The Fibreoptic Industry Association
www.fia-online.co.uk

Secretary: Jane Morrison

The Manor House
BUNTINGFORD
Hertfordshire SG9 9AB
United Kingdom

Tel: +44 (0) 1763 273039 Fax: +44 (0) 1763 273255

e-mail: jane@fiasec.demon.co.uk

CAMERA-BASED INSPECTION

by

FIA PROJECT TEAM CIC

Camera-based inspection provides a safe and reliable method for viewing the condition of the optical fibre end-faces and the barrels (or equivalent “walls”) of adaptors into which those end-faces are inserted. In some cases the camera-based inspection techniques provide an assessment system for the quality of those end-faces.

However, the most important advantage of any camera-based inspection system, whether or not an assessment is made, is the ability to save the inspected image and to document the status of a connection at a particular point in a contractual transfer of responsibility.

For the purpose of this White Paper, inspection systems can be classified as shown in Table 1.

Table 1 - Inspection system classification

Un-documented system		**Documented system**	
Direct view microscope	Video inspection	Video record	Video record
Plug only	Both plug and socket	Both plug and socket	Both plug and socket plus assessment

This White Paper explains the advantages and disadvantages of each class of inspection system and provides guidance to FIA members and the wider industry in relation to the value of each approach and the circumstances under which a particular approach has optimum value.

Inspection of end-faces prior to any connection is recommended because contamination trapped between those mated end-faces can lead to:

- excessive insertion loss and/or reduced return loss produced by the connection;
- permanent damage to one or both of the end-faces at that connection.

Equally importantly, if no controls are applied then contamination can be transferred to new connections and the problems are able to spread across an infrastructure.

Contamination vs. end-face damage

It is critical to differentiate between “contamination” and ”end-face damage”. Contamination is particulate or fluidic debris on an optical fibre end-face or within an adaptor “barrel” which, once identified, can be removed by appropriate cleaning techniques. End-face damage is permanent and comprises scratches and defects (such as chips and other marks) which either result from the polishing process or from subsequent damage - some of which is caused by the mating of contaminated end-faces within a connection.

Contamination can produce immediate deterioration of insertion loss and return loss performance whereas defects may or may not affect transmission performance – depending on their location, type and dimensions. Contamination should always be removed from optical fibre and ferrule end-faces before mating, so there are no acceptance criteria for contamination. Acceptance criteria are only applied to scratches and defects and such criteria always assume that any contamination has been removed before the assessment is carried out.

For these reasons, this White Paper begins by addressing inspection rather than assessment.

Inspection

As indicated above if contaminated end-faces are not dealt with systematically then transmission performance may be progressively degraded and may eventually take down an entire link – or defects can be created which may have the same effect.

This White Paper and many other internationally recognised documents recommend systematic and proactive, inspection of every connector end-face before connection.

There are several methods to perform basic inspection of optical connector end faces in a manual mode (i.e. without assessment of end-face defects being applied). These are described in Figure 1.

Direct View Microscopes

While being small and easy to use, these devices have the disadvantage is that the image is very small and sometimes poorly illuminated.

They are restricted to the inspection of the free plug, i.e. the "cord plug", part of interfaces and therefore are not really viable for the inspection of the fixed cabling element of an infrastructure.

There can also be health and safety issues in relation to the possibility of a "live" fibre, which could then possibly allow dangerous optical power levels to reach the eye.

Video inspection

These devices enable the user to inspect both the free plug and the fixed receptacle and adaptor parts of the interfaces of the connection. This is vital for any effective contamination control procedures.

They also eliminate any optical power safety issues as the image is viewed on a video screen.

However, basic video inspection microscopes do not grade the image, and are thus subject to the same operator errors as direct view microscopes with regard to the assessment or grading of end-face defects.

Video inspection providing a documentary record

These devices have the features of the video inspection equipment above but with the capability to produce an electronic record for contractual purposes.

Figure 1 - Basic inspection equipment

The FIA recommends the use of inspection equipment that does not record the images only if the examination is part of a quality assurance process within "factory" or on-site termination. For example, the termination of an optical fibre may require repeated inspection processes, the results of which may direct that process and would not be required to be stored. However, the final acceptance inspection applied to that termination (in either a supplied or as-built condition) should be recorded in the same way that its transmission performance would be. To be more general, and as stated above, the FIA recommends that the inspection system at a particular point in a contractual transfer of responsibility should feature the ability to save and document the inspected image.

Standards for inspection equipment systems

A British, European and international standard, BS EN [IEC] 61300-3-35[1], defines requirements for inspection systems of optical fibre end-faces. It was published in 2010 and is available via the FIA web-site home page at www.fia-online.co.uk. It is currently undergoing revision and should be re-published in 2014. However, this is a somewhat unusual[2] standard since it also defines assessment criteria for scratches and defects on those end-faces (see below).

[1] BS EN [IEC] 61300-3-35: Fibre optic interconnecting devices and passive components. Basic test and measurement procedures. Examinations and measurements. Fibre optic connector endface visual and automated inspection

[2] It is unusual but not unique that a test method standard also defines test limits.

The FIA recommend the use of inspection systems that conform to the minimum requirements of BS EN 61300-3-35 subject to the following additional qualifications:

> *The FIA recommends the use of inspection equipment that does not record the images only if the examination is part of a quality assurance process within "factory" or on-site termination..*
>
> *The FIA recommends that the inspection system at a particular point in a contractual transfer of responsibility should feature the ability to save and document the inspected image.*

Assessment criteria for optical fibre end-faces

As mentioned above, BS EN 61300-3-35, in addition to defining the requirements for inspection systems, defines assessment criteria for end-face damage. The Standard contains PASS/FAIL requirements for inspection and analysis of the end face of an optical connector, specifying separate criteria for different types of connections (for example, SM-PC, SM-UPC, SM-APC, MM, and multi-fibre (MPO) connectors).

The assessment criteria assume the absence of contamination i.e. end-faces should be inspected and cleaned, if necessary, before assessment for scratches and defects is undertaken. If any such end-face damage is found which fails the acceptance criteria, this shall be recorded as a protection for the person involved and allows decisions to be taken for any future re-work or replacement (immediate or phased).

Conformance to BS EN 61300-3-35 may be achievable throughout the life of an end-face provided that correct inspection and cleaning procedures are employed on all occasions. This would ensure the maintenance of the design level of attenuation and return loss. Poor handling may, in some circumstances, give rise to scratches and defects that would not comply with EN 61300-3-35. This is explained in the FIA ShortForm Guidance Note on Procurement in relation to Contamination, Inspection and Cleaning.

Moreover, although BS EN 61300-3-35 specifies a global common set of requirements for optical fibre connector end-face quality which are intended to guarantee insertion loss and return loss performance, work is underway within the standards bodies to re-examine the minimum requirements for "in-service" connector end-faces.

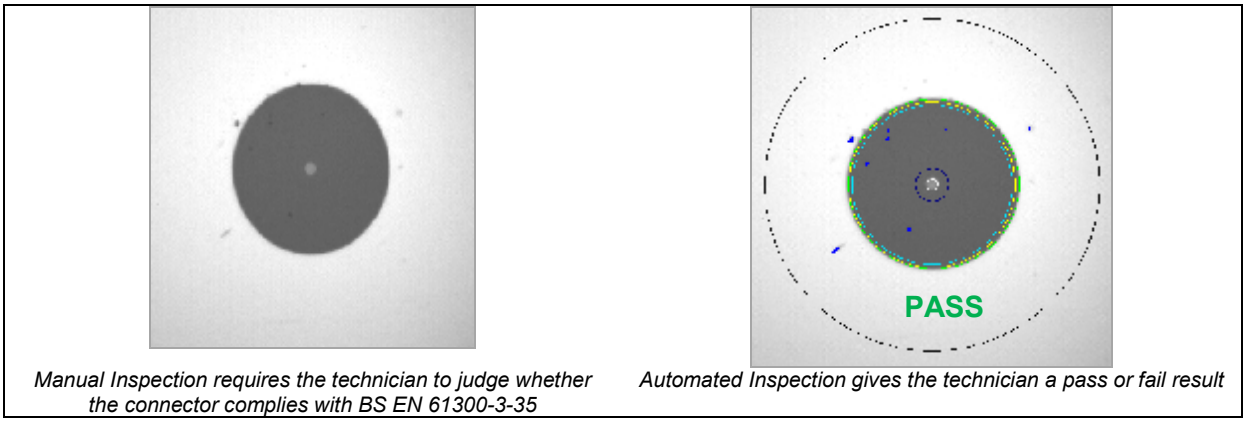
An end-face may not have been procured in accordance with the assessment criteria of BS EN 61300-3-35 or may not have been maintained properly. Such end-faces may fail the standard criteria but may deliver adequate transmission performance in the installed system. This is one reason for having documentary evidence at all contractual stages and the 'FAIL' will allow the network owner to take appropriate action.

How do the assessment criteria work?

BS EN 61300-3-35 defines the areas of critical interest on the connector and optical fibre end-face and defines the acceptable number and dimensions of the scratches and defects - based upon years of extensive testing of damaged connectors conducted by a coalition of industry experts including component suppliers, contract manufacturers, network equipment vendors, test equipment vendors, and service providers.

The criteria of BS EN 61300-3-35 require the assessment system to know the exact location and size of scratches and defects on the connector end-face (as illustrated in Figure 2). Manual assessment using only a video microscope can be difficult - depending on the technician's expertise but both manual and automated systems are subject to variable display settings and ambient lighting changes and an automated inspection system is subject to calibration error.

However, to ensure correct assessment, automated inspection of optical fibre connector end-faces using inspection and analysis software using the BS EN 61300-3-35 PASS/FAIL criteria is considered to be the most effective method available. With it technicians of all skill levels can effectively determine compliance through recorded images and reports as illustrated in Figure 3.



Manual Inspection requires the technician to judge whether the connector complies with BS EN 61300-3-35

Automated Inspection gives the technician a pass or fail result

133 Figure 2 – Comparative assessment approaches

134

135 Figure 3 - Video inspection equipment providing a documentary record and assessment of end-face quality

136

Assessment reports

Automated inspection software and analysis produces a visual record of the end face condition of the type shown in Figure 4, which can be used in reports and archived for future reference in Figure 5. As a result, automated inspection and analysis presents several clear advantages over subjective inspection:

- eliminates subjective assessment
- records product quality at time of inspection
- enables technicians of all skill levels to undertake inspection

It should be noted that as acceptance criteria are modified (either within BS EN 61300-3-35 or implemented to meet customer-specific requirements) the analysis tools can be updated accordingly.

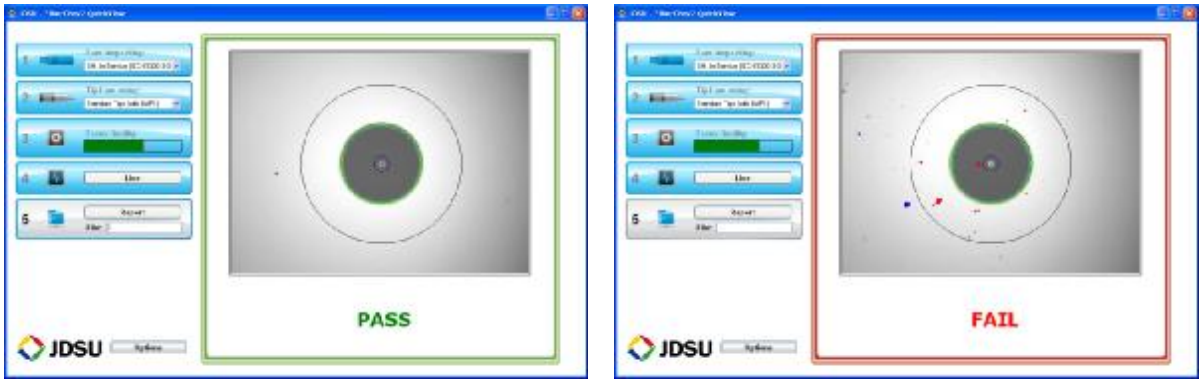


Figure 4 – Software analysis of end-face defects

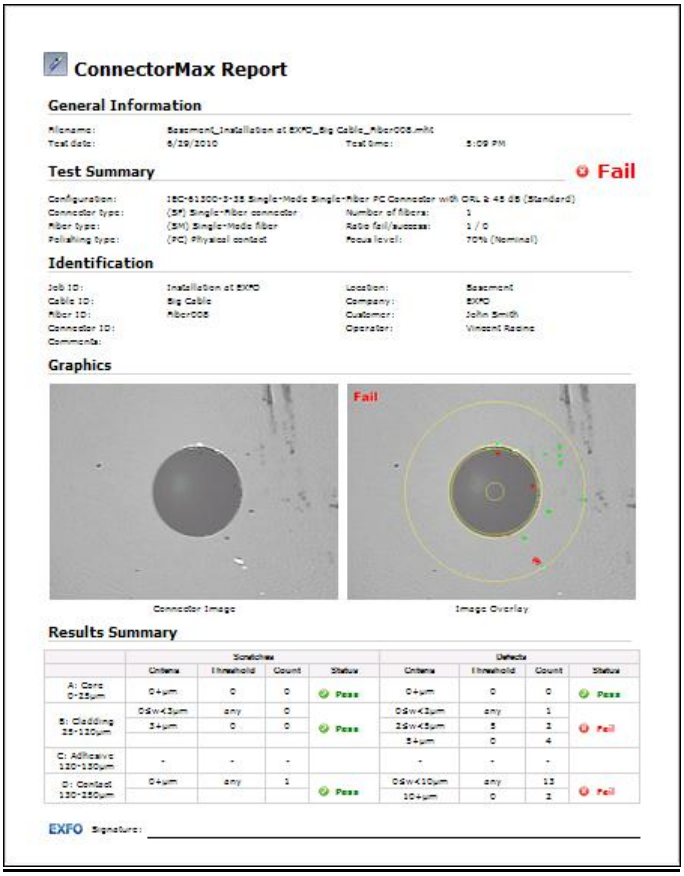


Figure 5 – Comprehensive documentary record and assessment of end-face quality