

Installing Array Cables between Offshore Wind turbines, from Land! FreeFloating over 40 km?

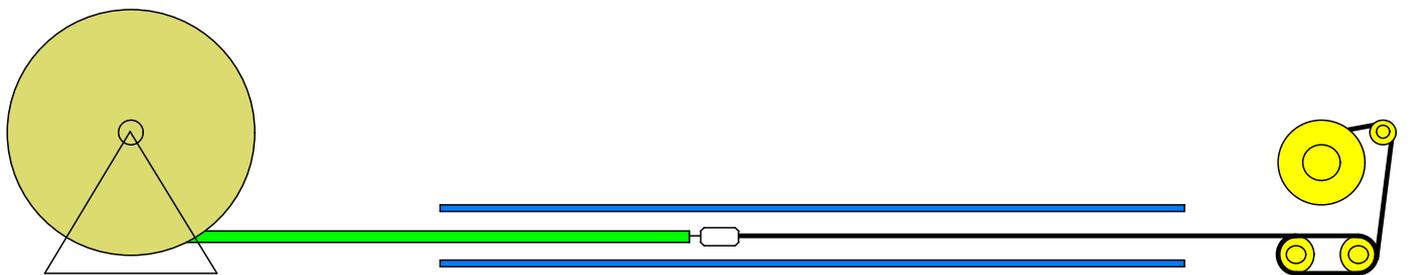
Willem Griffioen

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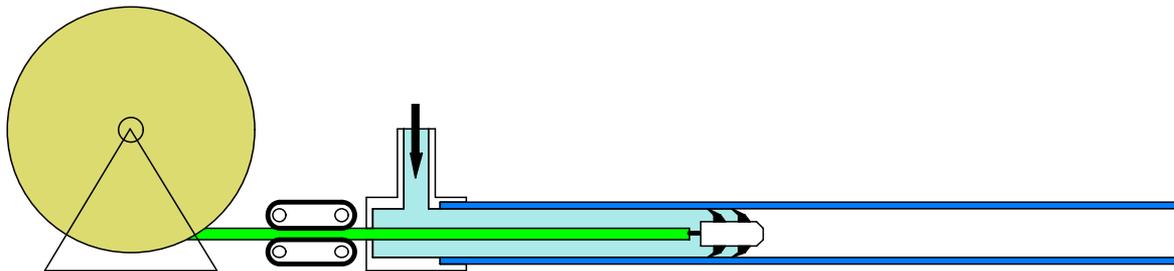
Introduction

- **Techniques to install cables into pipes**
 - **Winch Pulling**
 - Extra step of installing a winch line before pulling
 - Material and labour on both ends of pipe
 - High pulling and sidewall forces, lot of wear, limited length



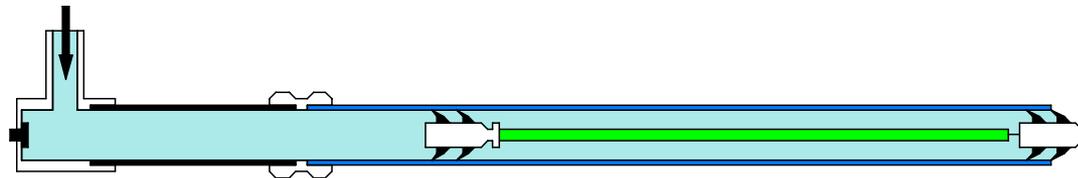
Introduction

- **Techniques to install cables into pipes**
 - **Winch Pulling**
 - Extra step of installing a winch line before pulling
 - Material and labour on both ends of pipe
 - High pulling and sidewall forces, lot of wear, limited length
 - **WaterPushPulling**
 - None of these drawbacks



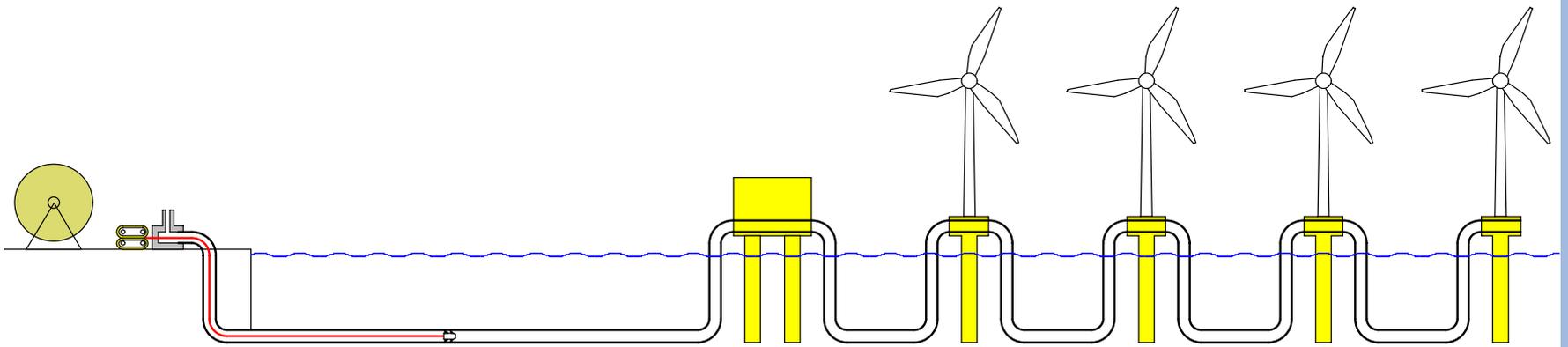
Introduction

- **Techniques to install cables into pipes**
 - **Bonus advantage for WaterPushPulling:**
 - Once installed with this technique the cable can be transported further through coupled pipes by the sole action of water, like “tube post”
 - **Called FreeFloating**



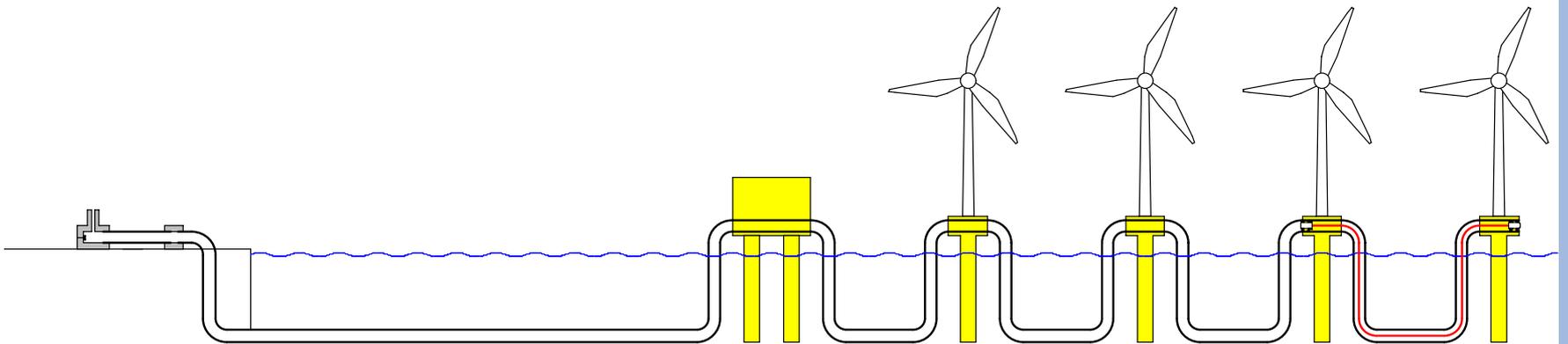
WaterPushPulling and FreeFloating from land

- **Start WaterPushPulling**
- **Continue until entire cable is inside pipe**



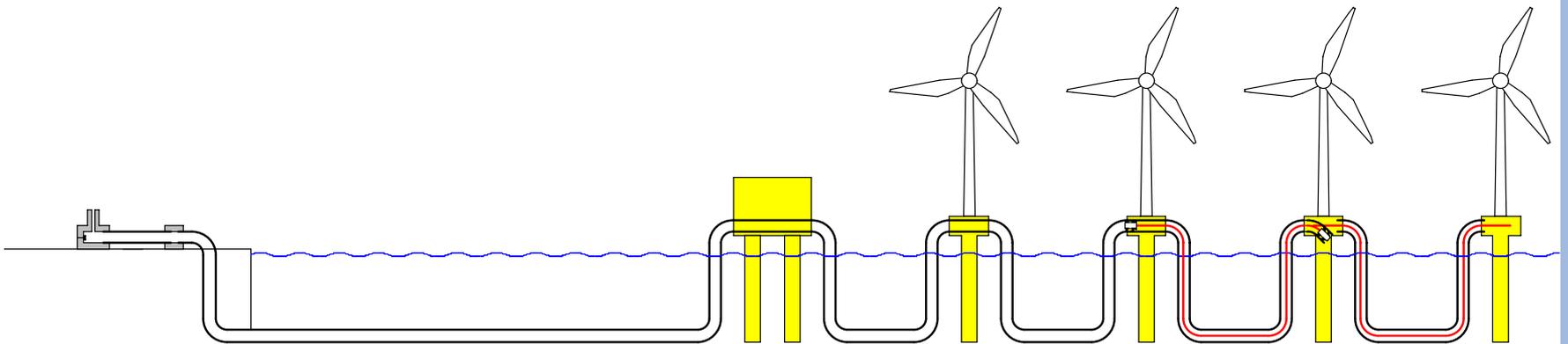
WaterPushPulling and FreeFloating from land

- **Change to FreeFloating**
- **Continue FreeFloating**
- **Until final destination reached**



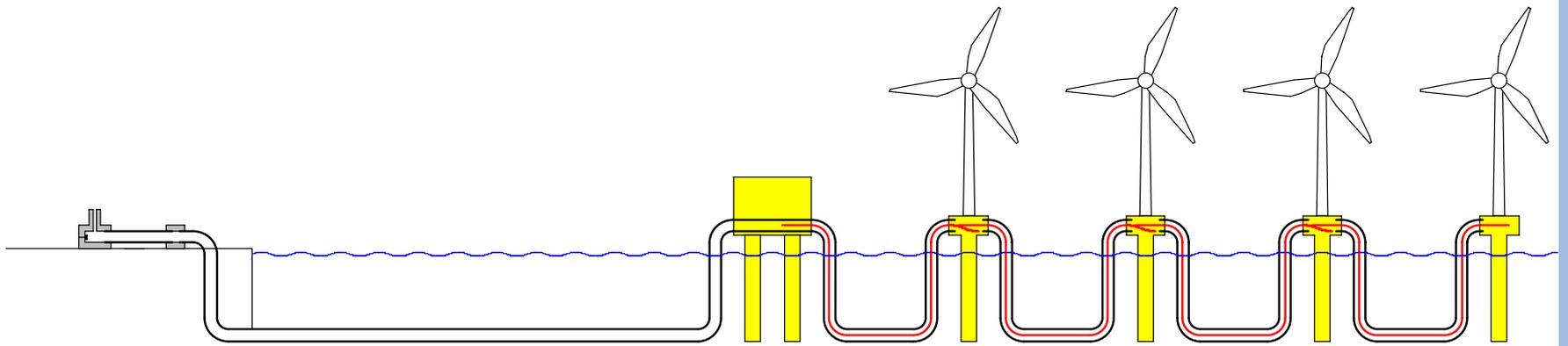
WaterPushPulling and FreeFloating from land

- Remove pigs and start new WaterPushPulling
- Continue FreeFloating
- Until final destination reached

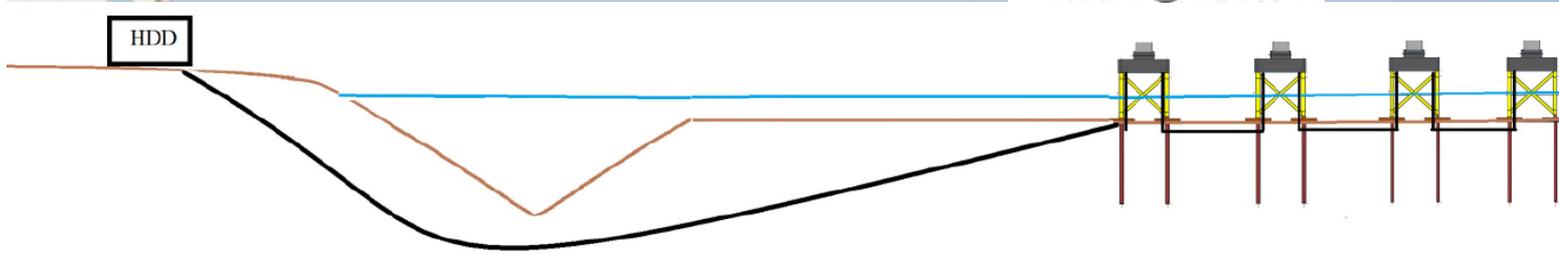
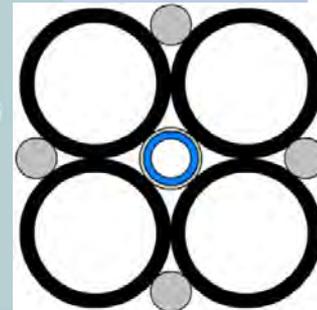
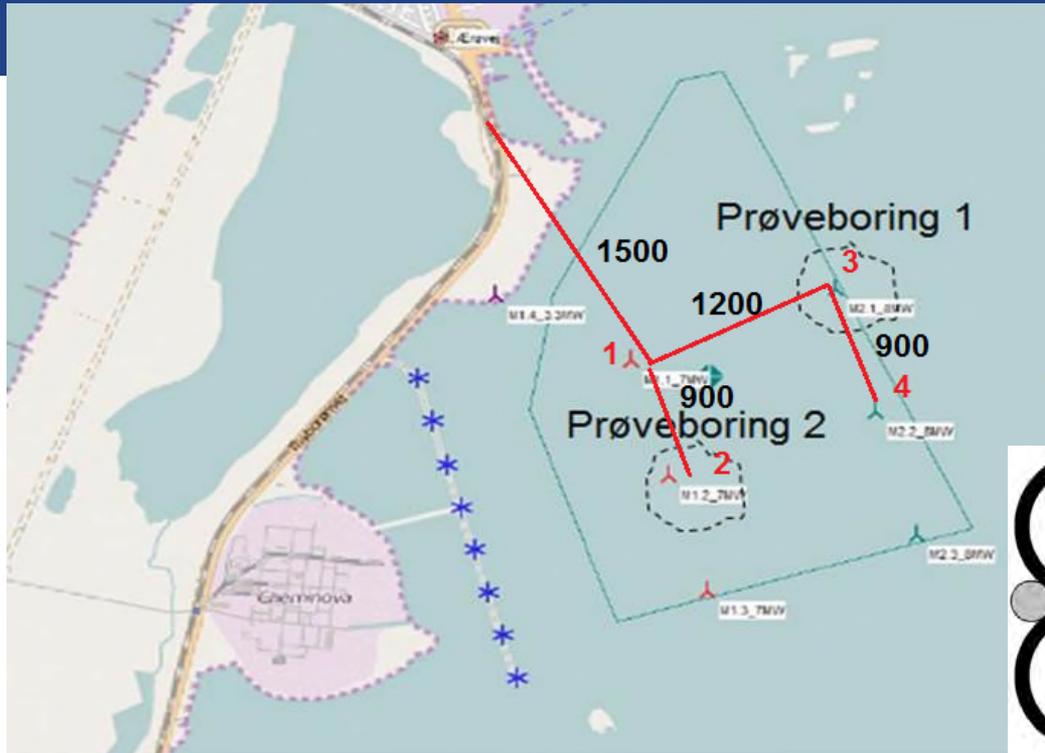


WaterPushPulling and FreeFloating from land

- Install rest of the cables
- All array cables installed



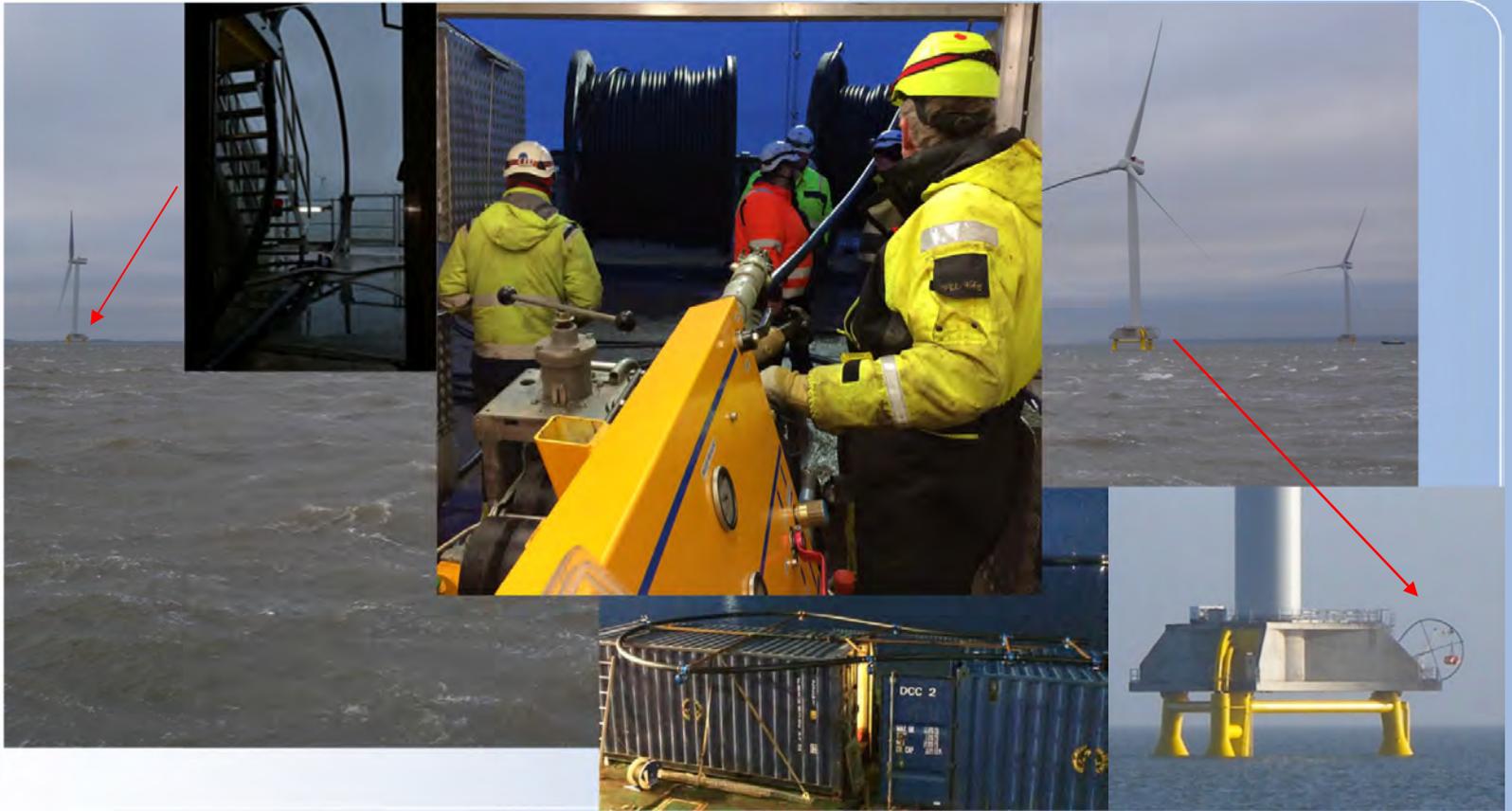
First offshore project, Nissum Bredning (DK)



First offshore project, Nissum Bredning (DK)

- **4 “nearshore” wind turbines, each 7 MW**
 - **Connection from land via HDD drill**
 - **Export and array cables the same**
 - **Duct bundle 4 × 110/90 mm, with steel ballast**
 - **Cables 72 kV, 68.1 mm, 4.6 kg/m, longest 1300 m**
 - **WaterPushPulling from land (export cables) and from sea (array cables)**
 - **FreeFloating from land (array cables)**
 - **Cable speed of 28 m/min reached!**
 - **Installed even with Beaufort wind force 8!**

First offshore project, Nissum Bredning (DK)



First offshore project, Nissum Bredning (DK)



FreeFloating

WaterPushPulling



First offshore project, Nissum Bredning (DK)

- **Advantages Cable in Pipe for Offshore**
 - Standard onshore cables on standard drums
 - Wider range of cable suppliers, cost reduction
 - Reduction in AC-losses (no steel armouring)
 - Pipe and cable can be installed with low cost vessels
 - Cable can also even be installed from shore
 - Trenching of pipe and cable less critical and can be done independent of other operations
 - Less (no) risk for cable damage during installation
 - Pipe damage easy to repair
 - Cable easily replaced when damaged in future

Limits and opportunities, speed and time

- **Water hammer**

- Joukowski: $p = \rho c v \rightarrow 60 \text{ m/min}$ gives 15 bar
- Much less because of pipe expansion

- **Cable speed**

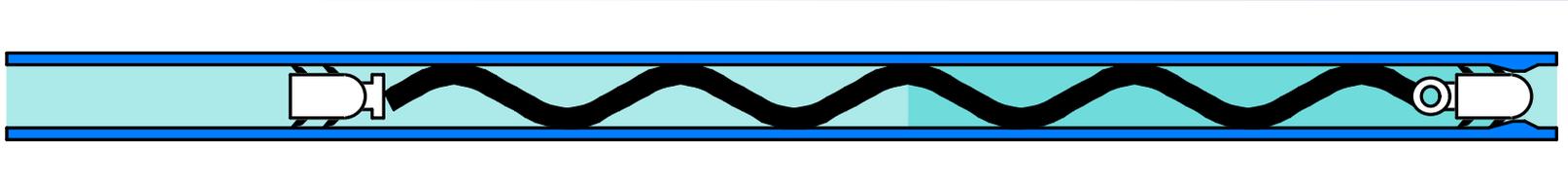
- Sudden stop \rightarrow inertia, calculation analogously water hammer

$$F_c = \sqrt{\frac{m_c}{\frac{1}{k_c} + \frac{c_b (D_d - D_c)^2}{4\pi^2 B}} \cdot v_c}$$

- Nissum Bredning cable 60 m/min $\rightarrow F_c = 12.9 \text{ kN}$

Limits and opportunities, speed and time

- **Cable and pig (!) hit obstacle**
 - “Buckle wave” and water hammer wave start
 - **Waves travel backwards until rear cable end**
 - During wave travelling max force and pressure (at wave part)
 - Buckle force and pressure (pig) force do not add
 - Buckle wave travels faster than ($\sim 2x$) pressure wave (1500 m/s)



More info: W. Griffioen, C. Gutberlet, A. Uhl, G. Laurent, S. Grobety, “Projects with Remote Installation (“Tube Post”) of Energy Cables in Ducts”, Proc Jicable, Versailles, 23-27 June (2019) paper A3.2

Limits and opportunities, speed and time

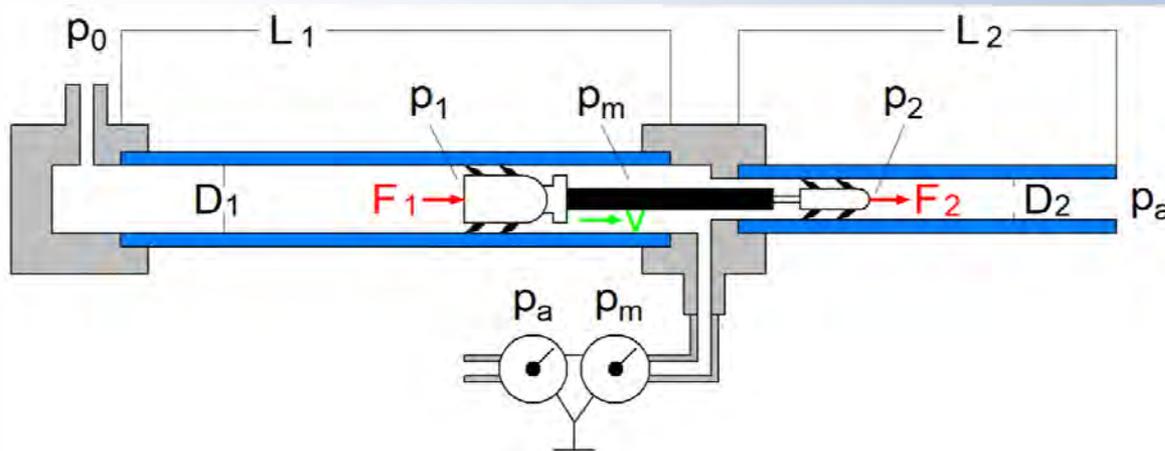
- **Max water speed through long pipe (Blasius)**

$$v = 2.9 \frac{D_d^{5/7}}{\mu^{1/7} \rho^{3/7}} \left(\frac{\rho}{L} \right)^{4/7}$$

- **Example: HDPE pipe 160/130 mm, 40 km long:**
 - Water speed of 40 m/min requires 12.4 bar
 - One cable takes 16.7 hours
 - SDR 11 pipe allows amply 20 bar water pressure (24 hours)
 - Rest available for FreeFloating
 - Larger pipes: higher speed and/or longer length possible (but stay below 60 m/min for safety)
 - In Nissum Bredning project 28 m/min was reached

Different duct diameters

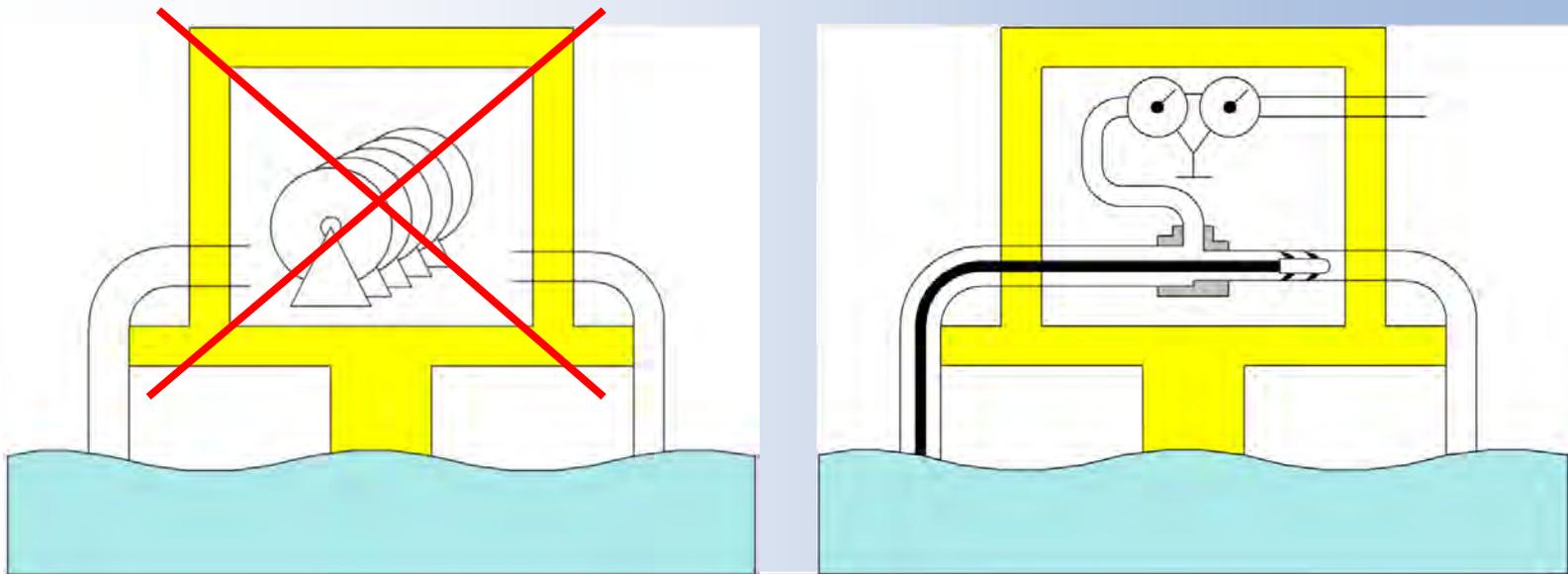
- Different duct diameters might exist
 - Smaller array pipes at edge of wind farm
 - Larger export pipe (might be used for FreeFloating)
 - Need to change pigs at points of diameter change



$$p_m = \frac{D_1^2 p_1 + D_2^2 p_2}{D_1^2 + D_2^2}$$

Limits and opportunities, speed and time

- **No need to store (heavy) drums on platforms**
 - **And no vessels needed either for cable installation**



Conclusions

- **FreeFloating can be done from any suitable launch location to any desired destination, avoiding difficult to reach places**
- **Offshore wind farm: done from land to offshore turbines (also at bad weather, like Beaufort wind force 8)**
- **FreeFloating can be done safely at high speed and over long lengths (e.g. 40 km with 40 m/min in 160/130 mm pipes)**
- **Avoiding cable installation from vessels and storage of cable drums (on vessels or platforms)**

Thanks for your attention

