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TECHNICAL REPORT

colour inside

Fibre optic interconnecting devices and passive components – Part 03-03: Reliability – Report on high-power reliability for metal-doped optical fibre plug-style optical attenuators

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FOREWORD

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 62627-03-03, 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/3458/DTR	86B/3506/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 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- withdrawn,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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Since 2000, the optical power in transmission systems has increased in conjunction with the increase in the number of channels for DWDM systems, with the help of deployment of RAMAN amplifiers and application of optical amplifiers. It is pointed out, however, that the transmission media of the optical transmission system such as the optical fibre, optical connector and optical passive components may sometimes be hazardous because of possible leakage of high-power light that results in personal injury, melting, or a damage possibly causing a fire.

IEC Japan National Committee (JPNC) and Optoelectronics Industry and Technology Development Association (OITDA) carried out the research on the high-power reliability and safety of optical passive components. The result was summarized in the OITDA Technical paper, TP04/SP-PD-2008 "Study on the High-Power Reliability of Optical Passive Parts for Communications." IEC/TR 62627-03-02 was published based on the above report. According to that report, deterioration of optical passive components at high-power input is caused by temperature rise due to absorption of light as well as consequential thermal distortion. It was decided to undertake additional research whilst utilizing these findings, specifically on the plug style optical attenuator, whose resistance against high-power is relatively small. The study result was summarized in OITDA TP, TP09/SP-PD-2010.

This technical report was prepared on the basis of OITDA TP, TP09/SP-PD-2010,"*Technical paper of investigation of high-power reliability for plug-style fixed optical attenuators*".

FIBRE OPTIC INTERCONECTING DEVICES AND PASSIVE COMPONENTS –

Part 03-03: Reliability – Report on high-power reliability for metal-doped optical fibre plug-style optical attenuators

1 Scope

IEC/TR 62627-03-03, which is a technical report, describes the investigation results of high-power reliability for metal-doped optical fibre plug-style attenuators.

This report contains the high-power test results for metal-doped optical fibre SC plug-style optical attenuators, the thermal simulation results and the analysis of degradation modes, long-term reliability test results under high-power conditions and the derivation of maximum limit of optical power for guaranteeing long-term operation.

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/TR 62627-03-02, *Fibre optic interconnecting devices and passive components – Part 03-02: Reliability – Report of high-power transmission test of specified passive optical components*

3 Outline of high-power test for optical attenuators in IEC/TR 62627-03-02

The test was carried out by inputting the high-power light into the SC plug style metal-doped fibre optical attenuators with an attenuation of 10 dB, 20 dB and 30 dB. The test ambient temperature was set at the assumed normal maximum operating temperature of 70 °C and the test method was the step stress test. The test result indicated failures in all the samples, i.e. the return loss decreased by 10 dB or more at 1,4 W to 2,3 W. Variation of the attenuation and the return loss before and after the test was within the range of measurement uncertainty. When the fibre end surface was checked after th test, it indicated either protrusion or withdrawal of the optical fibre.

On the other hand, thermal simulation was carried out and the result was that the maximum internal temperature reached 300 °C or more at the input power of 2 W for SC plug style metal-doped fibre optical attenuator of 10 dB attenuation.

In addition, the long-term reliability test of the optical attenuator was carried out for 500 h. The test conditions were 1 W for the input power and 70 °C for the ambient temperature. As a result of the test, it was found that the return loss did not decrease during the test, but withdrawal or protrusion of the optical fibre was found after the test.

Based on the result of the above tests, it was estimated that the mechanism of return loss decline consists of the softening of adhesive fixing the metal-doped optical fibre and ferrule, which in turn causes withdrawal of optical fibre and finally results in loss of physical contact (PC) between the fibre endfaces. Therefore, for the purpose of guaranteeing long-term reliability with high power, it is necessary to control the internal maximum temperature within the range in which the adhesive does not exceed the glass transition temperature. Thermal simulation results lead to the assumption that the input power of 500 mW is the limit at the ambient temperature of 50 °C for SC plug style optical metal-doped fibre optical attenuator of 10 dB attenuation.

After studying IEC/TR 62627-03-02, problems were found on the high power reliability for plug-style attenuators in the following areas:

– accuracy of internal temperature estimated by the thermal simulation;
– consideration of the variation of ferrule endface geometries for attenuators and optical connector plugs which affect the condition of PC (physical contact) detaching;
– identification of the mechanism of optical fibre withdrawal;
– confirmation of long-term reliability that considers temperature and humidity conditions.

4 Accuracy of the internal temperature estimated by the thermal simulation

In 2002, Yanagi et al. measured increasing temperature at high-power input for the MU plug-style optical attenuator [1][1]. Yamaguchi et al. used a similar test set-up when testing the SC plug style optical attenuator [2]. Figure 1 shows the test set-up of Yamaguchi et al. while Figure 2 shows their test results. Test samples were SC plug style optical attenuators without housing. The resistance temperature detector (RTD) was attached on the outer surface of the split sleeve to monitor the temperature. The ambient temperature was 23 °C. The test was carried out for the attenuation of 1 dB, 3 dB, 5 dB, 10 dB, 15 dB and 20 dB, respectively. Figure 2 shows the test result at the attenuation of 5 dB, 10 dB, 15 dB and 20 dB. It appeared that the temperature rose approximately linearly to the input power of 500 mW at maximum, then its rate of rise decreased. The temperature at the input power of 500 mW for 10 dB attenuator was 75 °C and the temperature rise from the ambient temperature of 23 °C was 52 °C.

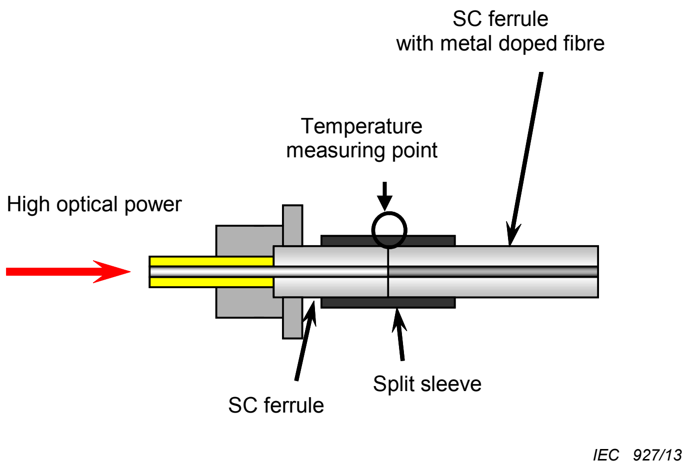

Figure 1 – Split-sleeve surface temperature measurement system on high-power input condition for the SC plug style attenuators by Yamaguchi et al.

1 Numbers in square brackets refer to the Bibliography.

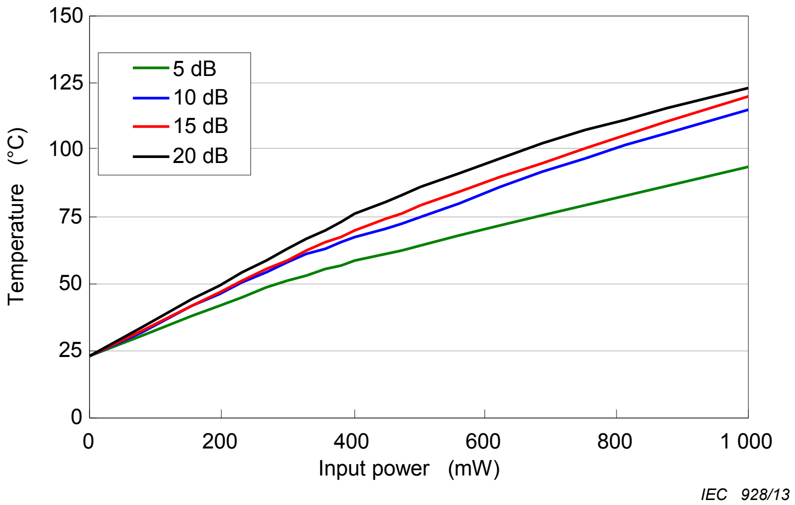

Figure 2 – Split sleeve out-surface temperature measurement results on high-power input condition for the SC plug style attenuators by Yamaguchi et al.

On the other hand, IEC/TR 62627-03-02 describes the thermal simulation results of the maximum internal temperature for SC plug style attenuators with and without housing. The thermal simulation of outer surface temperature of the split sleeve for SC plug-style optical attenuators without housing was calculated with the same method as that used in IEC/TR 62627-03-02. The simulation results are shown in Figure 3. For the SC plug style attenuator of 10 dB attenuation, the relation between the temperature rise ΔT (°C) and the input power P (mW) can be explained in the following equation:

$$\Delta T = 0{,}1169 \times P \tag{1}$$

As reported in IEC/TR 62627-03-02, the ambient temperature dependency of temperature rise was small. For SC plug style 10 dB attenuators, the temperature rise on the condition of input power of 1 000 mW could be calculated as 129,1 °C and 128,3 °C for the ambient temperature of 25 °C and 70 °C, respectively.

The test results of Yamaguchi et al. indicated that the input power of 500 mW optical powers into the 10 dB SC plug style attenuators made a temperature rise of 52 °C. According to the results of thermal simulation shown in Figure 3, the temperature rise is calculated as 0,116 9 × 500 = 58 °C. Accordingly, this thermal simulation could reproduce the demonstration results by Yamaguchi et al. under the condition of an input power of 500 mW or less. In Figure 2, the temperature rise rate tends to decrease at the input power of 500 mW or more. This is seemingly due to thermal conductivity between the RTD, split sleeve and the outside air. Note that the internal temperature rise of SC plug style attenuator with the attenuation of 10 dB is calculated by 0,133 7 × (input power (mW)).