Cable Blowing Revolution
How it All Started and How we Benefit from it Now

Authors

Willem Griffioen[1], Michael van Moppes[2], Vitor Goncalves[1]
[1]Plumettaz SA, Bex, Switzerland, [2]HMS Machines BV, Gouda, The Netherlands.

Abstract

Long time ago, in 1986, the Netherlands PTT was facing major problems to install their optical cables for the backbone network into ducts. This was the trigger to develop the blowing technique for cables, inspired by the blown fiber technology for flexible and lightweight fiber members, developed by British Telecom in 1982. But, this was now done with recognition that fiber members do not need to be lightweight and flexible at all to benefit from air propelling forces. In fact a certain cable stiffness is needed, to make possible the synergy of pushing and blowing (often called jetting), amply doubling the installation length. The advantages are so clear that blowing has become the standard method for installation of optical cables into ducts. Improvement of cables, ducts and lubrication made the blowing length increase and the fiber count in a duct rise. The development of microduct cabling, relying heavily on blowing technology, has also been discussed, as well as some special applications.

History

Long time ago, in 1986, when the installation of optical cables into ducts for the backbone network began to take place on a large scale, the Netherlands PTT was faced with major problems. Cable lengths were 2.1 km and they had to be pulled in one length, to avoid splices (at that time still a big effort). But, pulling length was limited to less than 300 m, so bad even that for flawless installation assistance was needed every 175 m, see Fig. 1. Installation was done from the middle, over 1050 m split into 6 sections of 175 m, with a winch and 5 intermediate Figure-8 capstans, see Fig. 2. Then the remaining length from the drum was buffered into Figure-8 (also another buffering technique was used) prepared for installation in the other direction. Needless to say that this installation practice was complicated by sync issues. It often took a full day to install in one direction, leaving the remaining cable length on the drum overnight. And then sometimes the cable drum was gone the next morning (copper thieves were not yet aware that optical cables have no copper inside).

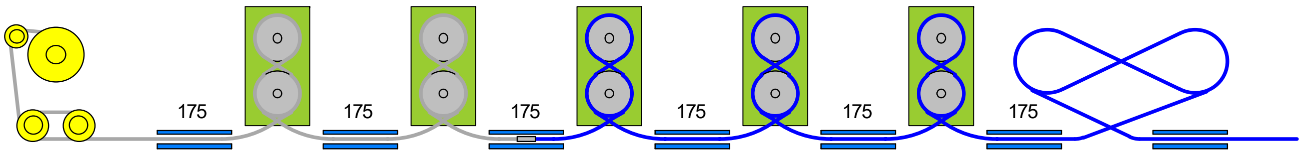

Fig. 1 Installation of optical cables into ducts in The Netherlands in 1986

Fig. 2 Figure-8 capstan

Fig. 3 Open trench with undulating ducts

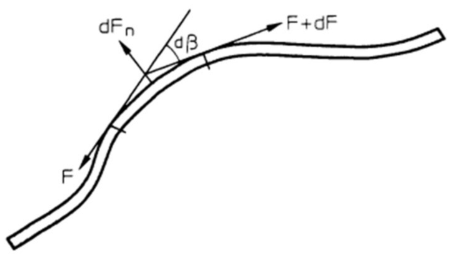

Fig. 4 Direction changes in undulations

Understanding why the cable could only be pulled over such short distances was lacking. Applying cable pulling theory, with gravitational friction on the straights and the capstan effect in bends, could by far not explain the limited pulling lengths. Suspect was the effect of cable stiffness in bends, for which no theory was found. So, the theory was developed at the Netherlands PTT. It turned out that indeed this stiffness effect contributed to the pulling force build-up, but it could still by far not explain the limited pulling lengths. Then it was recognized that straights were not fully straight, see Fig. 3. Undulations were clearly present, and they were severe because relatively small 32/26 mm ducts were used (in e.g. Germany, where 50/40 mm ducts were used, there were no such extreme pulling issues).

Like bends, these undulations contain direction changes, see Fig. 4, the true cause for the capstan effect. When also a theory was developed for undulations, present over the entire length, the limited pulling length could be quantitatively explained.

Knowing that the capstan effect in duct undulations was the cause of all problems, the blown fiber technique, developed in 1982 by British Telecom, was worth studying, because with blowing the capstan effect is mainly suppressed (pulling force build-up limited because propelling forces of the high-speed airflow locally compensate gravity friction). Problem was that blown fiber members had to be lightweight and flexible. But, now it was known that the effect of the cable stiffness was not as great as initially thought, and could also be quantified, it was found theoretically that blowing of real cables could also be an option. So, time to try it! This was done in a 4-loop test trajectory, previously used to evaluate functioning of Figure-8 capstans in tandem operation, see Fig. 5.

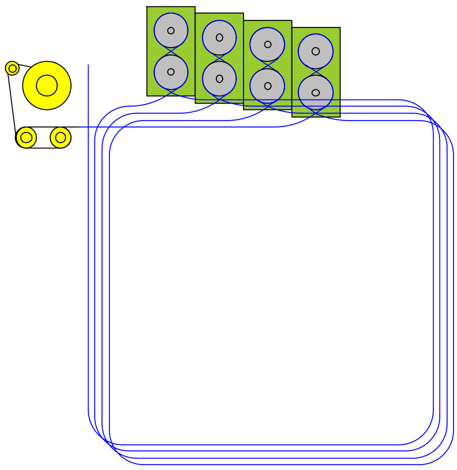

Fig. 5 Trajectory used to evaluate Figure-8 capstans

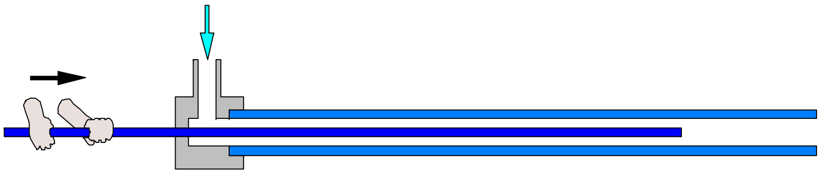

Fig. 6 Manual test to evaluate blowing of real cables

As no equipment yet existed to blow cables, the air coupling to install the winch line was used, the feeding hole increased to the size of the cable. To overcome the back-pressure force the cable had to be pushed in manually, see Fig. 6. This was hard work, done by 4 persons in turn. Some of them complained and did not believe in it, one said it was tried already without success (but that was with a pig at the foremost end of the cable and no feeding force). But, after reaching one loop, they became quiet, and when the second loop was completed they called it a miracle. It was not, because 2 loops (the double of pulling) was forecasted theoretically. As there were more loops the hard work was continued. Then loop 3 and finally the end of loop 4 was reached, 2 times as far as forecasted theoretically!

Thinking it all over, it was found that the air propelling forces are not constant over the length, but increase towards the end as a result of expansion of the compressible air. If then you push harder than needed for compensation of the back-pressure force, the excess pushing forces are working in synergy with the expanding airflow (this synergy of pushing and blowing is often called jetting). The pushing force extends far, because part is taken by the air propelling forces, the latter increasing further in the duct and finally taking over. The gain in length of a factor of 2 could be explained by a theoretical model. This was the basis for a patent in 1987, also supported by the fact that you need a certain cable stiffness to push the cable, see Fig. 7.

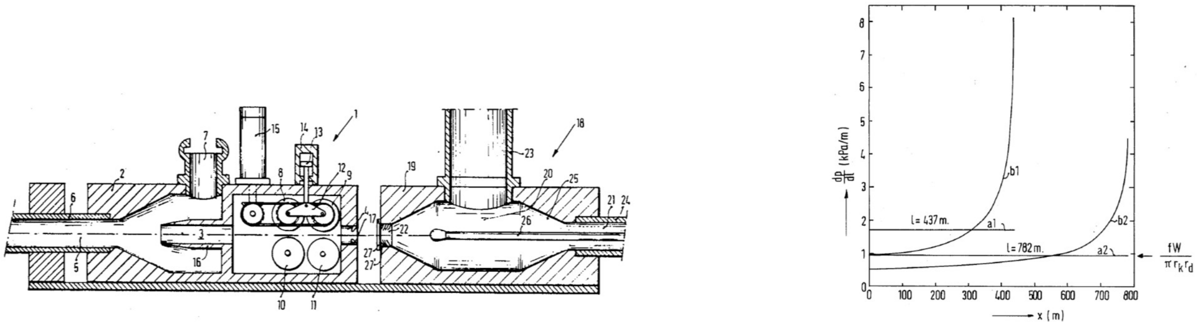

Fig. 7 Pictures from patent US 4934662 (1987)

The rest is history. A prototype blowing machine was made (with mechanical drive), see Fig. 8. After testing in the field the installation crew did not want to return it and ordered 4 more machines to try tandem operation. This also worked (the 2.1 km could be installed by 4 machines in tandem, without sync issues), machines also kept and 30 more machines ordered. After that all optical cable installation in The Netherlands was done by blowing (blowing length 700 m, but for flawless blowing 4 machines operated in tandem taking 525 m each) within half a year after the first manual trial. Installation crews, motivated to compete for a daily installation record, reached up to 12.6 km in one day. Visitors from other countries were amazed. Soon an exclusive license was given to the Swiss company Plumettaz, introducing the technique worldwide. The first commercial machine is shown in Fig. 9 and another commercial machine, in operation, in Fig. 10.

Fig. 8 First prototype of cable blowing machine in operation

Fig. 9 First commercial cable blowing machine

Fig. 10 Another commercial cable blowing machine in operation

Current situation

Not only the fact that long cable lengths can be installed by blowing, also other advantages made this technique conquering the world as the most used technique today. Installation is easy, one step, no need to install a winch line first. Furthermore, installation is all from one side of the duct, for labor, equipment and cable drum. Finally, the forces on the cable are low, an order of magnitude less than for pulling.

Today blowing distances are much longer (record today is 5.3 km in a single blow). Improvements made were on cable and duct and on lubricant and lubrication. An example of the latter is the Cable Lubricator, also produced by Plumettaz, see Fig. 11. Other improvements are the use of Compressed Air Coolers, Sonic Heads (Fig. 11) and Y-Connectors (Fig. 12) to make possible overriding cables in ducts already occupied with previously installed cables. The latter leads to **significant cost savings**, when upgrading cable routes **without the need to dig again**. Not only additional cables, also additional microducts (see further) can be blown, especially useful when additional blowing lengths for overriding cables are short, requiring a lot of cable buffering (not needed for microducts, which can easily be coupled by push/pull connectors).

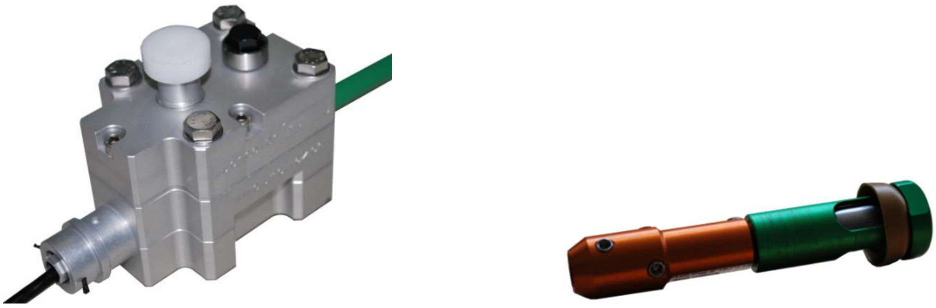

Fig. 11 Example of Cable Lubricator (left) and Sonic Head (right)

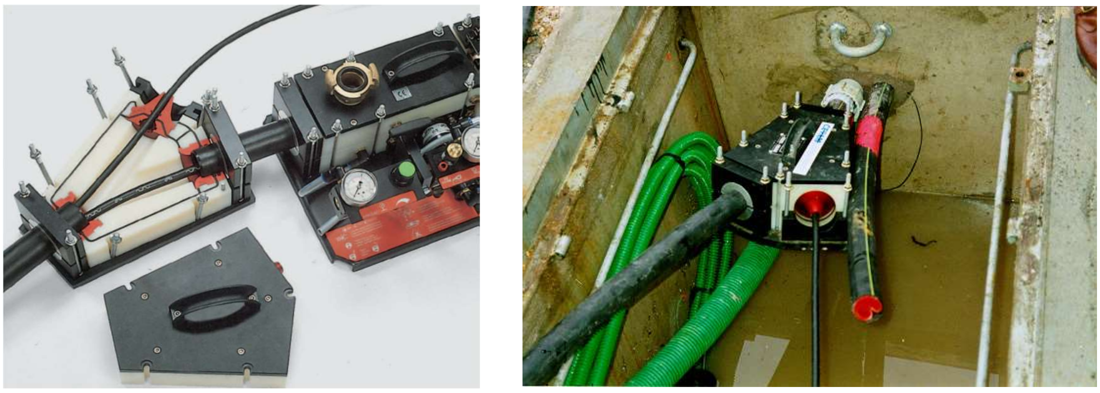

Fig. 12 Y-Connector, to override cables or microducts in ducts already occupied with previously installed cables.

Today's benefits of cable blowing summarized:

- Faster to install (80 -150 m/min & about 10 km per day) – Better ROI
- Less people needed (team of 3 people can install 8-12 km per day) – Easier to manage, quick answer to the market
- Less machinery (1 small blowing equipment and compressor can replace multiple winches and multiple people) = Much easier to handle, and quick start = Better ROI
- Safer for the Fiber Optical Cable (Low stresses during cable installation) = Longer life
- Thanks to the technique of blowing optical cables have been made lighter over time, and new constructions/design have been built to make them easier to install and with **considerable economic advantages** for the Telecom industry
- Less disturbance during installation / keep the roads opened
- Faster to deploy a network
- Taking advantage of existing HDPE duct in the local infrastructure
- Possible to override, generating **significant savings** because you don't have to dig and install another duct
- Easier to maintain. When it is a matter of maintenance or cable replacement, there's no better way than blowing to quickly refurbish a damaged network.

10 years after the invention of cable blowing it was also used to install microduct cables into microducts, the latter similar to the "bores" used for blown fiber. But, the microduct cables were quite stiff. The first use was with micro copper quad cables, for new installations of the copper access network, prepared for later replacement with micro optical cables. The first generation of these so-called microduct cables contained steel tubes, to cope with thermal expansion of these small cables. Later non-metallic microduct cables were used. This was made possible due to better cabling techniques and optical fibers with better micro- and macro-bending properties. The microducts were blown in loose bundles (containing easily up to 10 microducts) into larger ducts (the free space offering excellent mechanical protection), see Fig. 13 and 14. After the bundle of microducts is installed it is possible to make a mid-span branch at any time and any location using a dividable Y-connector, see Fig. 15, with one (or more) of the microducts coupled by push/pull-connectors to branch microducts. In this way optical cables can be blown through intricate routes, without the need to make a splice in the optical fibers.

Fig. 13 Blowing loose bundle of microducts into a larger duct

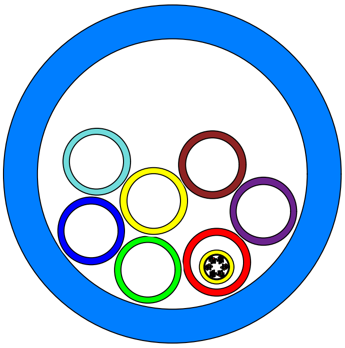

Fig. 14 Cross sectional view of duct with loose bundle of microducts

Fig. 15 Y-connector for branches in microduct networks

Advantage of microduct cabling are the ability to only install the fibers needed at the time of installation (pay as you grow), serial upgradeability (extend networks later by coupling new ducts and microducts), parallel upgradeability (later new customers can be connected any place any time) and building redundant connections by clever use of empty microducts (left and right "woven into each other", empty microducts beyond the branch used for other direction, see city ring and half rings in Fig. 16).

As already mentioned it is also possible to override existing cables by blowing microducts on top of them. As blowing lengths are not always long in this case, it is easier to blow short lengths of microducts and couple them to larger routes by simple push/pull connections (no splice). This can give huge (digging) cost savings. Example: the first cables blown in the Netherlands (in the 32/26 mm ducts) had a diameter of 9.7 mm and contained 6 fibers. At that time it was stated that the duct was fully used (recommended max filling diameter ratio of ~1/3). Many years later an upgrade is needed. Recommended filling ratio grew to max 80% in this time. It was possible to blow short lengths of 2 microducts 10/8 mm and couple them to longer routes, a real upgrade. Better materials and lubricants made possible cable blowing lengths of 1500-2000 m (compare to 700 m in 1987), even though the filling ratio was higher, and the cables contained 96 fibers each, an **upgrade by 3200%**!

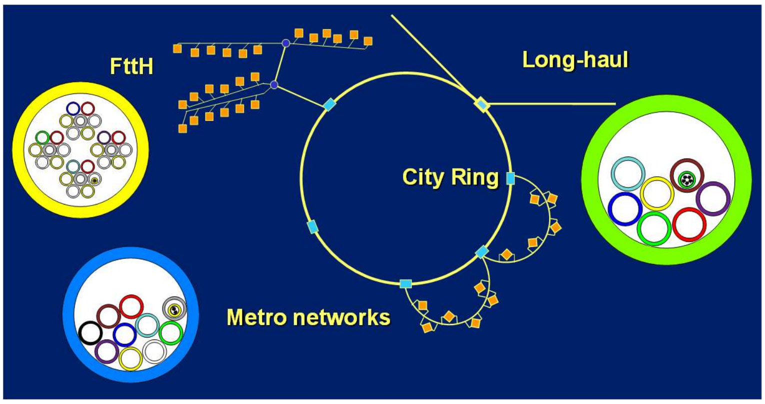

Fig. 16 Schematic view of access network, with redundant primary ring and redundant secondary half-rings for business customers.

At present also tight bundles of microducts are used, often buried directly into the ground without a larger surrounding duct, see Fig. 17, more in line with the original “bores” of the blown fibers. Also very small cables became available, closing the gap between microduct cables and blown fibers. Care shall be taken that the filling ratio is not too high with these tight bundled microducts, as micro-undulations might limit the blowing length, depending on how the bundles were buried.

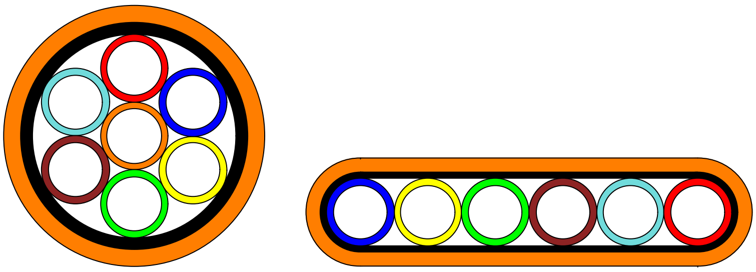

Fig. 17 Cross sectional view of examples of tight-bundled of microducts

Nowadays, with the microduct technology, it is possible to put in a small trailer, a van or a pick-up truck:

- Drum of FO Cables
- Drum stands
- Compressor
- Blowing machines
- Box of Tools and accessories

A team of 2 people is sufficient to reach over 6km per day. Where in the beginning it was thought that only special cables can be blown, today we know that all kind of cables can be blown, most of them originally meant (and still specified) for pulling. However, as already mentioned the blowing technique led to lower stresses on the cable during installation, allowing for less heavy cable construction / design, easier to install. Cables with different fiber-counts are blown today, ranging from 1 to 6912. To make the latter cable compact enough to be blown into traditional ducts special techniques are used, like rollable fiber ribbons, bend insensitive fibers and miniaturization of the fibers (fiber core still 125 μm, but coating reduced from 250 μm to 200 μm, recently even 180 μm). Also large copper quad cables (150x4) were blown into ducts. And when using water instead of air, cables can also be floated into ducts, again stretching the boundaries (record today is 12.4 km in one go). We are still on the move!

Conclusions

A review is given of the history of the cable blowing revolution, as a replacement of the traditional pulling technique. It arose from serious installation problems in The Netherlands. The technique, developed by the Netherlands PTT, was soon licensed to the Swiss company Plumettaz, marketing the technique worldwide. The advantages are so clear that blowing has become the standard method for installation of optical cables into ducts. Improvement of cables, ducts and lubrication made the blowing length increase and the fiber count in a duct rise. The blowing technique was also the trigger to develop the microduct cabling technology. The benefits are manifold and several variants are used. Today the trend is higher-fiber counts and the sky seems to be the limit. New developments continue to challenge cable installation technology.