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TECHNICAL REPORT

colour inside

Fibre optic interconnecting devices and passive components – Part 05: Investigation on impact of contamination and scratches on optical performance of single-mode (SM) and multimode (MM) connectors

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IEC/TR 62627-05, which is a technical report, has been prepared by subcommittee 86B: Fibre optic interconnecting devices and passive components, of IEC technical committee 86: Fibre optics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
86B/3442/DTR	86B/3489A/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all the parts in the IEC 62627 series, published under the general title *Fibre optic interconnecting devices and passive components* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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INTRODUCTION

Contaminated optical connectors result in degradation of optical performance, which can be quantified by return loss (RL) and attenuation (A), functional failures and increased deployment costs. Fibre optic connector endface cleaning is recognized as a necessity for optimal signal performance. It is known that contamination impacts signal performance by blocking the core and impeding light transmission, as well as by preventing direct physical contact creating an air gap between the two connector enfaces [1, 2][1]. If an air gap exists, optical performance will be impacted due to the change in transmission medium. As contaminated connectors are mated and demated, contamination can be redistributed around the connectors' endface and block the fibre core. This presents a risk of signal performance degradation during the service life.

Since 2002, the iNEMI (International Electronics Manufacturing Initiative) working group has done substantial work, both theoretical and experimental, on impact of scratches and contamination on connector optical performance (A and RL). The following connector types have been used for this research: single-mode (SM) physical contact (PC) connectors, SM angle polished connectors (APC) and SM APC MPO connector. The impact of polishing scratches has been investigated for SM and multimode (MM) connectors. The work presented in this technical report was used as a base work for the development of IPC-8497-1 [3] and IEC 61300-3-35 [4].

1 Figures in square brackets refer to the Bibliography.

FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS –

Part 05: Investigation on impact of contamination and scratches on optical performance of single-mode (SM) and multimode (MM) connectors

1 Scope

This part of IEC 62627, which is a technical report, summarizes the extensive industry research on development of cleanliness specifications for single-mode (SM) and multimode (MM) connectors.

The summary of the result shows Table 1.

Table 1 – Summary of the result

Samples		Scratch/Contamination/Defect	A/RL	Clause	Reference
SM/MM	Single-fibre/ multi-fibre				
SM PC	Single-fibre	Scratch	RL	3	[1], [5], [6]
MM PC	Single-fibre	Scratch	RL	4	[7]
SM PC	Single-fibre	Contamination	A and RL	5	[2], [6]. [8]
SM APC	Single-fibre	Contamination	A	7	[11]
SM APC	Single-fibre	Scratch	RL	7.2	[11]
SM APC	Multi-fibre	Contamination	A and RL	8	[12]

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61300-3-6, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-6: Examinations and measurements – Return loss*

IEC 61755-3-1, *Fibre optic connector optical interfaces – Part 3-1: Optical interface, 2,5 mm and 1,25 mm diameter cylindrical full zirconia PC ferrule, single mode fibre*

3 Abbreviations

A	attenuation
APC connector	angle polished connector
DUT	device under the test
GWPOA	gaussian weighted per cent occluded area
MFD	mode field diameter
MM connector	multimode connector

OTDR	optical time-domain reflectometer
OCWR	optical continuous-wave reflectometry
PC	physical contact
RL	return loss
SM connector	single-mode connector

4 Experimental methodology

In order to collect the data required to enable correlation between changes in optical performance (A and RL) with fibre optic images of the corresponding connectors, the experiment followed a multi-step process that involved

a) initially inspecting, cleaning and imaging connectors being tested (DUTs) and reference connectors; making multiple matings and dematings of each DUT with a reference connector, and recording A and RL data after each cycle,

b) manually applying dust to the cleaned endfaces of the DUTs, then

c) mating contaminated DUTs with clean reference connectors at least five times, taking A and RL measurements after each mating and saving fibre endface images for both connectors. The block diagram of the experiment is shown in Figure 1.

All DUTs and reference connectors were initially inspected and cleaned using a cleaning cassette. Endface images were saved using fibrescope and image analysis software. This software was used to accurately measure the number of particles, their size and their location at the connector endfaces. More than 80 cables with SC simplex connectors (the DUTs) were used for the experiment. A small group of DUTs (five cables) with FC connectors, ten DUTs with LC connectors, and five DUTs with MU connectors were added.

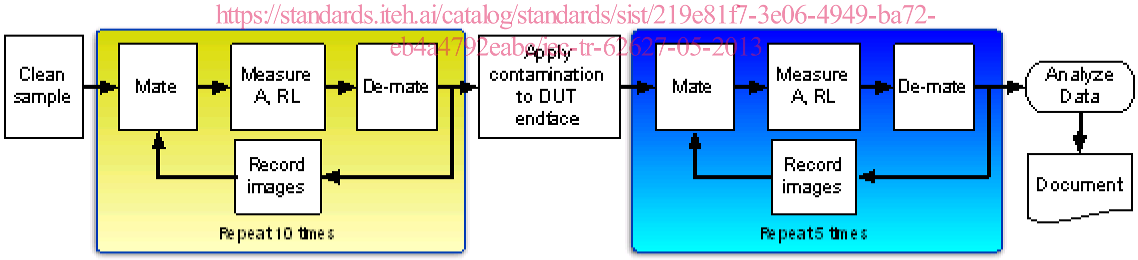


Figure 1 – Block diagram of design of experiment

After clean measurements and images were recorded, Airzona test dust was manually applied to the cleaned endface of the DUT. The two grades of Airzona test dust used for the experiment were ultra-fine (1-5 μm) and fine (6-25 μm). The contaminated DUT was mated with a clean reference connector. A and RL data were recorded. Each DUT and reference connector pair was mated and demated five times. After each mating, A and RL measurements were taken. After demating, the images of the DUT and reference connector endfaces were saved.

If the change in A or RL exceeded three times the standard deviation of A or RL for clean connector, the connector was judged a failure due to contamination. The pass criteria were achieved when both delta A and delta RL were within three standard deviations of A and RL.

The experimental methodology for SM APC connectors and for SM, APC MPO connectors was also based on design of the experiment shown in Figure 1. The details of the experimental procedure for these connector types are described in Clauses 8 and 9. The details of the experimental methodology for MM connectors are provided in Clause 6.

5 The impact of scratches on A and RL of single-mode connectors

A quantitative description of surface defects such as scratches and digs on optical performance was developed based on theory of surface scattering [5]. Further development led to a complete model for analysis of scratches impact on RL performance [6]. The model was based on the Gaussian distribution of incident power and included the effects from scratch location, size and number of the scratches. Based on the model it was predicted that the scratches through the fibre core cause some severe degradation, the scratches outside but near the core have some impact on RL, while scratches beyond 25 µm diameter centre area show little impact on RL performance [6]. These predictions were supported by experimental data [1]. To properly characterize the impact of scratches on performance parameters of mated optical connectors, first the optical performance parameters of pristine optical connectors were measured. Then, after applying scratches at different locations on the fibre endface, the optical performance parameters were measured again.

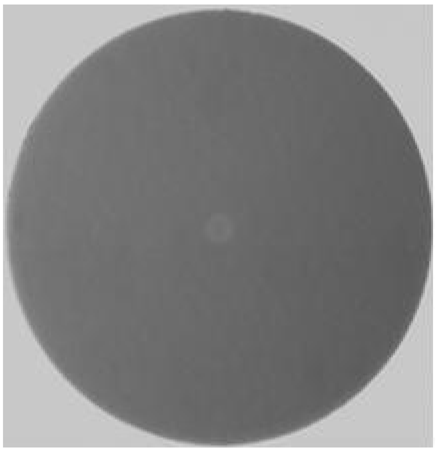
A sample set of 24 optical cable assemblies and launch cables were polished to PC performance using standard polishing process. The samples were divided into two groups. Scratches were induced only within the cladding region of the first group of connector endfaces, while for second group of optical cable assemblies the scratches were applied to the fibre mode field diameter (MFD).

The results of this study indicated that

a) polishing scratches and scratches made during connector cleaning, outside the fibre MFD, have no impact on A and RL of the mated optical connectors,

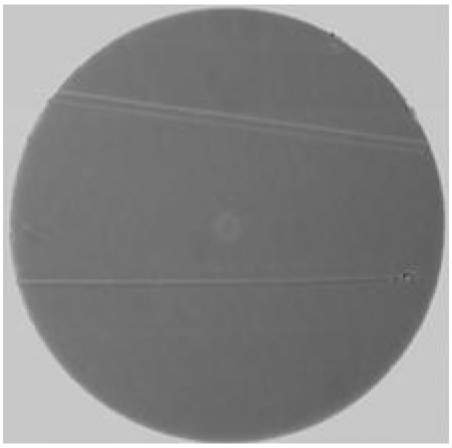
b) scratches 2 µm wide or less within the mode field diameter have no impact on A; the A change observed is within the measurement uncertainty of the test equipment,

c) scratches, within the fibre MFD, can degrade the RL of the mated connectors. The level of degradation depends on the size (width and depth), and the number of scratches crossing the fibre MFD. Figure 2 and Figure 3 provide the images of the connector endface with the scratches outside the MFD area and scratches through the fibre core correspondingly.



Key A = 0,14 dB; RL = 54,7 dB

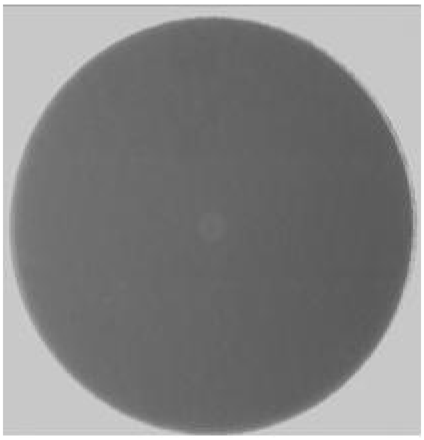
Figure 2a – Pristine connector



Key A = 0,11 dB; RL = 54,8 dB

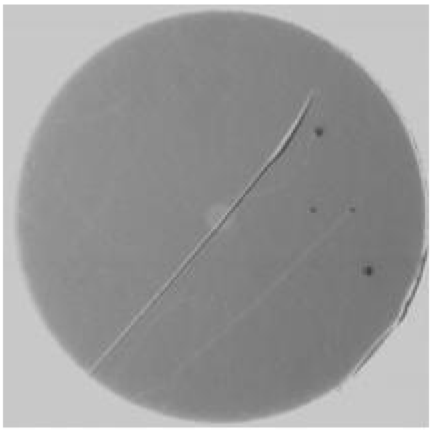
Figure 2b – Scratched connector

Figure 2 – Connector endface with the scratches outside the MFD area



Key A = 0,10 dB: RL = 52,7 dB

Figure 3a – Pristine connector



Key A = 0,10 dB; RL = 40,7 dB

Figure 3b – Scratched connector

Figure 3 – Connector endface with scratches passing through the core

6 Effects of scratches on RL of MM connectors

The effects of scratches on return loss of 50 µm core diameter MM connectors have been experimentally investigated. The results were presented at IEC SC86B, WG4 and WG6 meetings, Charlotte, in 2005. All samples had initial endface geometry according to IEC 61755-3-1. The samples were polished using 3 µm polishing paper. The RL measurements have been performed per IEC 61300-3-6 (Method 1, OCWR or Method 2, OTDR) at λ = 1 300 nm. The connector endface was characterized using a confocal microscope as shown in Figure 4. The data for scratch width, depth, and length were analysed and found to correlate with connector RL performance.

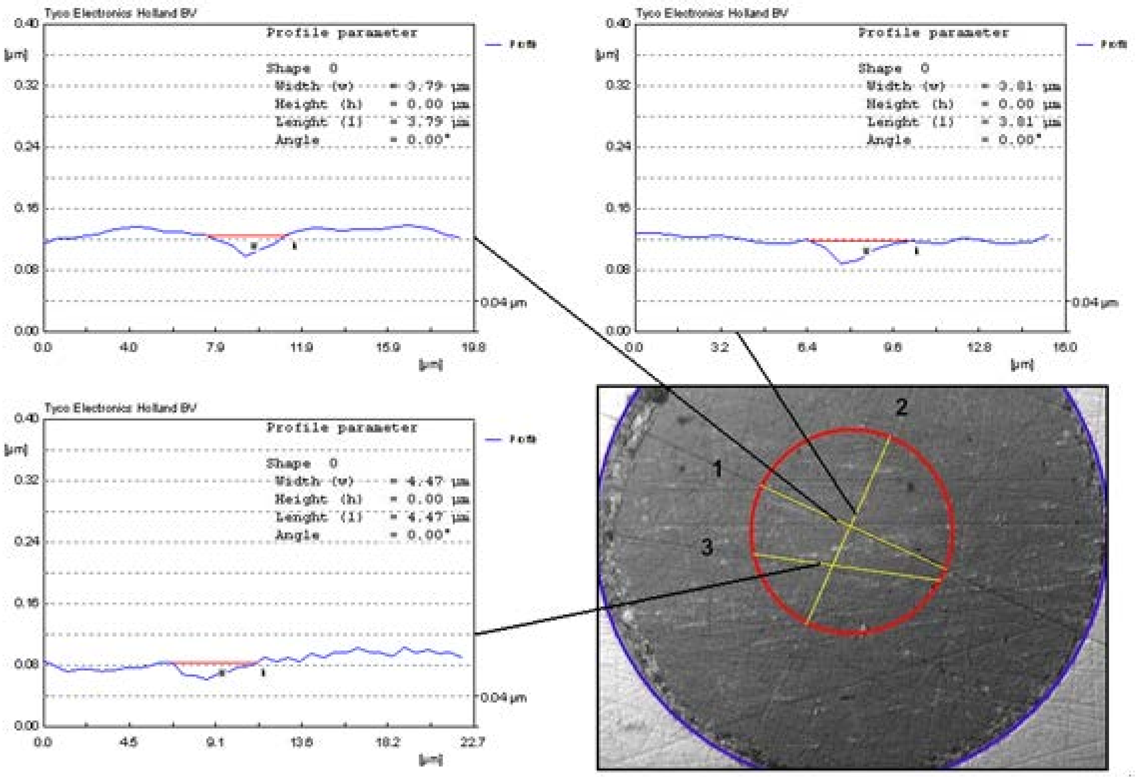


Figure 4 – Examples of characterized endfaces using confocal microscope [7]