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Cable Blowing, Cable Floating: which method to adopt?

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Cables (here mainly Optical Fiber Cables) have been installed in ducts since the mid- seventies. Initially, mechanical or manual pulling, later pushing combined with pulling were the main installation methods adopted by installers. The need for placing longer continuous sections of cable, requirements to improve optimal cable performance after installation and pressure to reduce costs led to the introduction of Cable Blowing in the Netherlands in 1987. At the same time in Northern and Eastern Europe, Cable Floating was adopted. Since 1990 Cable Blowing has been largely adopted in all continents, whilst Cable Floating remained mainly confined in its initial area. Since the end of the nineties, on one hand, in France and Italy Floating has been widely adopted by main utilities and installers, on the other hand, in some countries Cable Floating is still proscribed. In this paper, a review of the practical experiences with the two installation methods is given. A comparison of said methods showing their specific features is presented. From this selection criteria for choosing the most adequate method are identified. Performances quoted are issued from field results collected since 1999. Simulated performances are based on specific software built on the Cable Blowing respectively Floating theory. An adequate correlation between simulated and practical field results has been verified.

1. Introduction: some history

At the time of the introduction of Optical Fiber Cables (OFC) in the early eighties, telecom operators elected to install long haul OFC either into their existing metropolitan, urban and suburban underground duct networks, which were originally designed for copper technology (old duct system), or into newly built duct networks dedicated for OFC technology (new duct system). The new duct system predominantly consists of flexible PE ducts with 25, 32, 40 or 50 mm outer diameter, which are either directly buried or used for sub-ducting the old duct system. Initially the generally chosen method for installing OFC in old and new duct systems was, depending on labor cost, mechanical or manual pulling. Proper cable design and overload protection devices like breakaway links and winch dynamometers with overload cutout would prevent possible damages on the OFC during installation. The need for installing longer legs of OFC led to the introduction of improved pulling methods including buffering and intermediate assistance with capstans or linear pullers. In rural areas, long haul underground OFC would either be ploughed in directly or placed in flexible PE ducts, offering superior protection to the cable. However, fearing the difficulties encountered during winch pulling, caused by the adverse effect of severe undulations of the trenched or ploughed-in duct, large operators, e.g. AT&T in the US [1] favored direct buried armored OFC. Other operators, such as France Telecom, built an extensive buried long haul duct network across France. As a State organization, France Telecom enjoyed a strong position on matters relating to rights of way. Therefore they were able to design a duct network providing optimal conditions for later cable deployment. Also, specific duct installation procedures were applied to secure optimal straightness, thus avoiding undulations detrimental to cable pulling and maintain the integrity of the 50 mm duct. OFC sections reaching 2.4 km were regularly winched in without any buffering or intermediate assistance [2] [3]. At a later stage, i.e. in the early nineties, France Telecom increased the pace of the deployment of its long haul network by substituting winching by high speed Blowing with a tight shuttle. The high quality of the 50 mm duct infrastructure made such installation technology possible and efficient. Up to three 2.4 km long sections of OFC could be placed in one day by one installation team.

In the Netherlands, during the same period, the historical operator KPN, faced a different problem with the deployment of OFC in urban and rural areas, as their copper cables were directly buried, i.e. there was no duct system. Furthermore, in Dutch cities, the ground was often badly congested. New OFC would have to be either provided with heavy armor giving sufficient protection, considering the relatively shallow depth of direct burial, or installed in a new duct system to be built. KPN opted for the duct solution. For a few years, KPN tested various installation methods to place OFC in their new duct system. Pulling, buffering and intermediate assistance were experimented in various forms [4] with the aim to install continuous sections of OFC up to 500 meters in length. The unavoidable duct sweeps and undulations encountered, impeded any form of efficient pulling as too many temporary access holes were needed, inflating installation cost. Another more efficient placement method had to be found. As consequence of this, KPN gave a research mandate to their own development center in Leidschendam, The Dr. Neher laboratories. From this development program, a new installation method, named today Cable Blowing or Cable Jetting, emerged in 1987. It can be defined as follows: a technique to install OFC or other conventional cable in ducts whereby a stream of compressed air with a high rate of flow pushes the cable through a guide and protection duct. This feeding by compressed air is supported by an additional mechanical pushing force, which is essential for optimal results. Cable Blowing or Jetting is now well accepted in most parts of the world. Its success on the market was boosted by the deregulation of the telecom industry in the mid-nineties. Another installation technique using compressed air, simultaneous cable pushing and pulling with an airtight shuttle propelled by said compressed air (Pneumatic Push/Pull), was developed in Germany. This method did not break through as it had the same shortcomings observed with conventional pulling in direct buried ducts. Finally, in Denmark, an alternative method to install OFC in ducts was introduced: Cable Floating. It consists in feeding the OFC in the duct with pressurized water. Like for Cable Jetting this feeding is supported by an additional mechanical pushing force, which is essential for optimal results. Also, like OF Cable Blowing, OF Cable Floating does not include a tight shuttle, otherwise the above-mentioned shortcomings would also occur.

2. Cable Blowing

2.1 Operating principle

As mentioned before, Cable Blowing is characterized by the synergy of a positive mechanical pushing force exerted by friction on the OFC outer jacket and of a drag force acting on the cable, generated by a high speed compressed air flow (see Figure 1).

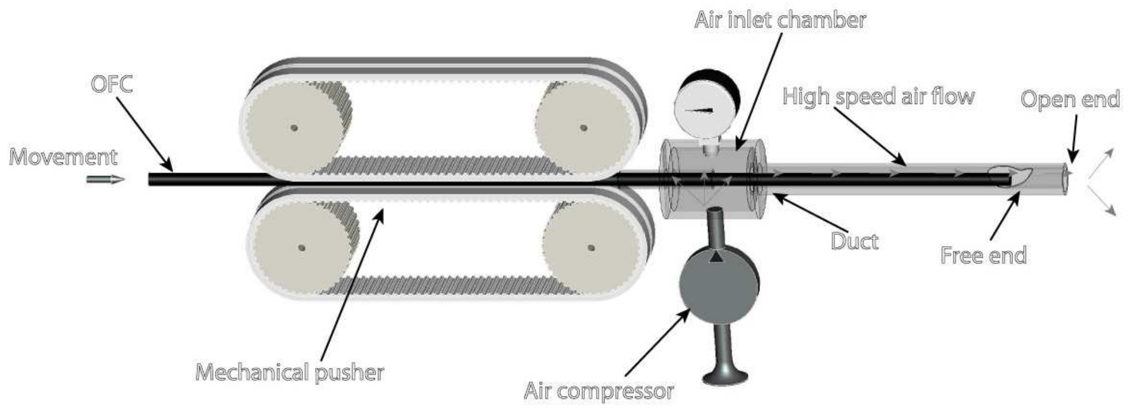


Figure 1: Cable Blowing

2.2 Adoption

From 1991 on, the Cable Blowing technique has spread worldwide. As a consequence of deregulation of the telecom industry, several new operators appeared on the market. Many of them built an extensive long haul network (backbone) on a national and international scale. Cable Blowing proved well suited for cable placement in modern flexible HDPE ducts, whether ploughed, directly buried or pulled in existing main ducts. They negotiated different rights of way such as railways, waterways, sewage, gas, etc. to deploy their duct network. Landowners' opposition often forced them to build their duct system along sinuous courses. To improve cable performance and reliability as well as to control cost, duct-cable drum length was considerably increased, i.e. from 1 to 4 km, later 6 and finally up to 12 km.

The Cable Blowing technique proved to be better suited to meet the challenges of:

- Placing OFC in a safe manner, i.e. with low stress, over an uninterrupted distance of at least 2 km, through undulating ducts along sinuous courses
- Placing efficiently OFC sections up to 12 km long
- Reduce installation cost

This can be explained as follows:

- Compared to pulling, the Cable Blowing performance is less influenced by the sweeps and undulations of the duct course as no force concentration at the head of the cable occurs
- The Cable Blowing technique is easily applicable in cascading mode (see Figure 2 below)

Compared to the pulling method, the Cable Blowing technique is faster hence more cable is installed per day and per person.

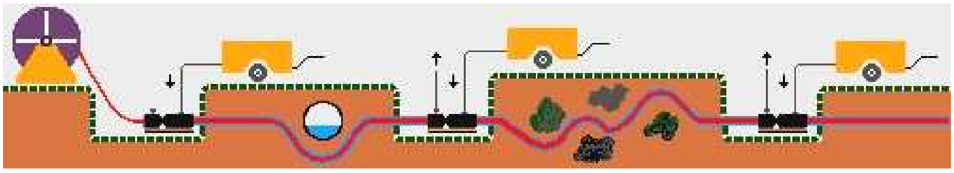


Figure 2: Cable Blowing in cascading mode

3. Cable Floating

3.1 Operating principle

Placing a cable in a PE duct up to 50 mm ID, whereby the cable is pushed into the duct by a flow of pressurized water. This feeding by pressurized water is supported by an additional mechanical pushing force, which is essential for optimal results.

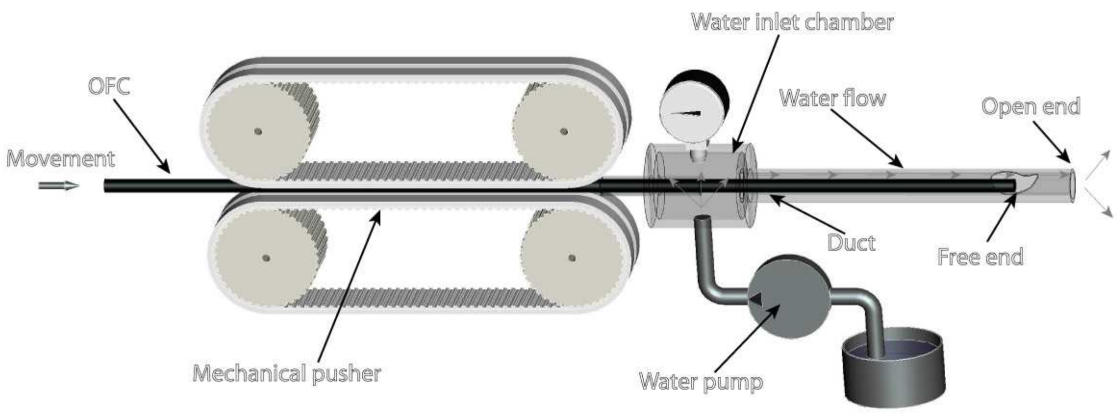


Figure 3: Cable Floating

3.2 A fundamental difference

To define the Cable Floating technique, one just needs to modify the definition of the Cable Blowing technique as quoted in the introduction of this paper, by replacing the words "compressed air with high rate of flow" by "pressurized water". This explains already partially why most Cable Blowing equipments can be used to operate according to the Cable Floating technique. Substituting air by water has a great influence on the level of installation performance, i.e. length installed in one step. Both techniques include a) an essential mechanical pushing force, b) a driving force exerted by the gas or fluid on the cable. The Cable Floating has an additional major feature: a significant Archimedes' uplift, which has a beneficial effect on the installation performance. The best performances will be achieved with cables having a density equal to water density, i.e. equal to 1 g/cm^3. Such cables behave like a weightless body when immersed in water. As a direct consequence of this, the forces resulting from friction between duct and cable caused by gravity are fully neutralized. It must be noted however that other friction forces may occur, caused by a stiff cable advancing through a sinuous duct; indeed a wall contact will be unavoidable. This must remain under consideration when comparing Cable Blowing and Cable Floating techniques.

3.3 Adoption

The Cable Floating technique, introduced shortly after the Cable Blowing technique, remained confined to Northern Europe and Hungary until mid-nineties. One possible reason for this is operators' reserve about the idea of steeping OFC in pressurized water. Water and OF don't live well together… From 1995 on, the company LD Cable in France built an extensive long haul network along waterways. Water being easily available, the Floating technique seemed the obvious choice for this project. Performances quoted under paragraph 6 "field experience" will prove that this choice was good. In Italy also, Floating cables along highways has been carried out extensively; the main reason for choosing this technique was a quality problem encountered with the 3 x 50 mm duct system, which could not withstand pressures and temperatures normally occurring for Blowing cable over the required minimum continuous length of 2 km. France Telecom research department (CNET) developed a Cable Floating method and equipment for the secondary network (local loop) and for the upgrade of existing parts of the long haul network. Here again, Cable Floating offered specific advantages, which will be shown later.

4. Factors influencing Cable Blowing and Cable Floating performance

Cable Blowing or Cable Floating performance is governed by the interaction between all elements listed below. For each element the relevant physical factors are the following:

ELEMENT	PHYSICAL FACTOR
Cable	Outer diameter OD (mm) Linear weight w (g/m) Stiffness S (Nm^2) Density ρ (g/cm^3)
Duct	Inner diameter ID (mm) Undulation: Amplitude A (cm) & Period T (m) Course: Slopes* α (deg.), Bends (Radii R + Location L) (m)
Duct/cable/lubricant (match)	Coefficient of friction μ (-)
Air compressor / water pump	Flow Q (l/sec), Pressure P (bar)
Mechanical pusher	Pushing capacity F (N)
Mode of installation	Empty duct, occupied duct, bundle Blowing/Floating

(*) Important level differences along the duct course can create serious problems with the Cable Floating technique (1 bar static pressure per 10 m level difference); therefore Floating along a course in mountains area is not always possible.

Table 1: List of influencing factors

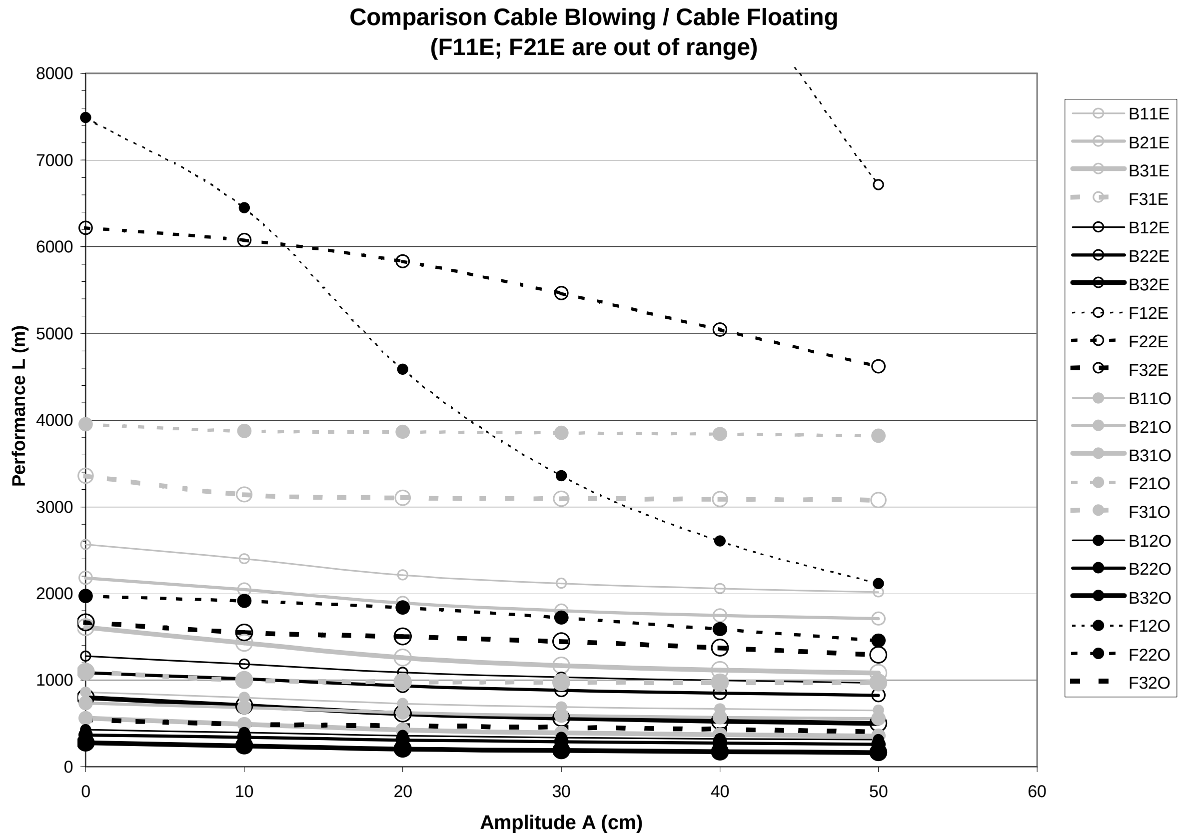
5. Comparing Cable Blowing with Cable Floating performance

For clarity, the meaning of the word performance in this paper is: the maximum length (m) of cable installed under specific physical conditions in an uninterrupted duct. Except for cable density and slope angles, the physical factors shown on Table 1 have the same impact on both techniques. Charts on Figure 4 below show the influence of cable density, duct undulation and friction on

Blowing and Floating performance. Performance values are derived from theoretical calculations [4] confirmed in the field. For comparison purpose, only 4 elements are considered:

- 3 types of cable:
  Cable 1: OD = 11 mm, ρ = 1.05, S = 1, w = 100 g/m, e.g. non metallic
  Cable 2: OD = 11 mm, ρ = 1.26, S = 1, w = 120 g/m, e.g. armored
  Cable 3: OD = 11 mm, ρ = 2.10, S = 3, w = 200 g/m, e.g. copper
- The level of complexity of the duct course qualified by the amplitude A, which varies between 0 and 50 cm, the period of 6 m remains constant
- The match cable, duct and lubricant characterized by μ = 0.1 and μ = 0.2
- The installation mode: empty duct and occupied duct (1 x cable OD 13 mm)

Other elements: duct ID = 32 mm; course: straight & horizontal; F = 400 N; P = 12 bar; Q = 160 l/sec / 2l/sec.



B = Blowing; F = Floating; E = Empty; O = Occupied; 1st digit (1, 2, 3) = Cable type; 2nd digit (1, 2) = μ = 0.1 and 0.2

Figure 4: Performance Chart

General observations:

1. When Floating, cables with density close to 1 perform better
2. Floating performance is superior to Blowing performance
3. Floating is much more sensitive to density than Blowing: when Blowing, the performance drop between cable 1 and 3 is approx. 40 to 45 % (μ = 0.1) and 50 % (μ = 0.2); when Floating the drop is above 70 % depending on amplitude.

4. The coefficient of friction affects in a similar manner the Blowing and the Floating performance. Performances are approximately twice as high for each cable and each technique (note: for Floating only cable 3 is within range on the Chart).
5. Performance obtained in empty duct drops by approx. 66 % when cable is installed in occupied duct (valid for $\mu = 0.1$ or $\mu = 0.2$). This percentage depends on the ratio between resident and installed cable OD.

6. Field experience

Table 2 below shows a non-exhaustive list of typical performances reached with Cable Blowing and Cable Floating in different states from 1995 on.

STATE	CABLE OD (mm)	DUCT ID (mm)	TECHNIQUE CB/CF	DRUM LENGTH (km)	DAILY PROD. (drum/day)	MODE (E/O/Sim)	PERFORM. (km)
FR	15-17	27	CB	3	2-3	E	1.4-2.2
FR	13-14	41	CB	4.8	2	E	2.5
FR	11-13	32	CB	5	2	E	1.5
FR	2 x 12	41	CB	4.8	2	Sim	2.8
FR	11	32	CB	4	2	O	1
FR	12	41	CF	10	1	E	10
FR	11	33	CF	9.5	1	E	9.5
FR	2 x 13	41	CF	5	2	Sim	5
FR	12	33	CF	6	2	E	6
IT	12	41	CF	4	2	E	4
NL	10	27	CB	4	1-2	E	1
US	12	33	CB	12	1-2	E	2-2.5
FR	2 x 11	33	CF	4	2	Sim	4
CZ	12	33	CB	6	2	E	1.7
CB = Cable Blowing; CF = Cable Floating; E = Empty duct; O = Occupied duct (1 cable); Sim = Simultaneous installation of 2 cables							

Table 2: Summary of field experience

7. Advantages / disadvantages of Cable Blowing and Cable Floating

The Table 3 below features a list of pros and cons of both techniques:

Considered Aspects	Cable Blowing	Cable Floating
Logistics	Simple	More complex: water management
Operators' training	Short training required	Longer training required
Set up time	Faster	Slower
Predictability	Good (software)	Good (software)
Removing cable from duct	Risky (cable speed)	Safe, cable cleaned
Personnel safety	Hazards inherent to compressed air	Safer

Considered Aspects	Cable Blowing	Cable Floating
Ecology	Higher energy consumption: approx. 40 to 50 kW needed (compressor + machinery)	Opposition by authorities (Germany); water pollution risks with inadequate lubricant
Low temperatures (< 0°C)	Improved Blowing performance	Ice formation (freezing)
High ambient temperatures	Hot air causing duct bursting	Duct cooled by water
Slopes	No specific problems	Problem with static pressure in duct
Installation inside buildings	OK with dry pre-lubricated duct; risk of spreading lubricant vapors	Flooding
Medium supply (air or water)	No limits	Problems in dry zones (e.g. Spain)
Placing cable into occupied duct	Performance obtained is 30 to 50% of the one obtained in empty duct	At least once to twice the performance achieved when Cable Blowing
Reliability	No preference	No preference
Road traffic safety	NA	Risk of flooded road surface
Integrity of cable	Hot air temperature reducing stiffness and increasing friction	Risk of water penetration

Table 3: Advantages / disadvantages

Each method has its specific merits. For placing cables up to 2 km, Cable Blowing is the fastest method. For installing continuous lengths of 6 km, assuming easy access to water and limited height variation, Floating is more efficient.

8. Conclusion

Cable Blowing and Floating are 2 reliable installation techniques having specific features. When planning new construction, both methods should be considered. For both techniques the major issue of friction is valid. Friction must be optimized, i.e. kept as low as possible. Therefore, the match between duct, cable and lubricant must be imperatively validated prior to any procurement.

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