclear is attempting to ensure the following:

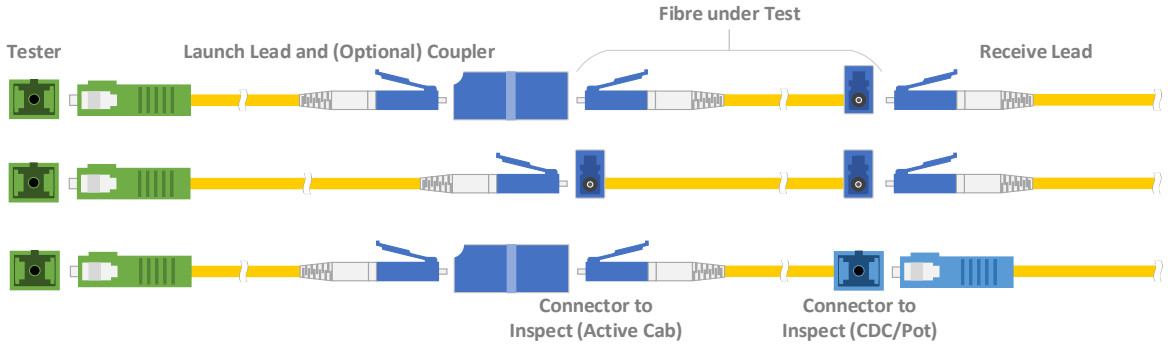
- That the fibre path under test will operate for the purpose that it has been designed for
- That the elements making up the path (splices, connectors) have been built to the required standard, and that workmanship and materials are of the quality and type expected
- That documentation of the built network is as complete and correct as possible for effective and fast repair work to be undertaken in the event of a fault or fibre break

Gigaclear has three main network segments: access, aggregation (cabinet-to-cabinet) and transport (DWDM, long-haul/metro). This section explores the tests required to evidence each segment and the pass-fail criteria for elements. The required as-built return shall contain all new paths built as part of a work package.

## 8.1. Access – CDC (blown network) or Pot (legacy network) to Active Cabinet

The following tests are required for all access ports built:

- Endface inspection of CDC port (blown networks) or pot microclosure port (legacy network) (LC/UPC bulkhead or SC/UPC bulkhead)
- Endface inspection of active cabinet fanout (old cabinets) or patch panel port (new cabinets) (LC/UPC connector or LC/UPC bulkhead)
- iOLM at 1310/1550nm from active cabinet fanout or patch panel port to CDC port (blown networks) or pot microclosure port (legacy network)
  (LC/UPC connector or LC/UPC bulkhead to LC/UPC bulkhead or SC/UPC bulkhead)




These tests are generally conducted with a technician at the active cabinet with an iOLM test device, launch lead, and fibre inspection probe, and another technician at the CDC with a wireless inspection probe, mobile phone (for TestFlow) and receive lead.

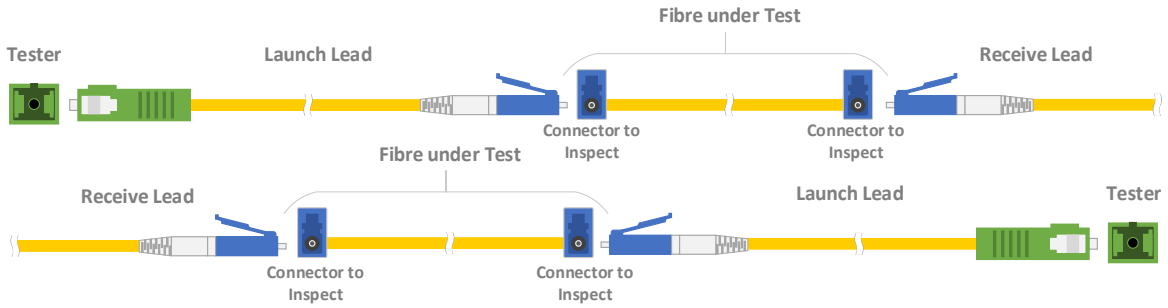
Cabinets will not be considered ready for service until *all* tests are passing. Pots will not be considered ready for service until the pot's test is passing.

## 8.2. Aggregation – Active Cabinet to Active or Gateway Cabinet

The following tests are required:

- Endface inspection of A end and B end patch panel ports (LC/UPC bulkhead)
- iOLM at 1310/1550nm from A to B (LC/UPC bulkhead)
- iOLM at 1310/1550nm from B to A (LC/UPC bulkhead)

Some legacy areas of the network may use unterminated fanout cables for backhaul connectivity. In these areas, LC simplex couplers will be required in addition to perform tests; generally, these couplers will be installed permanently in a patch panel in the cabinet, and testing should be done at this point.

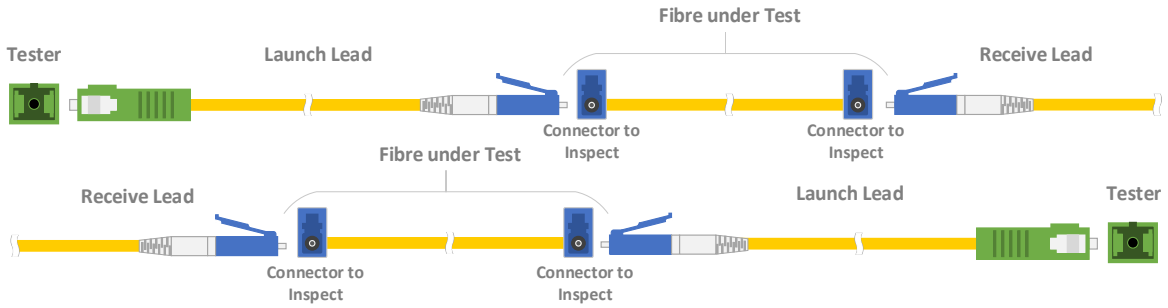



These tests are most efficiently conducted by two technicians with iOLM test devices, launch and receive leads, and fibre inspection probes at each cabinet. However, they can be conducted with only one iOLM test device, with technicians swapping ends partway through.

## 8.3. Transport – Gateway Cabinet to Gateway Cabinet

The following tests are required:

- Endface inspection of A end and B end patch panel ports (LC/UPC bulkhead), to be repeated for each test/reconnection
- iOLM at 1310/1550/1650nm from A to B (LC/UPC bulkhead)
- iOLM at 1310/1550/1650nm from B to A (LC/UPC bulkhead)
- ILM from A to B (LC/UPC bulkhead)
- ILM from B to A (LC/UPC bulkhead)




As TestFlow does not currently support ILM measurements, ILM tests must be performed manually and labelled manually. Chromatic and polarisation mode dispersion measurements may also be requested by Gigaclear Engineering to verify fibre type and CD/PMD performance (see 9.2) where unusual events are observed in iOLM traces.

# 9. Non-Standard Tests

Gigaclear may require additional testing to be conducted on request. These tests are not typically conducted as part of most network builds.

## 9.1. Insertion loss measurement (ILM)

Insertion loss measurement may be required if mode field diameter mismatch or other condition that prevents accurate insertion loss determination by OTDR is suspected on a link; or when a more accurate determination of overall link loss is required. This would typically be performed on links that are close to operational margins.

Insertion loss measurement requires a reference to be taken. Use of calibrated power meters (such as provided on the EXFO FTBx-940 or MaxTester 940) built into the test set to perform local references is permitted but discouraged. On the Gigaclear network a 2-cable reference or 3-cable reference will sometimes be required to allow for connections to be measured bulkhead-to-bulkhead, but 1-cable references should be used wherever possible.

Once a reference is taken, the reference cables must not be disconnected, or the reference must be considered invalid. References should be repeated daily, even if connectors are not disturbed, and with a minimum 5 minute stabilisation period for light sources.

**Transceivers (cSFP/SFP) should never be used as the light source for insertion loss tests!**

The use of a stabilised, adjustable-wavelength light source is mandatory in all insertion loss testing; SFPs do not provide stable light output and are not sufficiently reliable light sources in terms of wavelength consistency/bandwidth.

## 9.2. Enhanced backhaul testing

Sometimes, Gigaclear deploys high power, long-haul transmission systems on the network. Fibre must be more thoroughly tested prior to deployment of these systems to ensure that the systems will work correctly and to allow for system design prior to deployment.

At minimum, each span tested must be tested with the Gateway to Gateway profile (section 8.3). Additionally, chromatic and polarization mode dispersion measurements are performed to confirm the fibre type and highlight any potential issues on the segment.

## 9.3. Fibre drum testing

Gigaclear encourages all contractors to proactively test the stock that they receive prior to using it in the network. Typically, a single fibre OTDR/iOLM test should suffice to show any significant damage to the cable that may have been incurred in transit.

This can be achieved by stripping the cable drum back, splicing a pigtail onto one fibre, and running an iOLM test through a launch lead. This should provide a completely clear trace, save for the pigtail connector and splice.

Fibre that is installed without testing and later determined to be faulty remains the obligation of the contractor that installed the fibre. For this reason, Gigaclear recommends tests are performed on all cable stock and records kept.

## 9.4. OTDR testing

Where more detail is required than that which can be acquired with iOLM, a series of OTDR traces may be required. This should be captured with an EXFO MaxTester 730C or EXFO FTBx730/740/750 series OTDR module in OTDR mode. Refer to the OTDR testing SOP for detail of testing processes.

# 10. Fibre, Port, Cable and Test Labelling

Gigaclear requires all built assets to be clearly, unambiguously labelled to allow quick identification of assets.

Label templates for all labels can be provided by Gigaclear and should be used wherever possible.

## 10.1. Colours

Generally, neutral colours (white, yellow and grey) are used to label cables, or as colours of items such as splice trays.

Different colours are often used to signal high risk sections of the network. Red cables are used to indicate backhaul or DWDM network segments, for instance. Splice trays may be labelled with a red flag, or a red (or black) splice tray may be used in place of a white one. Note, however, that in older sections of the network this colour scheme was not used and so white or yellow trays may also include fibre used for purposes other than access. If in doubt, consult with Gigaclear.

| ITEM | COLOUR | APPLICATIONS |
|---|---|---|
| Splice tray/tray label | White | Access<br>***In legacy areas/previous standard versions, used for all applications including aggregation and transport*** |
| Splice tray/tray label | Black | Aggregation/transport/DWDM |
| Splice tray/tray label | Red | Aggregation/transport/DWDM |
| Splice tray/tray label | Yellow | Access – drop pigtails/splices |
| Patch cable/fanout jacket | Yellow | Access – standard single mode cable<br>***In legacy areas/previous standard versions, used for all applications including aggregation and transport*** |
| Patch cable/fanout jacket | Red | Aggregation/transport/DWDM |
| Patch cable | Cyan | Standard multi mode cable; typically used for aggregation/transport/DWDM equipment |
| Label – cable/duct (TipTag) | Yellow | Mixed, general labelling for all cables |
| Label – cable/duct (TipTag) | Red | Aggregation/transport/DWDM<br>*In legacy areas/previous standard versions, used to label "outgoing" cables in closures/chambers* |
| Label – cable/duct (TipTag) | Green | No longer used<br>*In legacy areas/previous standard versions, used to label "incoming" cables in closures/chambers* |

Other colours must not be used for labelling purposes or to colour splice trays, patch panels, etc. Gigaclear may use other colours for other purposes in future.

## 10.2. Cabinet Labels

Cabinets are typically labelled on the front of the cabinet with an engraved plate (in the case of active cabinets) and/or on the backboard (in the case of passive cabinets). Backplate labels should be Helatag 1204 or similar labels and must be printed rather than handwritten.

The label must show the full cabinet code (for example RC-CBNM or RC-CBNM-PCA001) and may optionally show the long-form name for active cabinets. Closure labels for closures contained within a CDC may optionally be applied as separate labels.

Cabinets should be labelled when installed, before the site is left. This minimises the risk of mis-identification.

Some cabinets such as a CDC may also have a patch field label fitted to allow identification of properties locally.

## 10.3. Closure Labels

Closures are typically labelled internally, using a yellow TipTag label zip-tied to the metal riser, but may also be labelled externally using a TipTag zip-tied to the *lower body* of the closure (not a cable) or a Helatag 880/1102 label placed below the sealing ring above the cable ports. 11x65 TipTags are recommended.

Labels should be fitted before cables are installed, so that the closure being worked on is clearly identified from the outset.

Labels should not be attached to the sealing ring, external brackets, or the closure cover.

## 10.4. Cable Labels

Cables must always be labelled clearly, using approved HellermannTyton TipTag labels only. These labels must be printed with the TipTag label printer TT430 or other printer approved by HellermannTyton for this purpose. Handwritten labels will not be accepted into service.

Cables must be labelled with 11x100mm or 15x100mm TipTag labels. Where these cables carry *predominantly* (>50% of fibres allocated as backhaul) transport/backhaul services, cables should use a red tag to indicate the higher risk. Otherwise, tags should be standard yellow tags, even if some aggregation links pass through the cable.

## 10.5. Patch Panel and Fanout Labels

Patch panels are generally labelled left-to-right, top-to-bottom. Unless otherwise stated, each patch panel in a 19” or 23” rack is considered to be a 1U panel; sometimes, 2U chassis are used but each 1U is addressed individually.

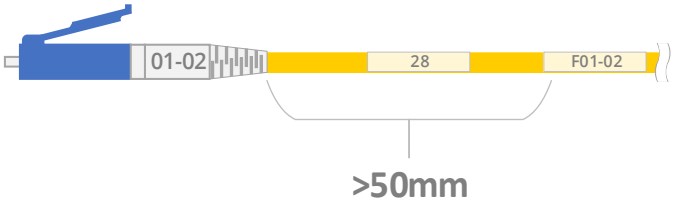
Port and fibre labels for patch panels are individual to a specific fibre – for instance, a duplex connector should be labelled with two identifiers, one for each fibre (e.g. port 1-2, port 3-4).

### 10.5.1. Access network fanouts

The most commonly found configuration in our network is a set of fanout cables in the access cabinet, with each cable providing up to 48 connections. These fanouts are typically spliced in fanouts in the cabinet’s chamber.

Each cable is assigned a number within the cabinet, preceded with the letter F. For instance, the first cable will be labelled F01. Within each fanout, each individual fibre connector is labelled by appending the connector number to the fanout number, separated by a dash. For instance, the 7th connector in fanout cable 2 would be F02-07. Both numbers are zero padded to two characters.

Fanout connectors should be labelled in full (including the F character) greater than 50mm from the end of the strain relief. Fanout cables often include another label to indicate the connector’s fibre; this should not be covered by the fanout label. The connector may optionally be labelled on the body as shown below, omitting the “F” prefix, but a label that is visible when the connector is mated in a dense patch field is always preferable.




The label type to use is not stipulated in this standard, but must be of an adhesive (not heatshrink) type and must be printed, not handwritten. In practice, fanout cables are ordered pre-labelled from HellermannTyton and so labels are not required – this documentation pertains mainly to repair works.

### 10.5.2. Access network patch panels – Commscope MFPS

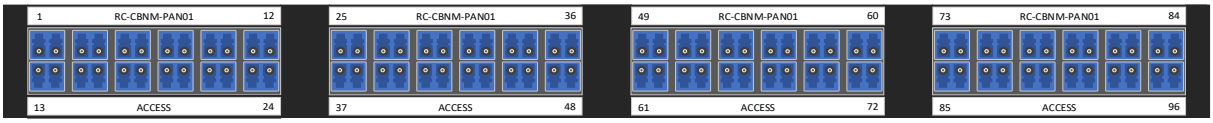
Newer cabinets such as the Gen2 Small cabinet use a Commscope MFPS panel in two varieties – a 192 port 2U version and a 96 port 1U version.

MFPS panel ports are intrinsically labelled as shipped from the factory with a port number.

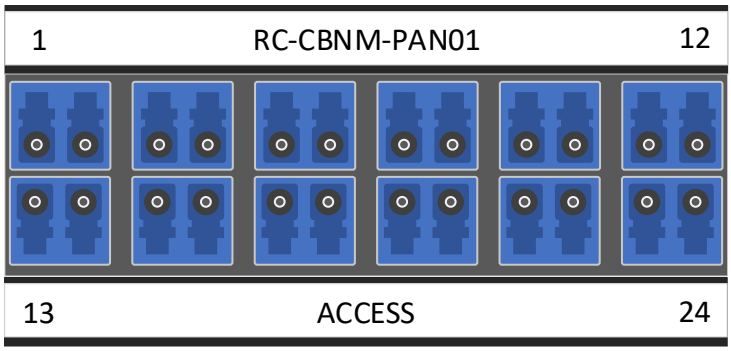
The patch panel must be labelled on the front of the panel cover as well as on the side of the panel. Panels in a cabinet are generally labelled bottom-up (PAN01 at the bottom, PAN03 at the top, with PAN04 for aggregation links, in a standard Small cabinet). The label should be a printed adhesive label.

### 10.5.3. Access network patch panels – HT RapidNet style

Some cabinets make use of a patch panel in the access cabinet to ease cable management. In these cabinets, labelling of the patch panel is used, with each 1U group labelled from port 1-96.




Each patch panel is labelled with the patch panel identifier along the top (repeated for each bank of ports), and the word “ACCESS” along the bottom. If the panel name is unknown or unspecified, then the cabinet name may be used. Alternatively, a panel name may be generated of the form “CABNAME-PANXX” where XX is a number from 60 to 79.



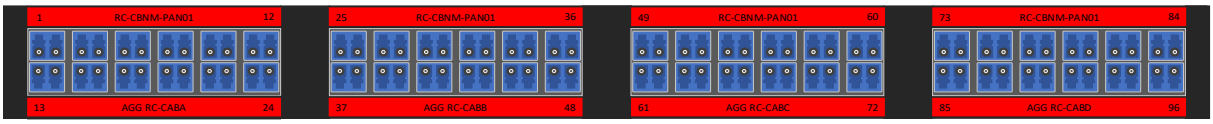

This panel should be labelled in black on a white background. The fully-qualified identifier for a port should be considered “CABNAME-PANELNAME-PORT”, zero-padded – for instance, “RC-CBNM-PAN01-02”.

### 10.5.4. Aggregation and transport network patch panels

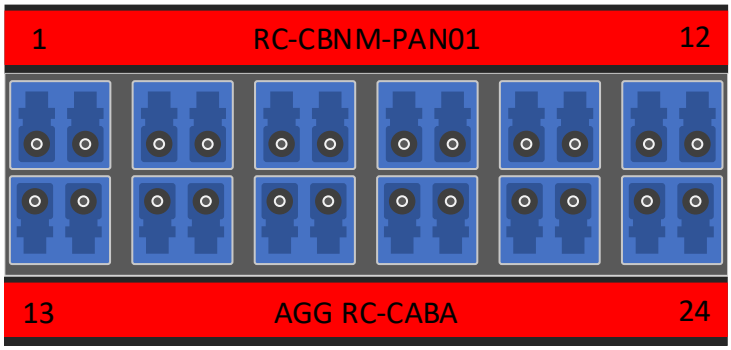
There are several types of aggregation panel in the network.

The first is a panel using HellermannTyton RapidNet cassettes, which is similar to the access patch panel. This panel is labelled identically, but in black or white on red.

If the panel name is unknown or unspecified, then the cabinet name may be used. Alternatively, a panel name may be generated of the form “CABNAME-PANXX” where XX is a number from 80 to 99.




Rather than labelling the lower of the panel with “ACCESS”, the lower label should indicate either “AGG CABNAME“ where CABNAME is the cabinet served by this slot, or “TRANSPORT CABNAME” on DWDM and transport network segments. Aggregation and transport may be mixed in the same patching frame, but not in the same slot (block of 24). The fully-qualified identifier for a port should be considered “CABNAME-PANELNAME-PORT”, zero-padded – for instance, “RC-CBNM-PAN01-02”.




There are a range of other panel types in the network. The general label scheme detailed here should be used, though the label types, positions and layout may differ. Labels must be clear, unambiguous, and consistent across a panel. Where a single panel connects to multiple different cabinets, the cabinet served must be indicated for each port. For most of these panels, HellermannTyton Helatag 880 15x9 labels or similar ~15x10-20x10mm labels will fit most panels.

## 10.6. Customer Drop Cabinet and Drop Closures

Within CDCs, patch ports are labelled through mouldings adjacent to each port. In a typical CDC, each cassette of eight ports is labelled 1-8 or 1-12, and each cassette is labelled A to F. These are combined to identify the port, eg port A1 is the top left port in the patch. The full name of each port is the CDC name followed by the port number.

Within a connectorized closure each port is labelled 1-24. The full name of each port is the closure name followed by the port number.

## 10.7. Test Labels

Most tests – those performed for evidence of completion – will be issued and returned via EXFO TestFlow. This system is populated by Gigaclear from our asset database, and so test results can be associated to our asset database automatically. This allows for quick review of what assets have been tested successfully, which helps speed up financial sign-off. The identifiers shown in TestFlow should clearly indicate the test to be performed. Test jobs in TestFlow will usually refer to a single cable segment or work package, for instance all of the tests related to a single CDC.

Where tests are manually performed, the labels must allow for unambiguous identification of the connectors to which the launch and receive leads or microscope are attached.

The name of the operator and contractor must also be stored in the test.

### 10.7.1. Examples

The following table shows an example of correct labelling, as the tests should be configured in the Identification tab of the test application (assuming EXFO test equipment):

| Scenario | Location A | Port A | Location B | Port B |
|---|---|---|---|---|
| Active cab fanout to CDC port | RC-CBNME | F01-01 or PAN01-01 | RC-CBNME-PCA001 | A1 |
| Aggregation – cab to cab | RC-CBNTA | F01-12 or PAN01-12 | RC-CBNTB | F01-12 or PAN01-12 |

This of course is only clear if the ports/connectors themselves are also labelled in accordance with the guidance in this section.

### 10.7.2. File naming

The file name should include at minimum both location and port records in the following format:

LOCA_PORTA_LOCB_PORTB

Underscores (_) should be used for separators between location and port, as hyphens (-) are used in names but underscores are not. Spaces may also be used to separate the two, but this is not recommended. Hyphens must never be used as separators in filenames, as they are contained in names. Other information should be prefixed to the file name, for instance:

PROJNAME_LOCA_PORTA_LOCB_PORTB

An example of a correct filename, following an example above, is as follows:

RC-CBNME_F01-01_RC-CBNME-PCA001_A1

This unambiguously identifies the two ends of the test and complies with permitted characters.

# 11. Fibre Enclosures/Closures/Joints

Gigaclear uses a range of different fibre closures (also known as joints), and contractors will be expected to install any of them as specified on the design.

Installation guidance for closures is supplied from the manufacturer, and Gigaclear generally follows these procedures. However, detailed guides for some joints showing Gigaclear's desired installation method are provided alongside this document.

## 11.1. Inside Plant

Gigaclear has a number of fibre enclosures designed for interior usage.

### 11.1.1. Mills/Standard Splice-Patch panels

Commonly, fibre optic panels with a small splice tray are used for aggregation links or ad-hoc connections (e.g. between gateway and access cabinets).

Care must be taken to strip back 900 micron coatings to avoid tray congestion.

### 11.1.2. Commscope MFPS Splice-Patch panel

The MFPS panel is a 1 or 2U patch panel system with fibre splicing trays in the rear of the panel. Pigtails are preinstalled and laid up ready to splice; flexible conduit is used to bring buffer tubes into the panel, or cables can be anchored directly on the rear of the panel using the appropriate cable termination unit.

## 11.2. Outside Plant

These closures are used in chambers or on poles outside.

### 11.2.1. HellermannTyton (HT) – FDN, FST, FRBU, and UFC

Most commonly found in the network are HellermannTyton's FDN59TB closures, these have a capacity up to 144 splices. HellermannTyton UFC closures are used where a larger capacity is required and have a capacity of 864 splices. FRBU and FST closures have been used in the past to splice where a smaller capacity is needed but are not recommended for new builds.

All HT closures use a mechanical Cablelok seal. This seal *must* be used, and the correct seal must be used for the cable being sealed. Heatshrink seals are not accepted on the Gigaclear network. Cablelok seals are installed by lubricating the cable and pulling it into the sealing grommet, and then pulling the grommet into the joint.

Most HT closures used on the network are tubed closures, meaning transport tubes are used to route fibres around the joints. Tubes and labels are supplied in all kits.

All HT trays used in the network are designed for 40-45mm splice protectors. 60mm splice protectors should not be used as fibre damage may occur.

An additional kit is required for FDN and UFC joints if metallic earthing is required or if more than 3 cables are being installed within a joint.

### 11.2.2. Commscope (CS) – TENIO, FIST-MSC, CCS, OTE, OFDC

Gigaclear is introducing closures from Commscope to meet new requirements in some areas as a trial. These include:

- TENIO closures – up to 144F with mid-span/branch capacity

- FIST-MSC closures – up to 1728F with mid-span/branch capacity, supports ribbon splicing
- CCS closures – up to 48F with mid-span/branch capacity
- OTE closures – aerial drop nodes up to 48F with splicing and mid-span/branch capacity
- OFDC closures – aerial and UG drop nodes up to 48F with splicing and branch capacity

All Commscope closures use a compressive gel sealing mechanism. The correct cable termination units must be used for the cable and joint being used to properly anchor the cable.

Where closures have modular gel sealing blocks, the correct seal size must be selected and used.

Gel seals must be kept clean and free of debris such as tape.

### 11.2.3. Prysmian (PRYS) – CMJ

Gigaclear may use the Prysmian CMJ joint in some locations as a trial. This is a small modular joint.

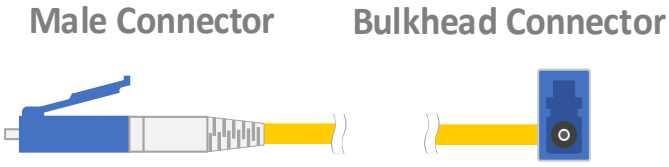
Prysmian closures use a mechanical screw-down seal kit which is supplied with the joint.

# 12. Connectors, polish types, and patch cords

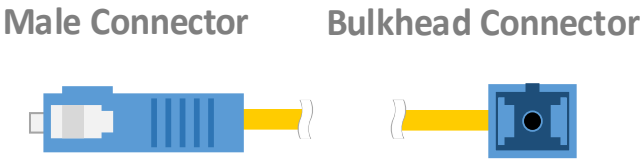
This section provides a brief explainer on connectors and patch cords you are likely to see while working on the Gigaclear network.

The following connector types are present in the network:

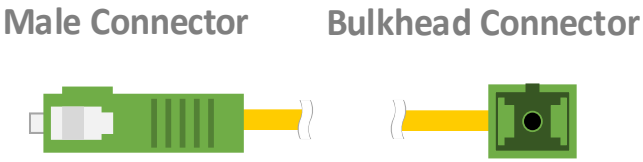
- **LC/UPC** – Widely used in active cabinets, passive cabinets/CDCs, and on equipment. The most ubiquitous connector in the network by far.




- **SC/UPC** – Used predominantly in the home and in the legacy network. In the older parts of the network, where direct burial was used to install fibre to pots outside homes, these connectors are found in the pot microclosures.




- **LC/APC or SC/APC** – In Gigaclear's older networks rarely used, found only in gateway sites for high power optical systems such as Raman amplified DWDM links. Used ubiquitously in PON areas where reflectance is not acceptable. **Not compatible with UPC connectors**. Commonly found on test equipment.




Note that APC connectors, because they have an angled polished end, have a "right way up". This is relevant when inspecting connectors, particularly male connectors. Microscopes will require an APC tip, which will have a notch to indicate the correct rotation of the connector so the microscope looks at the end "flat on". All fibre connection types are keyed to ensure correct orientation.

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**NEVER MATE UPC AND APC CONNECTORS – THIS WILL CAUSE IMMEDIATE DAMAGE TO BOTH**
The angled tip of an APC connector will fracture if mated with a UPC connector.

This includes connectors in test equipment (typically APC) and network equipment (typically UPC).
*Power meters are the only test equipment that may accept both APC and UPC connectors – check with your equipment vendor if you are unsure of the connector fitted to your equipment.*

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Occasionally, you may see beige connectors. These are multimode connectors and should not be present anywhere in the network. Rarely, multimode connectors are used within a cabinet (with an **aqua** jacketed cable), but multimode is never used for links between cabinets.

While not a fibre cable, contractors should be familiar with DC power cables (-48VDC) within a cabinet, which typically use blue and grey wiring. AC power cabling typically uses a **black** or grey jacket.

Most patch cables within cabinets will be yellow or red jacketed, 1.2mm, 2.0mm or 2.3mm jacket singlemode G.657.A1 type cables.

## 12.1. Hardened connectors

Various vendors have “rugged” or “hardened” connectors which are weatherproof when mated. The integrity of these connectors typically relies on a sealing plug being fitted when not in use.

Most hardened connectors such as the Corning Optitap or Commscope DLX are SC/APC type connectors and can be inspected and cleaned with standard SC/APC cleaners and microscopes.

For OTDR testing, an adapter cable is required, specific to the connector under test.

## 12.2. Backhaul patching

Gigaclear’s network topology is varied, but typically in areas where build is still progressing and so redundant aggregation or backhaul paths may not yet exist, there is a reasonable chance that single points of failure will exist. This means that unplugging a single cable can have serious repercussions and affect thousands of customers.

Given the dense and intermingled fibre management in most cabinets, Gigaclear takes steps to mitigate this risk by making clear where patch cords are likely to carry significant customer traffic. This is done by using red markers, or red cables, to indicate these cables.

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Backhaul cables and equipment interconnect cables typically use a **red jacket** to indicate that multiple sites would be affected by the removal of the cable.

**These cables are more likely to carry high power optical signals, and may have a large impact on the network if damaged or disturbed**

Take extra care around red jacketed cables, and **never inspect them with an optical microscope**

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# 13. Pass/fail criteria

The following pass criteria are to be observed as an absolute minimum for ad-hoc testing and building test configurations that align to Gigaclear's standards. These standards are aligned with industry and international standards such as ISO/IEC 14763-3:2014 [1] and IEC 61300-3 [2].

## 13.1. Loss and Reflectance

Cables and spans within a trace shall meet or exceed the following:

- Span reflectance: $< -35dB$ reflectance
- Span loss at 1310nm: $< 0.35dB/km$
- Span loss at 1550nm: $< 0.25dB/km$
- Span loss at 1650nm: $< 0.25dB/km$

Splices and connectors shall meet or exceed the following:

- Splice: $< 0.3dB$ unidirectional loss, $< 0.1dB$ bidirectional loss
- UPC connector: $< 0.5dB$ unidirectional loss, $< -40dB$ reflectance
- APC connector: $< 0.5dB$ unidirectional loss, $< -55dB$ reflectance

### 13.1.1. Link Specific Limits

For the following link types, overall pass limits are also observed to ensure the proper functioning of equipment typically deployed on these links:

- Active cabinet fanout or patch panel port to CDC, pot or NTE: $10dB$ loss at 1310nm

The active cabinet to CDC/port/NTE budget may be extended by $3dB$ *in extremis,* and only where repairs have been performed on the link, as a $3dB$ safety margin for in-life repairs is included in the $10dB$ pass/fail threshold. At initial build time, this safety margin must not be considered for the purposes of pass/fail criteria.

## 13.2. Dispersion

Chromatic dispersion coefficient shall not exceed:

- $3.2\ ps/nm \cdot km$ at 1310nm
- $18\ ps/nm \cdot km$ at 1550nm
- $22\ ps/nm \cdot km$ at 1650nm

The polarization mode dispersion coefficient shall not exceed $0.1ps/\sqrt{km}$ on any link.

# 14. Passive component specifications

Gigaclear uses a variety of different suppliers for almost all components in the network. The following specifications outline some key requirements for various passive elements where it is important to the proper functioning of the component in Gigaclear's network. These requirements can be used alongside application-specific requirements in supplier selection.

Note that cables, patch cables, couplers, patch panels, connectors and other passive components *must* be approved by Gigaclear explicitly prior to being used in the network. Gigaclear has approved suppliers for all components, and these suppliers *must* be used. Components installed in the network which have not been approved for use by the Chief Engineer will need to be replaced at the contractor's expense.

Losses in this section are as measured at 1310nm unless specified otherwise.

## 14.1. Fibre Connectors

UPC connectors must have an insertion loss variance lower than $0.25dB$ and a typical insertion loss of less than $0.5dB$, in alignment with IEC 61753-1 grade C. Grade B connectors ($\leq 0.12dB$ mean loss, $\leq 0.25dB$ max loss) will be preferred when used in loss-sensitive applications such as ODFs. UPC connectors must use a blue connector body, and a white boot.

APC connectors must have an insertion loss variance lower than $0.3dB$ and a typical insertion loss of less than $0.5dB$. APC connectors must have a return loss of $> 60dB$. APC connectors must use a green connector body, and a white boot.

Connectors must be of LC or SC types.

Strain relief boot lengths shall generally not exceed 35mm. Assemblies shall demonstrate insertion loss increases of $\leq 0.3dB$ under physical load as specified in Telcordia GR-326 (up to 2kg at 90 degrees).

## 14.2. Patch Cables

Patch cables must use fibre of type G.657.A1 or G.657.A2.

Patch cables with a length less than 10m should have an insertion loss of less than $0.35dB$ in addition to connector insertion loss.

Patch cables may have a yellow or red jacket.

Multimode patch cables are permitted for equipment interconnection within a cabinet, but not for other purposes. Multimode patch cables must use an aqua coloured jacket.

## 14.3. Splitters

Optical splitters are not currently generally used in the network. However, where their use is specified, splitters shall be of a planar lightwave circuit (PLC) type.

Symmetric splitters shall have light split ratios of 1:2, 1:4, 1:8, 1:16 or 1:32.

Asymmetric splitters shall present no more than 8 tap ports.

Loss shall not exceed – in any circumstances – $0.8 + 3.4\ \log_2 n$, where $n$ is the ratio (e.g. 2, 4, 8, etc). This is drawn from Telcordia GR-1209. The following table summarises the target optical performance of splitter components, and does not include connector losses:

| *Ratio* | *Loss at 1310nm and acceptable manufacturing variance* |
|---|---|
| 1:2 | $3.7dB \pm 0.5dB$ |
| 1:4 | $7.1dB \pm 0.5dB$ |
| 1:8 | $10.5dB \pm 0.5dB$ |
| 1:16 | $14.1dB \pm 0.5dB$ |
| 1:32 | $17.3dB \pm 0.5dB$ |

Splitters must have a loss variance $\leq 0.2dB$ across an operating temperature range of -15c to +85c.

Symmetric splitters must have a uniformity across all ports of less than $\leq 0.2dB$.

Splitter directivity must be $\geq 50dB$.

Splitters should be tested to comply with Telcordia GR-1221, particularly mechanical shock, vibration, thermal shock, high temperature storage, temperature cycling and cyclic moisture resistance tests.

Splitters shall have similar characteristics across the entire operating wavelength range which shall be between 1260nm and 1650nm.

Splitters must be supplied as an assembly with *angled* cleaves on all output fibres, with a total return loss from an unterminated splitter of $\geq 50dB$.

## 14.4. Buried and Blown Cables

Cables must be of type G.657.A1 or G.657.A2 unless expressly permitted for specific purposes.

Cable used in the network must generally have the following characteristics. Testing of these characteristics may be performed by a cable manufacturer or, on request, by Gigaclear or the National Physical Laboratory:

- Span loss at 1310nm $< 0.35dB/km$
- Span loss at 1550nm $< 0.25dB/km$
- Span loss at 1650nm $< 0.25dB/km$
- Chromatic dispersion of $< 19\ ps/nm \cdot km$ at 1550nm
- Chromatic dispersion of $< 23\ ps/nm \cdot km$ at 1650nm
- Mode field diameter at 1310nm: $9.1\mu m \pm 0.4\mu m$, with manufacturing variance $< 0.5\mu m$
- Mode field diameter at 1550nm: $10.3\mu m \pm 0.4\mu m$, with manufacturing variance $< 0.5\mu m$
- Cladding diameter: $125\mu m$, with manufacturing variance $< 5\mu m$
- Coating diameter: $250\mu m$, with manufacturing variance $< 25\mu m$ - $200\mu m$ fibres are not permitted, $900\mu m$ coating is permitted in some circumstances
- Core concentricity error: Maximum $0.8\mu m$

Measurement of variance shall involve random sampling from different batches, with no fewer than ten samples tested. Generally, data sheets from manufacturers are considered adequate evidence but Gigaclear may request to see proof of testing and details of test methodologies; normally, adherence to IEC standards such as IEC 60794 and related families will be expected for all parameters noted above.

# 15. Supporting Documents

Other supporting documents including build guidance for closures can be found in the standards pack in which this document is distributed.

## 15.1. International Standards

This document, and Gigaclear's fibre optic build and test standards more generally, are aligned to international standards wherever possible and follow guidance established as best practice by international bodies such as the International Telecommunications Union. Key standards that may be referred to or drawn from include:

- The IEC 60825 family, which discussed laser and optical safety
- The IEC 61300 family, which specifies single mode fibre optic measurement techniques
- The ISO/IEC 14763 family, which specifies fibre optic cabling testing principles
- The IEC 60793 family, which specifies procedures for testing of fibre optic cabling

Guidance and recommendations such as those found in ITU-T Rec. G.650.3 may also be of interest to readers looking to better understand the field.

# 16. Version History

| Version | Date | Notes |
|---|---|---|
| **1.0** | 2019-03-14 | First issue |
| **1.1** | 2019-04-20 | Various typo fixes and improved specification clarity for equipment |
| **1.2** | 2019-06-12 | Clarified label types and tidied up some sections for initial release |
| **1.3** | 2019-06-25 | Added specification for splitters and improved clarity on connector testing and strain relief boot parameters; added notes on hardened connectors |
| **1.4** | 2019-11-18 | Added section on fibre closures |

# 17. Bibliography

[1] ISO/IEC, *ISO/IEC 14763-3:2014,* 2014.

[2] IEC, *IEC 61300-3-35:2015,* 2015.

[3] International Telecommunication Union, “ITU-T Rec. G.657,” 11 2016. [Online]. Available: https://www.itu.int/rec/T-REC-G.657-201611-I/en.