WHITE PAPER

THE IMPACT OF WATER ON FIBRE OPTIC CABLE

Fibre optic cables are frequently installed in non-watertight piping and cable ducts. The fibres need to be effectively protected from humidity and wet in order to ensure the operational reliability of the cables. This White Paper describes the impact of water on cables and fibres, gives an overview of current standards and test methods, and pinpoints the aspects to be borne in mind when selecting suitable fibre optic cables.

The state of the art relating to standard single-mode fibres

For years most fibre and cable manufacturers have been producing their single-mode cables using fibre quality OS2, G.652.D or EN 60793-2-50:2008, B1.3. The fact that there are several standards for single-mode fibres is due to the international standardisation bodies involved. The ITU is the International Telecommunication Union, a specialised agency of the United Nations, which among other things specifies standards for global telecommunications. The IEC (International Electrotechnical Commission) and its European counterpart CENELEC (Comité Européen de Normalisation Électrotechnique) draw up standards for private applications.

Standard G.652 was drawn up by the ITU. IEC/CENELEC incorporated these types of fibre as “OS1” and “OS2” in the standards for application-neutral, generic cabling, ISO/IEC 11801 and DIN EN 51073 – the attenuation values here being higher than in IEC and CENELEC (60793-2-50) documents referred to in this standard. The parameters of IEC 60793-2-50 are similar to those of standard ITU G.652.D.

	ITU-T G.652.A	ITU-T G.652.B	ITU-T G.652.C	ITU-T G.652.D	Datwyler G.652.D
attenuation 1310 nm	≤ 0.5 dB/km	≤ 0.4 dB/km	≤ 0.4 dB/km	≤ 0.4 dB/km	typ. 0.34 dB/km
					max. 0.36 dB/km
attenuation 1383 nm			≤ 0.4 dB/km[1]	≤ 0.4 dB/km[1]	typ. 0.34 dB/km[1]
					max. 0.36 dB/km[1]
attenuation 1550 nm	≤ 0.4dB/km	≤ 0.35 dB/km	≤ 0.3 dB/km	≤ 0.3 dB/km	typ. 0.22 dB/km
					max. 0.24 dB/km
attenuation 1625 nm		≤ 0.4 dB/km	≤ 0.4 dB/km	≤ 0.4 dB/km	typ. 0.24 dB/km
					max. 0.25 dB/km
PMD	≤ 0.5 ps/√km	≤ 0.2 ps/√km	≤ 0.5 ps/√km	≤ 0.2 ps/√km	typ. 0.05 ps/√km
					max.0,2 ps/√km

[1] attenuation after hydrogen ageing test

Table 1: Comparison of minimum SM fibre attenuation values according to ITU-T G652 (for wide area and city networks).

Extreme case: this cable duct is completely under water.

Fibres with a reduced attenuation peak

It is common knowledge that OH ions are responsible for attenuation increases in optical fibres – with a absorption peak at 1383 nm. With the first single-mode fibres (G.652.A and -B) this attenuation peak was the reason why the wavelength range around 1383 nm could not be used for transmission.

For a decade now single-mode (SM) fibres have only been produced in G.652.D quality. In EN 50173-1 both SM fibres, OS1 and OS2, are described as fibres conforming to EN 60793-2-50:2008, fibre B1.3 or B.6_a. This means that both OS1 and OS2 fibres have a reduced attenuation peak at 1383 nm. They are often referred to as “low water peak” or “zero water peak” fibres.

According to EN 50173-1 the only difference between the two fibre types OS1 and OS2 is their maximum attenuation at wavelengths 1310, 1383 and 1550 nm. For fibre type OS1 the maximum attenuation is 1.0 dB/km, and for the OS2 fibre it is 0.4 dB/km (for all the wavelengths mentioned).

Wavelength	maximum attenuation OS1	maximum attenuation OS2
1310 nm	1.0 dB/km	0.4 dB/km
1383 nm	1.0 dB/km	0.4 dB/km
1550 nm	1.0 dB/km	0.4 dB/km

Table 2: Performance requirements for SM fibres in accordance with DIN EN 50173-1:2011, Tables 55-56 (for application-neutral building cabling).

Standards for water impact

There are two standards dealing with the impact of water on optical fibres. IEC 60793-1-50 covers the measurement method and the "damp heat" test procedure. IEC 60793-1-53 covers "immersion in water". In the first test the fibres are exposed to the action of damp heat (+85°C, 85% relative atmospheric humidity). In the second they are immersed in temperature-controlled water (+23°C). Both tests last for 30 days, during which period a defined attenuation increase must not be exceeded in either. The repellent effect of the primary protection – i.e. the efficacy of the fibre coating against exposure to water – is also tested.

Fibres at risk

If a fibre optic (FO) cable is damaged or stored without end caps, it is important that water should not be able to "creep" through the cable without restriction. Water penetration into a FO cable is not inherently dramatic because the bundles, which consist mostly of polyethylene (PE), are themselves very watertight and because the filled bundles, together with the primary protection and the fibre sheath, afford the fibre core a high degree of protection. The transmission characteristics of an optical fibre are therefore relatively well safeguarded.

If, however, the water is able to spread to a closure or splice box, at this point the fibres only have their primary protection as well as splicing protection. Damage to the fibres cannot be ruled out, particularly if the fibre coating is not of the quality stipulated by the standards mentioned above. An irreversible increase in attenuation takes place if water diffuses into the fibre optic material (Si_2O). Water molecules also move into microcracks in the fibres, enlarging them and dramatically reducing fibre life.

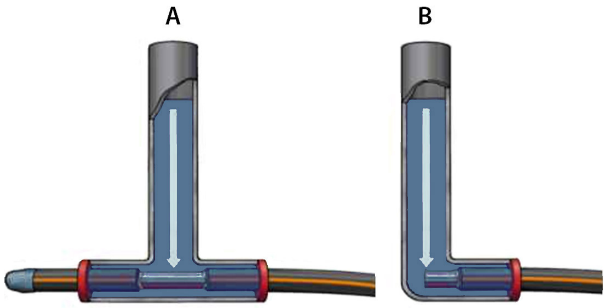
Longitudinal watertightness

In view of the possible impact which moisture can have on the fibres it is hardly surprising that longitudinal watertightness is one of the most important environmental parameters for FO cables. In accordance with IEC 60794-1-2 F5 a cable is considered to be longitudinally watertight if penetrating water is only able to spread along a defined length in the cable core.

Years ago, in order to protect cables from water "creep" caused by capillary action, or at least keep it to the bare minimum, the stranding gaps in stranded cable assemblies were packed with petroleum jelly, a Vaseline-like gel. This solution has two drawbacks, however: the filling is highly flammable and the installer has to remove this gel from the bundles again, a very time-consuming process requiring special detergents which then have to be disposed of as hazardous waste.

Innovative cable manufacturers like Datwyler have therefore developed a different method of meeting the requirement for longitudinal watertightness. Nowadays manufacturers fill the stranding gaps and strain relief elements – glass or aramid yarn – with swellable materials. If the cable is damaged, these materials absorb any water which has penetrated and seal the site of the damage. Unlike a petroleum jelly filling, swellable materials do not contribute to fire propagation. Last but not least, there is no need to clean the bundles when processing the cables.

Datwyler tests the longitudinal watertightness of its FO Outdoor and FO Universal cables to standard IEC 60794-1-2-F5 using Method B, which simulates more stringent conditions. Whereas Method A describes the penetration of water into a damaged cable, Method B examines the behaviour of the cable when water is able to penetrate into an open end not sealed by a shrink end cap. The key test criterion specified by Datwyler is that the spread of water in the cable should not exceed three metres within 24 hours.



Test for longitudinal watertightness in accordance with IEC 60794-1-2-F5, Method A and B.

No standard for "lateral watertightness"

Contract specifications often require fibre optic cables to be laterally as well as longitudinally watertight. As yet, however, the "lateral watertightness" parameter, which refers to the penetration of water or moisture into intact cables, does not feature in any standard, and there is consequently no relevant test method.

The reason for this is that there is a very low probability of water or moisture penetrating the entire cable assembly – i.e. cable sheath, absorbent materials, PE bundles, bundle gel filling, primary protection and fibre sheath. In addition, the penetration of water through different media is always a very lengthy diffusion process. The cable would have to be tested by exposing it to the action of surrounding water for years under defined conditions in order to obtain any meaningful results.

The only exception is test method F10 for underwater cable, which simulates the conditions affecting a cable on the sea floor. This method is totally unrelated to conditions in cable duct systems, however, as the water pressure is very different.

Universal cable for underground installation?
Outdoor cables with a HDPE (high-density polyethylene) sheath are very suitable for direct burying – i.e. for damp environments. This sheath material is highly impermeable, and typical water diffusion from the soil through the sheath is therefore minimal.

Universal cable sheaths, on the other hand, are made from polyethylene containing mineral additives. PE is highly combustible, but is halogen-free and does not release any toxic (corrosive) substances in the event of fire. The additives improve the fire behaviour of universal cables by enhancing the flame retardant, low-smoke and self-extinguishing characteristics of the sheath material. The FRNC/LS0H sheath (Flame Retardant, Non Corrosive, Low Smoke, Zero Halogen) is based on the fact that universal cables were developed chiefly with a view to their use inside buildings.

The additives in the sheath material also increase water diffusion in a universal cable, although penetration as far as the fibre core is unlikely due to the structure of the cable, particularly because of the swellable elements in the cable. And if the water does diffuse as far as the primary coating it still has to penetrate the primary fibre protection, the efficacy of which is demonstrated by the hydrogen ageing test following fibre manufacture. Long-term damage to the fibres cannot, however, be ruled out. Datwyler has therefore decided to omit the wording "suitable or direct burying" in its FO-U (Fibre Optic Universal) cable data sheets.

Of course you can install a universal cable in dry ground. But who can guarantee that the moisture level will not rise – and with it the diffusion of water in the cable?

Installation in cable duct systems
For safety's sake a universal cable should never be installed in any situation where there might be a risk of water ingress into a duct or pipeline and hence of long-term exposure to water: an outdoor cable with an HDPE sheath should be used instead. Water ingress can occur rapidly.

In some countries where many conduits are made from precast concrete components – mainly Switzerland but also occasionally Denmark, Finland, Great Britain and Italy – water ingress may be accompanied by high pH values. HDPE sheaths function as effective "barriers" here, even against high pH values. Datwyler's FO-O (Fibre Optic Outdoor) cables are longitudinally watertight and "virtually laterally watertight", as their combination of HDPE sheath, swellable elements and gel-filled strands offer the best protection against exposure to water.

FO Outdoor cables with an additional corrugated or aluminium-coated sheath are completely resistant to external water because they are hermetically sealed. Here again any possible negative effect from moisture inside the cable is ruled out by the swellable materials and gel-filled strands. However the installer must make provision for earthing when laying metal sheathed cables. They also take rather more effort to strip than cables without a metallic sheath.

Datwyler's FO Outdoor cables are "virtually laterally watertight" due to the combination of HDPE sheath, swellable elements and gel-filled strands.

Tested for ease of outdoor installation
Following on from the question of whether universal cables are suitable for burying and installing in cable duct systems, it should be noted that of course all Datwyler FO-U cables have passed the suitability test for outdoor installation. This test simulates accelerated weathering and reproduces damage which can be caused by sunlight, rain and dew. During testing the materials are exposed to alternating cycles of UV light and moisture at controlled high temperatures. The action of sunlight is simulated by special UV fluorescent lamps, the impact of dew and rain by condensing moisture and/or water spray. Within a few days or weeks the test thus reproduces damage which would take months or years to develop in the open air.

Conclusion
Datwyler's Fibre Optic Universal (FO-U) cables are suitable for indoor and outdoor installation. For safety reasons, however, Datwyler recommends that universal cables should not be buried directly in the ground or routed in ducts or pipelines – except for dry cable duct systems. It is preferable to use Datwyler's longitudinally watertight and "virtually laterally watertight" FO Outdoor cables (FO-O) in cable duct systems at risk of water penetration or in which there is permanent standing water.

