

## BLOWN FIBRE EXPERIENCE IN THE LOCAL LOOP

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### ABSTRACT

British Telecom is embarking on an installation programme to directly "fibre" its major business customers. In the years ahead this will be extended to serve smaller business customers with the ultimate aim of an "all fibre" network encompassing the residential market also.

In support of this activity Blown Fibre has been introduced as a radically new way of installing optical fibres into the local loop.

Blown Fibre as the name suggests is a technique for installing optical fibre by "blowing" using compressed air into a pre-installed network of small bore tubing.

A brief review of single-mode fibre performance and effects of the cabling process will be followed by a description of blown fibre.

### INTRODUCTION

As the benefits of the rapid advances in technology, in particular optical transmission, are pushed closer to the customer it is of particular importance that great attention is given to the optical-fibre infrastructure necessary to support not only current but future transmission systems.

The local loop, more familiarly being termed the access network, poses particular operational problems as opposed to the long distance trunk network.

Currently within British Telecom, as elsewhere, the local loop is predominantly copper, having been deliberately planned and constructed, over a period of 100 years, in a piecemeal fashion. That is, rate of growth has been determined by economic planning rules.

The net result is a physical network in a constant state of evolution and growth. A

sad consequence of this activity is the poor performance perceived by the customer as a result of all this "working party activity".

Hence a major feature of an access network optical fibre infrastructure must be that it is enduring both in terms of current required optical performance and perceived future needs.

Clearly the wholesale replacement of a fibre network to take advantage of new technology is neither desirable nor economic.

### FIBRE PERFORMANCE

Current silica-based optical fibres can be made with losses approaching intrinsic limits over a wide wavelength range.

Fig 1 shows the spectral attenuation of a typical single mode optical fibre.

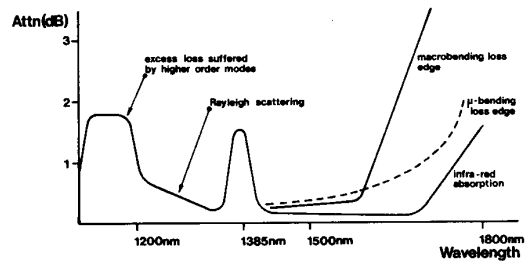


Fig.1 Spectral Attenuation of a typical single mode optical fibre.

Two major mechanisms are apparent:-

- Rayleigh Scattering (from fluctuations in the material smaller than the wavelength under consideration) leads to a loss edge at low wavelength.

- Infra-red absorption from bonds in the silica leads to a loss edge at high wavelength.

Between the two edges peaks due to residual water (OH ions) in the silica are the major

## 10.1.1.

non-intrinsic loss contributor. The result of these mechanisms is to leave two major low loss 'windows' centred around 1300nm and 1550nm wavelengths. Typical production losses at these wavelengths would be 0.3dB/km and 0.2dB/km respectively, with useful windows of 1275nm to 1325nm and 1475nm to 1575nm.

The majority of systems currently operate in the 1300 nm window Region where relatively low cost lasers are readily available. It is clear however that the availability of low cost narrow linewidth lasers (eg DFB lasers) operating in the 1550 nm window make wavelength division multiplexing an increasingly attractive proposition. This being the case the importance of preserving optical performance, from manufacture, through cabling to installation in the ground, is a major consideration.

#### OPTICAL FIBRE CABLE

The structure of the optical fibre cable is designed to protect the fibres from tensile and radial stresses, provide adequate bend performance during and after installation and give environmental protection to the fibres over their design lifetime.

The major factors affecting the optical performance once the cable has been laid are:-

- macrobending and microbending loss.
- stress corrosion.
- hydrogen absorption loss.

These are generated in service due to interaction of fibre stress with moisture and other contaminants, cable materials and environmental temperature variations.

#### MACROBENDING AND MICROBENDING LOSS

These are two distinct loss mechanisms affecting fibre performance in cables. In both cases the optical signal couples out of the fibre resulting in a transmission loss. Macrobending loss occurs when a fibre is progressively bent in a pure bend configuration. Microbending loss occurs when small periodic perturbations are introduced into the fibre. Both loss modes can be generated at any stage during cable manufacture, the cable installation process, or during service due to environmental effects.

#### HYDROGEN ABSORPTION LOSS

The effect of hydrogen on optical fibres has

been known to cable designers for some time. The presence of hydrogen is known to cause excessive optical loss. The source of this hydrogen is believed to be generated from certain fibre coatings and from electrolytic action of the metallic parts of the cable in the presence of moisture.

In practice this effect is small for single mode fibre.

#### STRESS CORROSION

Stress corrosion is a mechanism whereby molecular bonds at a fibre surface flaw, under the action of stress and moisture, will grow and eventually fail, leading to fibre failure.

The aforementioned loss or failure modes are by no means all that the cable designer and manufacturer have to take into account. They should however give an indication of the complexity of cable design and therefore cost.

#### BLOWN FIBRE

In 1983, a paper was presented at the 32nd International Wire and Cable Symposium describing a technique called blown fibre. At that time it was very much an R&D project at British Telecoms Research establishment, Martlesham. This technique is now currently in use in British Telecoms access network.

The principle of blown fibre is that a composite unit of optical fibre is installed into a small bore tube by the viscous flow of air.

The essential components of the system are three fold - microduct, fibre unit and blowing head.

#### MICRODUCT

The microduct is a small diameter tube, currently 6 mm bore, extruded from low-density polyethylene specially doped to provide a low-friction static-free bore. Several of the tubes are bundled together (current sizes 2, 4, 7) and given an overall sheath of polyethylene for use externally or PVC for use when fibre resistance is required, as in buildings. The sheath incorporates an aluminum foil, not as a moisture barrier but to facilitate stripping of the sheath from the microduct bundle, and as in the case of conventional optical fibre cable to act as a heat-sink when shrinkdown closures are used.

## 10.1.2.

Tube bundles are pulled into ducts using conventional cabling techniques, but of course are far easier to handle and manipulate than cable. The individual micro-duct tubes are joined together very simply with readily available push-on fittings, to provide a continuous leak-free path. Individual tubes can be extracted from the bundle as required to provide a customer feed.

#### FIBRE UNIT

The second component is the fibre unit. Various unit sizes are being developed the most widely used currently being of 4 fibres.

The four individually coloured and buffered fibres are held in a symmetrical unit, together with a ripcord to aid stripping, with a coating of foamed polyethylene.

The unit has an overall diameter of 2 mm and weighs 2 gm/m.

#### BLOWING HEAD

The final component is the blowing head which can best be described by reference to Fig 2. The fibre unit is fed into the

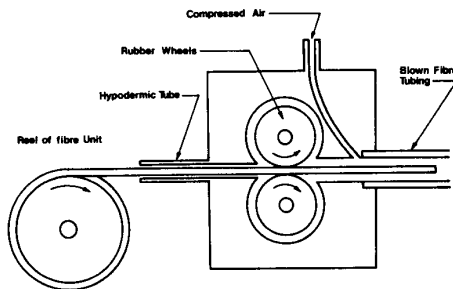


Fig.2 Blowing Head

blowing head via the hypodermic tube and is then taken up by the rubber drive wheels. The rubber wheels are driven under a constant torque just high enough to overcome the effect of the pressure drop along the air-sealing hypodermic tube, and to feed the fibre unit off the drum.

As the fibre unit enters the microduct tube it comes under the influence of the air-flow from the compressed-air source. The fibre unit is carried along by aerodynamic drag and hydrostatic forces distributed along the whole of its length as it travels through the microduct. Rates of 30 metres per minute are typical.

#### BLOWING DISTANCES

The maximum length that can be cabled with a single head is directly related to tube friction, tube and fibre unit diameter, system operating pressure and to a lesser extent the number of bends in the route. Theoretically derived relationships between these parameters supported by practical experiment led to a planning limit being imposed of 600 metres at a maximum pressure of 150 psi in the 6 mm bore tube. There are in fact many situations where 1000 metres is achievable (generally substantially straight runs) but applying a planning limit of 600 metres caters for all practical field environments.

#### ADVANTAGES

Perhaps the most novel feature of the blown fibre technique is the packaging of fibres into a rugged but extremely light bundle (2gm/metre) and then distributing the installation forces along its total length.

The resultant strain imposed on the fibres upon installation is negligible. The virtual elimination of fibre strain as a result of the installation technique obviates the requirement for a strength member (generally metallic) or the need to exclude moisture (usually achieved by metallic moisture barrier).

Removing the need for metallic elements eliminates the major contributor to hydrogen generation, hence significantly reducing any remaining concern over hydrogen absorption loss.

Design and careful selection of materials greatly reduces the effects of microbending and macrobending in the fibre unit.

A significant advantage of blown fibre is the ability to defer fibre provision. Whilst the inexpensive microduct tubing can be installed at an early stage the fibre itself need only be installed when required.

#### EXTENDING BLOW-LENGTHS

No sooner had the problems of consistent blowing over 600 metres been solved than techniques were investigated to extend the use of blown fibre in the access network. Currently three methods have been devised.

#### METHOD 1 - MID POINT BLOWING

Quite simply in this method the equipment is placed somewhere near the centre of the

route to be installed and the fibre unit is blown first in one direction and by inverting the fibre dispenser the remainder is blown in the other direction, giving a consistent end-to-end planning limit of 1200 metres.

In order to achieve this it is necessary to store the fibre torsionally in a pan, with one twist per turn built in. In this way fibre unit can be dispensed from both ends of the pan as necessary without rotation of the pan, the in-built torsion falling out during the dispensing process. This technique is used further in method III.

#### METHOD II - TANDEM BLOWING

This method is called "tandem blowing" and as the name suggests consists of inserting another blowing head some 600 metres along the route. With single head blowing the operator must observe and adjust the installation rate to ensure that the fibre unit is not forced into the microduct tube causing undesirable buckling.

The tandem blowing process has been automated to avoid the need for operator co-ordination. This is achieved by the use of a fibre-unit "buckle detector" either side of each blowing head. The "detector" incorporates an optical detector to sense the relative position of the fibre unit within the microduct tube and, as part of a feedback loop, controls the installation speed at each blowing position.

In theory, there is no limit to the number of blowing head that can be placed in series.

#### METHOD III - END LOOP FEEDING

The third method is by a technique called end loop feeding (ELF). It is based on single head installation and relies on the ability to rewind excess fibre at the end of a 600 metre blow and blow a further 600 metres distance, if necessary rewinding yet again for further blowing. The ELF machine contains a rotating arm device which loads constant diameter loops of fibre unit into toroidal pans. As the fibre unit is coiled in the pans torsion is stored in each loop whose notional centre is incremented eccentrically around the pan centre, creating a rosetted format. This enables fibre unit to be pulled from the stationary pan without tangles or lifted turns.

#### OPTICAL PERFORMANCE

Most of the trials of blown fibre were carried out in the city of Leeds. Initial trials were based on multimode fibre units but in 1986 British Telecom standardised on single mode fibre for its access network.

Measurements of optical performance were made on the fibre units before and after installation. The comparisons are shown in Figs 3 and 4 for a sample of seven fibres at 1300 nm and 1550 nm. The route length of fibres was 3.2 kms.

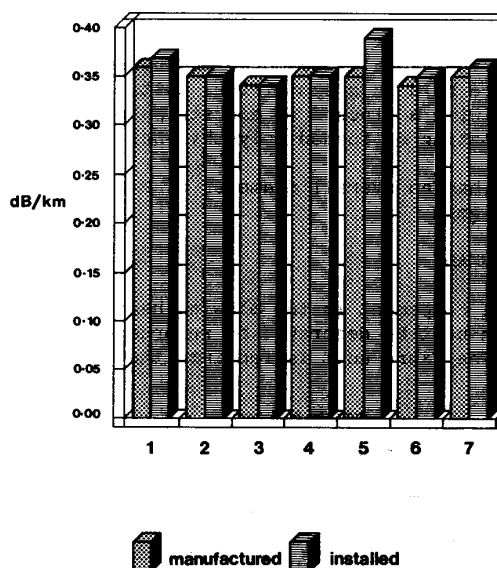


Fig.3 Fibre Performance at 1300 nm

It can be seen from these results that the blowing technique does not adversely affect fibre performance. These same routes were re-visited 9 months after the original installation and demonstrated no discernable increase in loss.

#### NETWORK VISION

It is clear that blown fibre as a technique, used in concert with other more conventional fibring methods, has a significant role to play.

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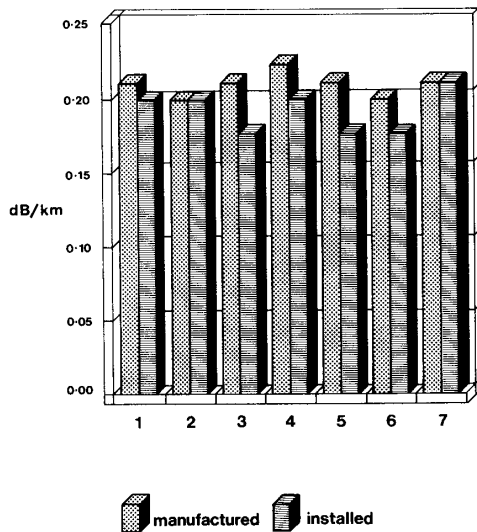


Fig.4 Fibre Performance at 1550 nm

Currently within British Telecom the access networks being planned consists of a number of different cable types ranging from 96 fibre external cable through the fibre count range to 4 fibre internal cable designs (or even blown fibre bundle). A typical route might involve four or more cables all requiring splicing activity. Regardless of the splicing technique employed, be it fusion, mechanical, elastomeric or connector the same degree of precise fibre preparation is required implying costly and time-consuming operations. It is likely that splicing losses will approach or exceed that of the fibre itself. In addition some splicing techniques will introduce reflection points into the network. These may prevent the use of the fibre for future bi-directional working or coherent transmission, both processes being sensitive to a level of back reflection. Clearly it is worth reducing the number of splices.

Given that the processes outlined for extended blow length could achieve the whole of the access route the vision of central office to customer links becomes a possibility.

A network could be constructed of blown fibre tubing interconnected using simple pressure connectors. It could extend from

the Central Office equipment room directly into the customers premises. This network can of course be planned and installed well in advance of requirement using the simplest cheapest components. Optical fibre provision is then installed, almost on demand, from Central Office to customer without intermediate splicing.

Not only has the optical performance of the fibre been preserved, but intermediate splicing degradations have been eliminated.

Whilst not having been studied in detail it is clear that the ability to defer fibre provision, coupled with cost savings associated with the elimination of splicing, splice housings etc, is an attractive economic package.

#### CONCLUSIONS

All networks, based upon optical fibre as the transmission medium, must comprehend future transmission performance requirements to avoid wholesale replacement of a significant investment.

The blown fibre technique has demonstrated how single mode optical fibre can be installed and its optical performance preserved. Within British Telecom blown fibre has been used to provide an optical network at Heathrow, is being installed in the City Fibre Network, and is planned for installation in the dockland development areas of London.

Further developments of blown fibre will be aimed at achieving the vision of spliceless networks.

#### ACKNOWLEDGEMENTS

The author wishes to thank the many colleagues who have contributed, many unknowingly, to this paper and to the General Manager Network Systems Engineering (Transmission) for permission to publish.

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