



International Conference

GEO4CIVHIC

Most Easy, Efficient and Low Cost
Geothermal Systems for Retrofitting
Civil and Historical Buildings

15th November 2023

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TITLE

NAME

Luc Pockelé

ORGANISATION



EMAIL

Luc.Pockelé@red-srl.com

WEBSITE

www.red-srl.com

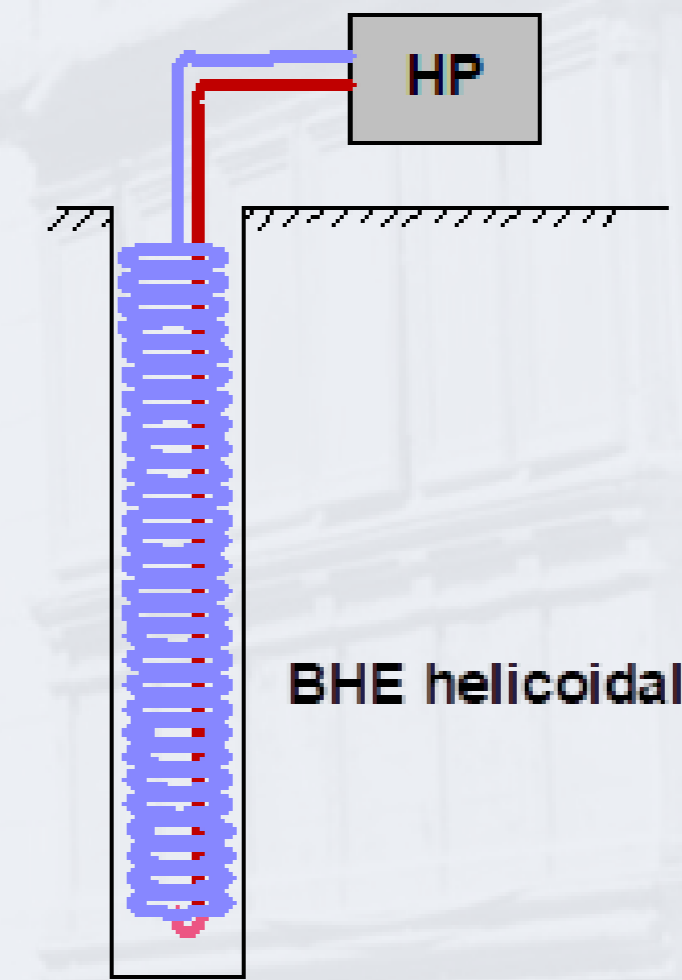
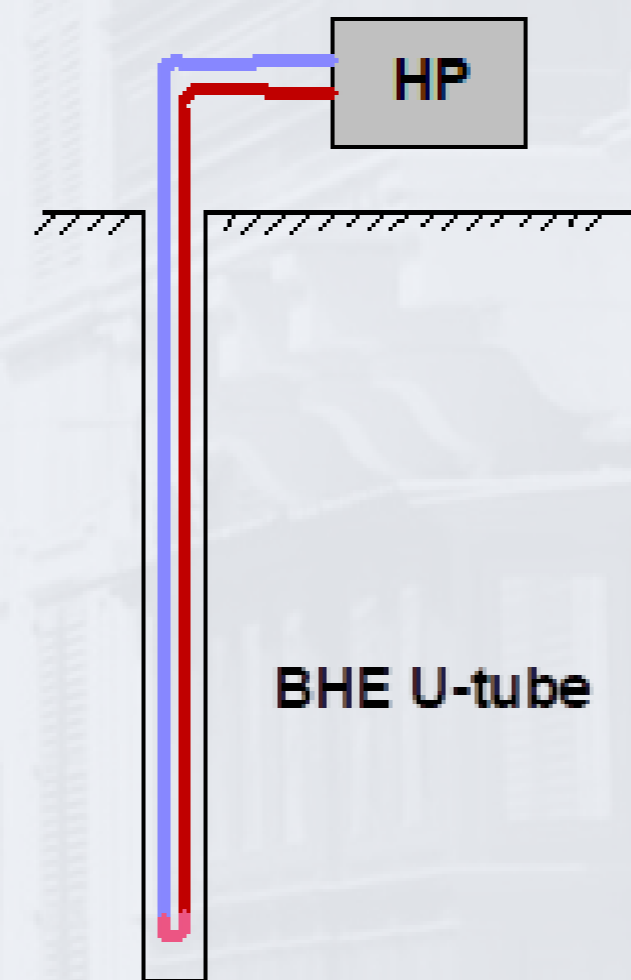
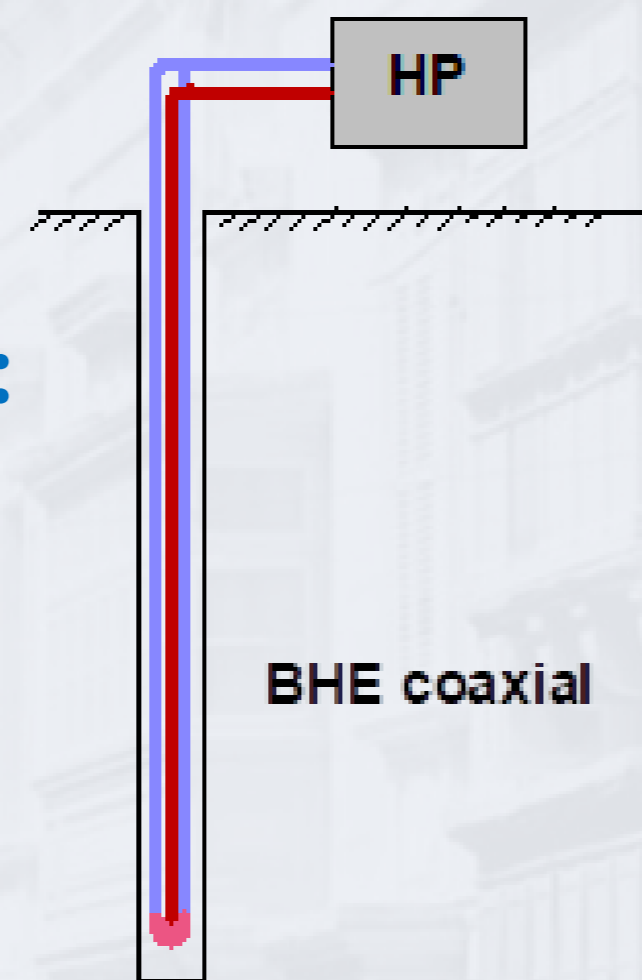
BASICS OF GEOTHERMAL DRILLING METHODS AND BOREHOLE HEAT EXCHANGERS

State of art of vertical Borehole heat Exchangers: history and types

Mature technology

- ✓ First idea's > 75 years ago
- ✓ First experiments in Germany in mid-70's
- ✓ First modern BHE out of PE in the 80's

Main configuration types:



Typical depths:

100 – 150 m

5-20 m

State of art of vertical Borehole heat Exchangers: history and types

Function

Exchange energy between geothermal fluid in pipes and soil

Materials

Mostly plastics

U-tube
Coaxial

HDBE, RC100, PEX
PVC

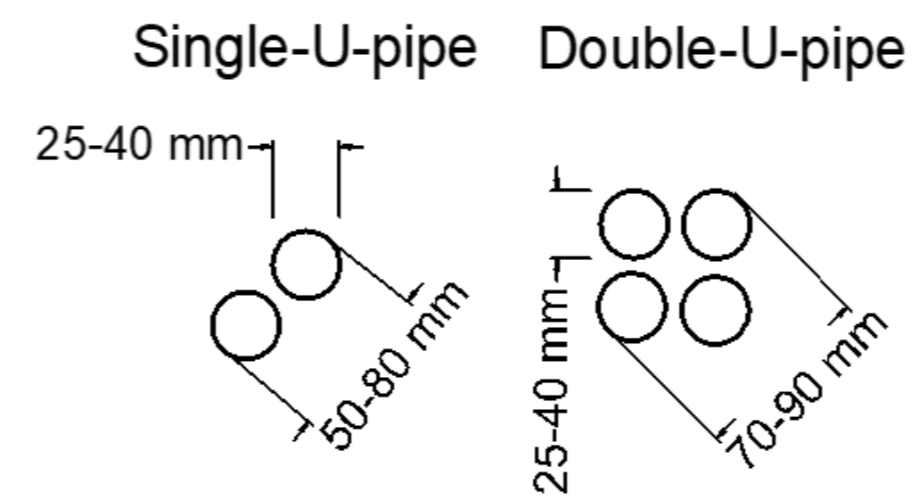
Sometimes metal

Coaxial

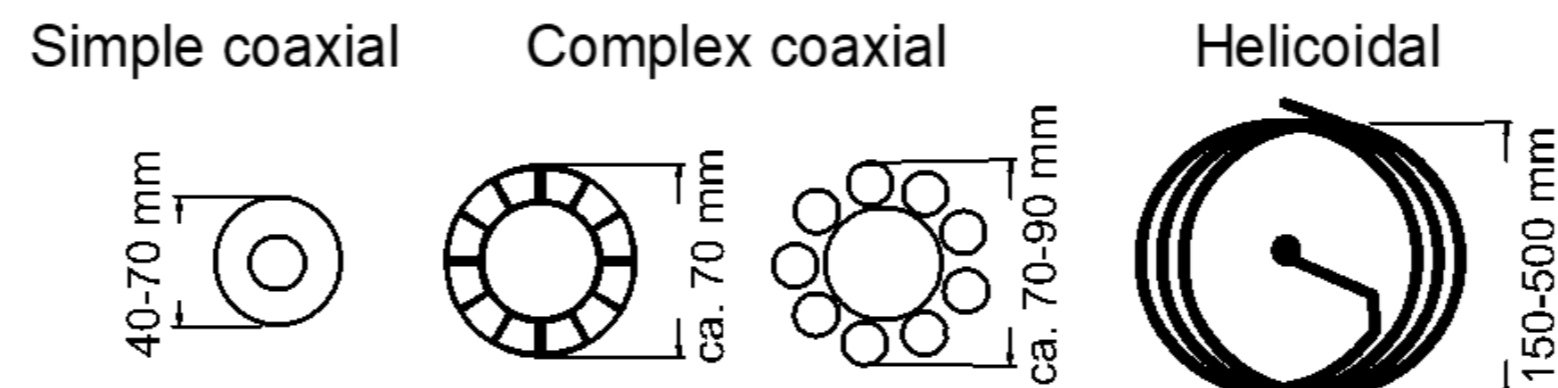
SS304L, SS316L, CS

Geometries

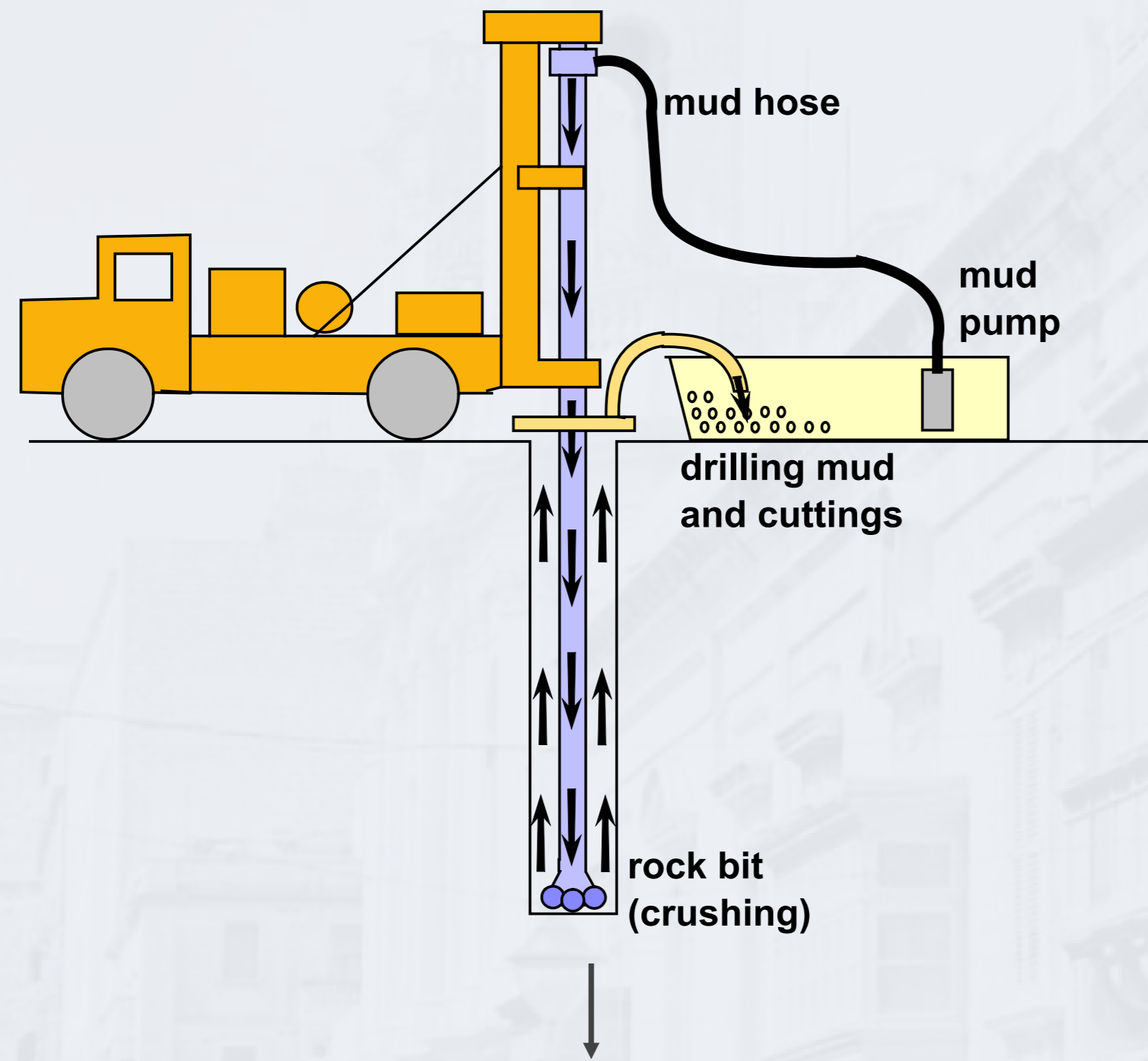
Basic pattern: U-tube



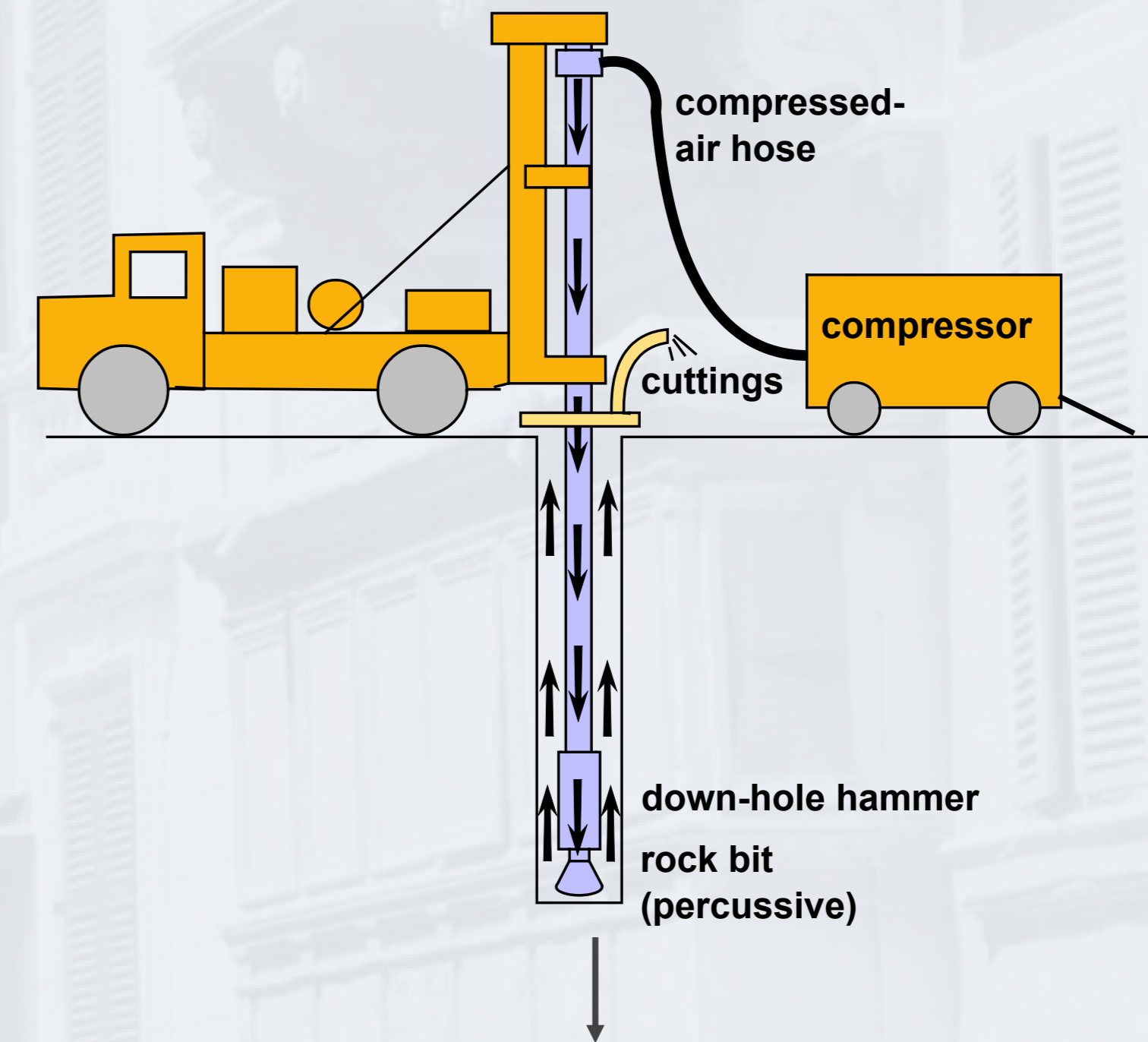
Basic pattern: Coaxial



Drilling techniques for vertical borehole heat exchangers:
main classic drilling methods for all types of soil



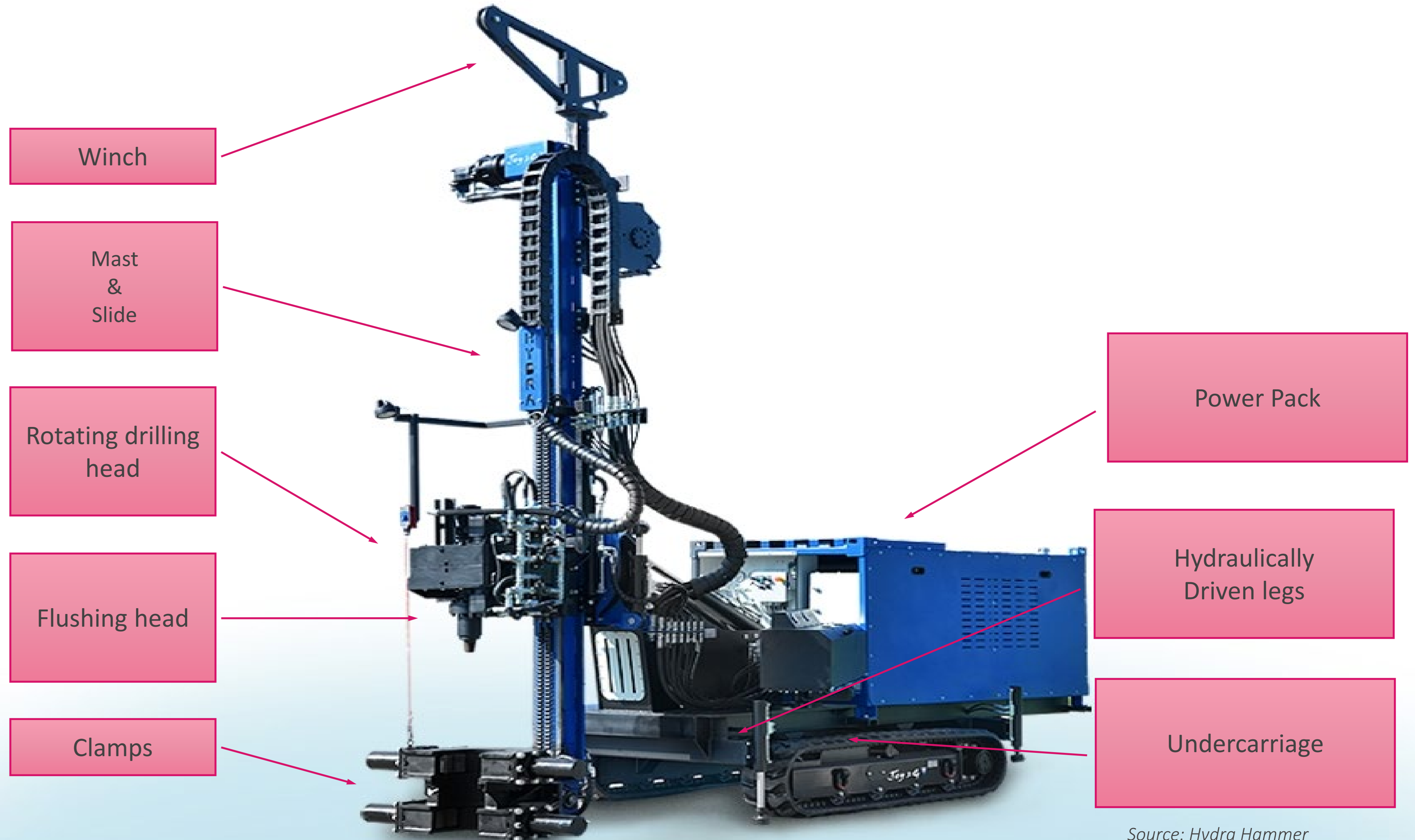
Cutting and loosening the soils with rotating tool
Bring up the material with drilling mud (H₂O + additives)



Breaking up the rocks with a rotating hammer driven by compressed air
Bring up the material with compressed air and foam

Principles

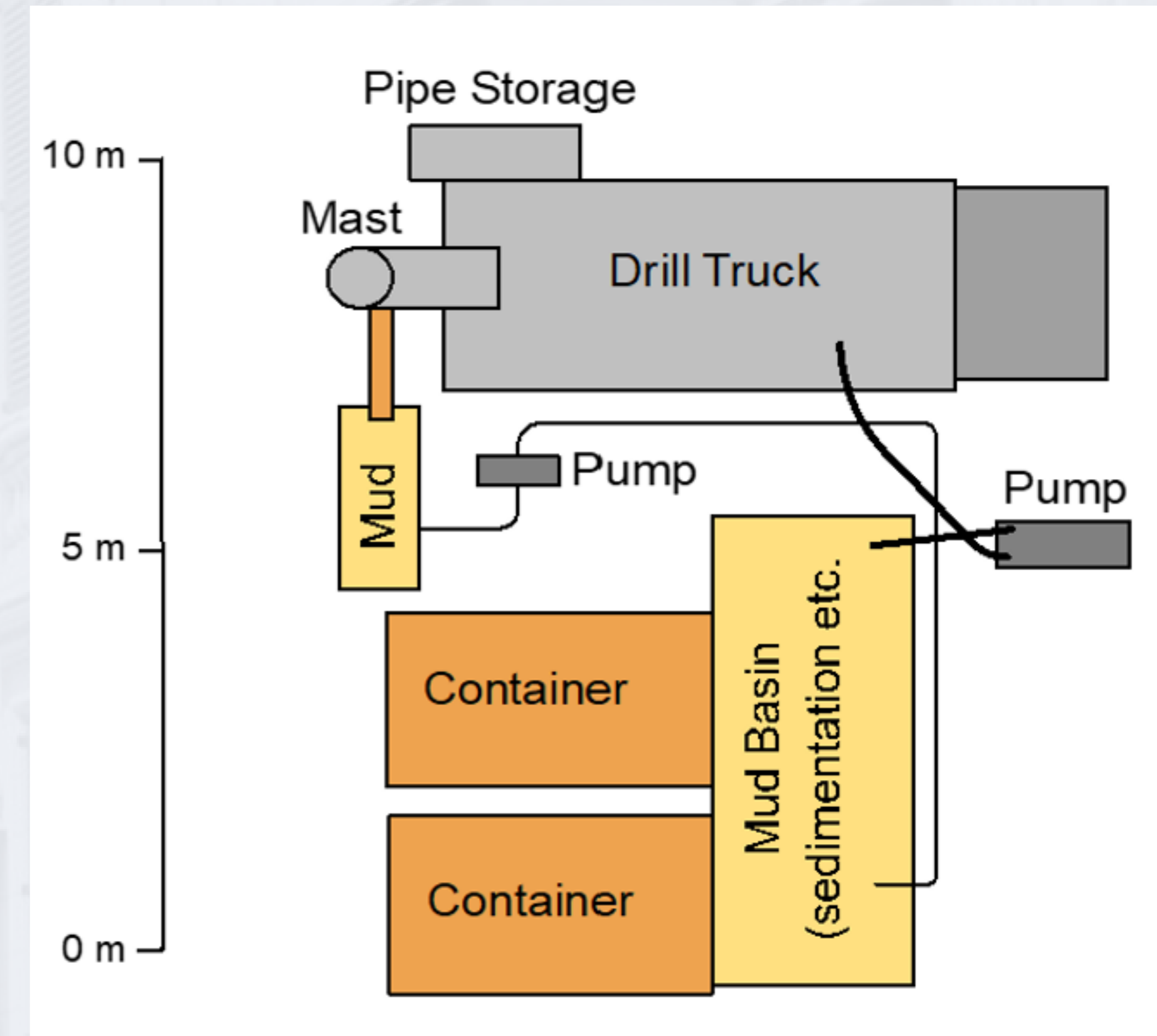
Drill rig anatomy and description of accessories: drill rig anatomy



Constraints for drilling in built environment

Space requirements

- Classical rotary drilling and ancillaries for depths up to ca. 200m need substantial space
- An area of at least 100m² is typical
- Around existing buildings, the space required is often not available



Smaller, versatile drilling rigs and fast drilling technologies in space restricted areas are needed for a wider application of shallow geothermal

A COMPACT, ROTATING AND VIBRATING DRILLING HEAD (RVD) FOR URBAN AREAS

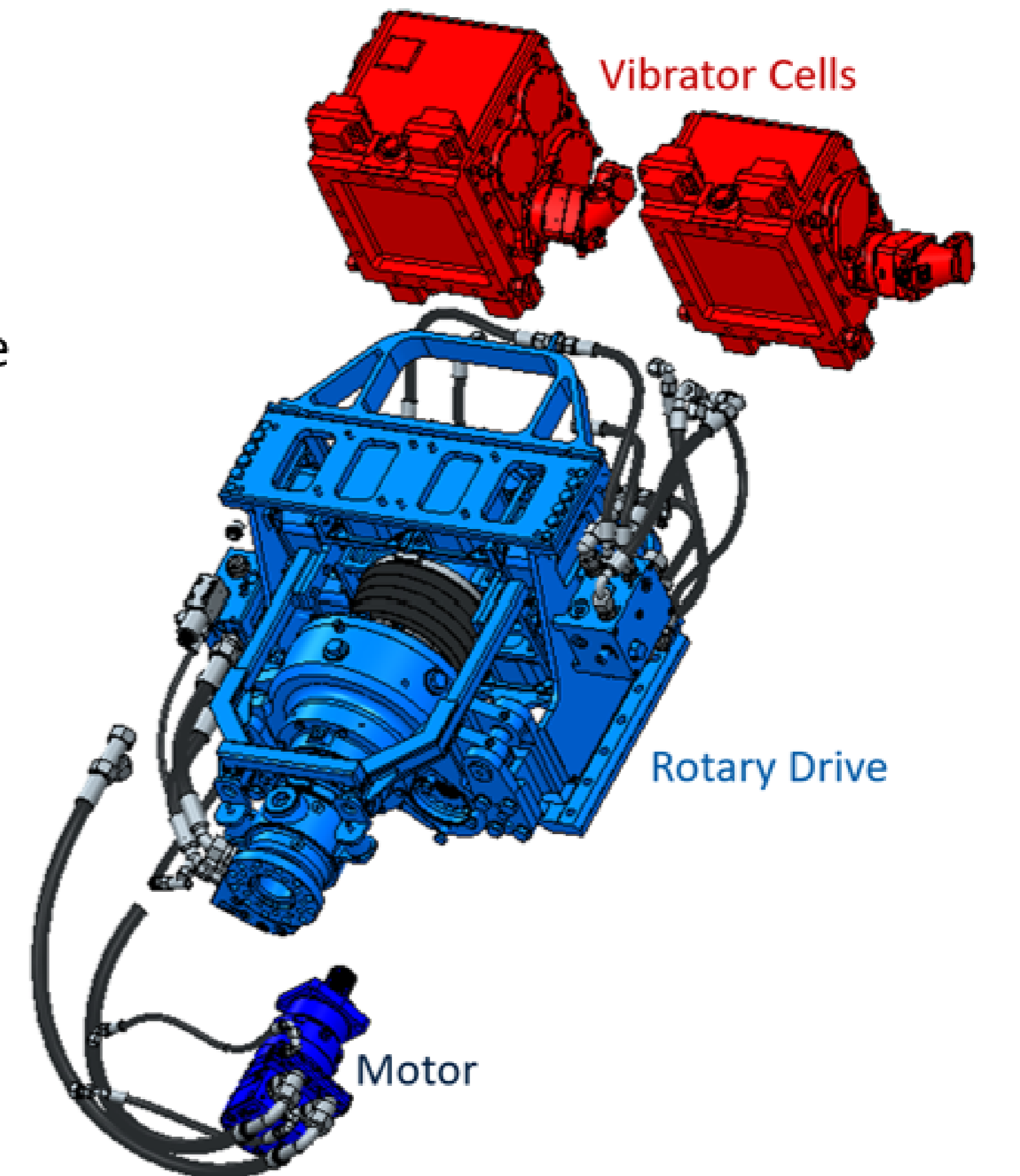
Configuration VibroDrill type VD80

Rotary Drive

- Could be equipped with 1 or 2 hydraulic drive motors
- A second motor could be installed
- 3 different motor sizes (480 / 677 / 940ccm) are available

Vibrator Cell

- Could be equipped with 2 or 4 unbalances
- In addition to the standard steel unbalances, tungsten unbalance with 25% more static moment are available
- Configuration as 80Hz / 105Hz / 130Hz VibroDrill (or on demand) by installing different unbalances



A wide range of configurations with the same basic machine is possible

Basics of Vibration Technology

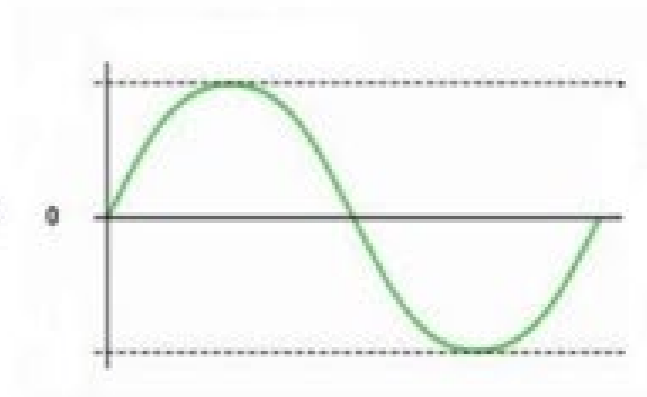
Excentric Moment

$$M_{exc} [kgm] = m [kg] \times r [m]$$



Amplitude

$$S [mm] = 2 \times M_{exc} / M_{dyn}$$



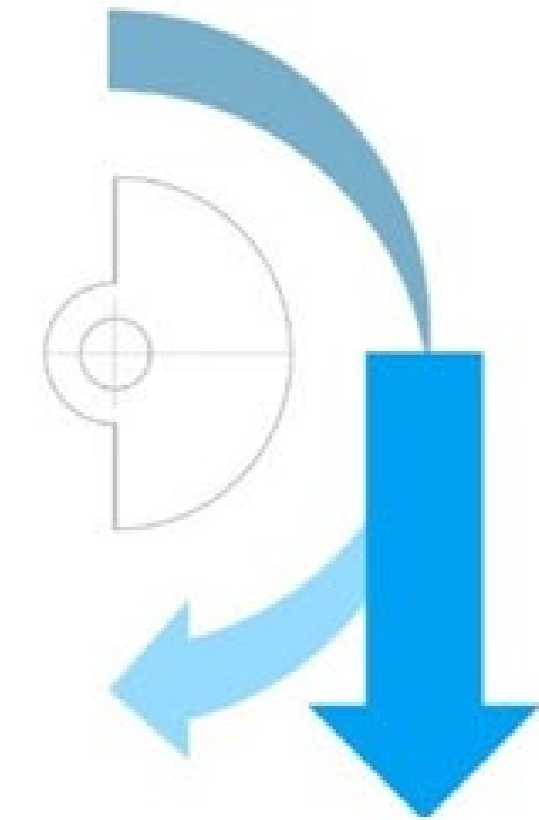
Rotation Speed / Frequency

$$n [min^{-1}] \quad f = n / 60 [Hz]$$



Excentric Force

$$F [N] = M_{exc} * \left(\frac{\pi * n}{30}\right)^2$$



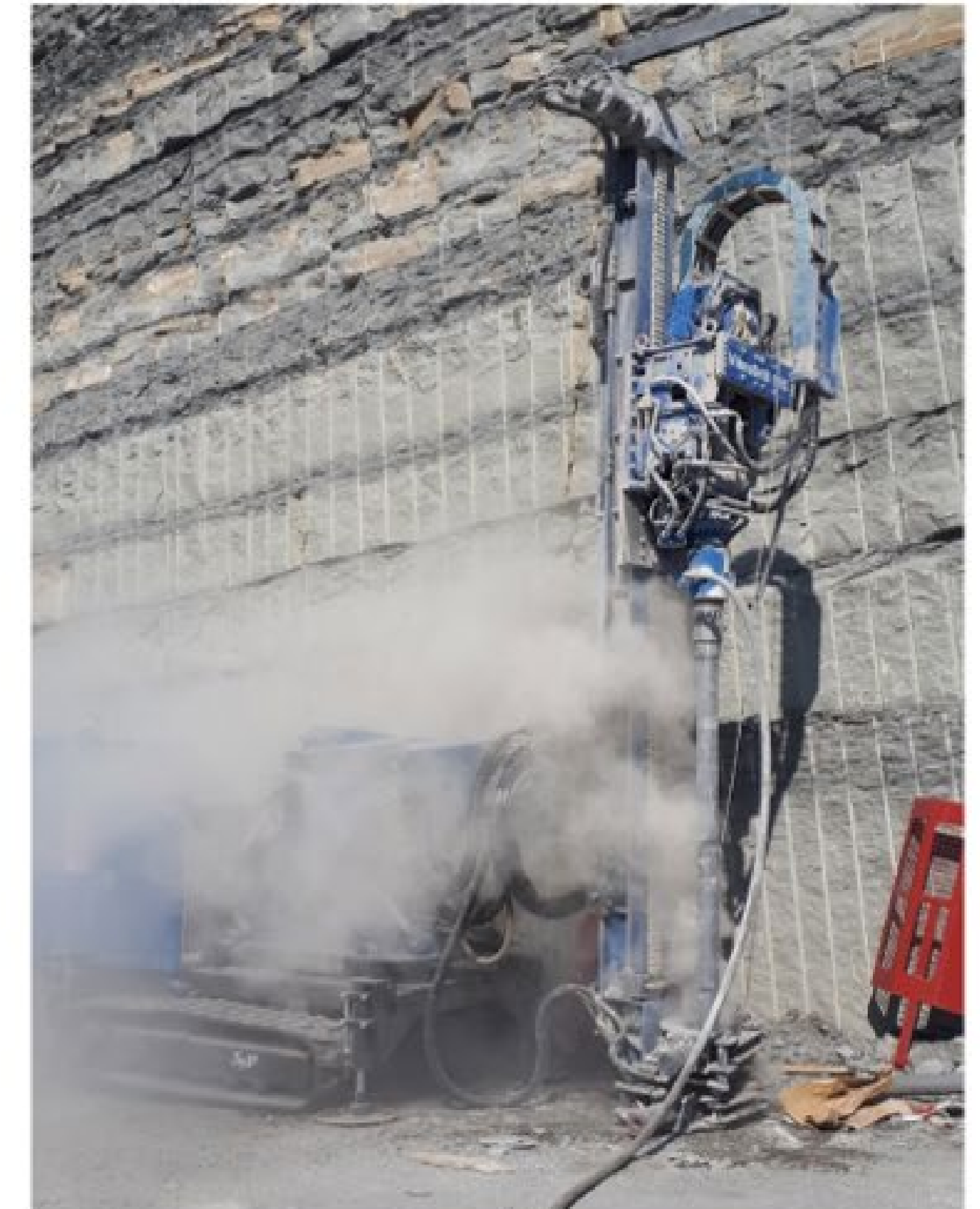
These are the 4 key figures for the efficiency of vibration drilling

Vibration Drilling – an innovative technology for the installation of geothermal probes

- Vibration Drilling means best drilling performance in almost all soils thanks to frequencies from 80 to 130 Hz.
- Vibration Drilling means low soil friction, long-life drill pipe threads, approx. 3-times the life of DTH drill bits, and precise vertical drilling that guarantees high vertical installation of geothermal probes (about 2% deviation only).
- Twice the drilling speed as comparable top-hammers and DTH-hammers and only one outer casing is required.
- Significantly reduced noise pollution (max. approx. 90dBA in 5m distance).
- Environmentally friendly due to lower consumption of drilling fluid.



Drilling with water flushing in clay, sand, gravel



Drilling with air in a slate quarry

Geothermal drilling sites and quarries in different countries

Demo drilling sites	Soil conditions	Flushing with	Depth	Casing diameter
<u>Molinella</u> - Italy	Unconsolidated soil mainly clay and sand	water	100 m	114 mm
<u>Firenzuola</u> - Italy	Soft/medium-hard rock (slate quarry)	air	102 m	114 mm
<u>Alsfeld</u> - Germany	Very hard rock (basalt quarry)	air	12 m	114 mm
Greystones – Ireland	Soft rock, medium-hard rock and hard rock	air	90 m	114 mm
La Valletta – Malta	Soft rock (sandstone)	water	100 m	114 mm
Udine - Italy	Medium-hard rock and very hard boulders	water	95 m	152 mm

The Terra-Infrastructures drilling method for co-axial Borehole heat Exchangers

1. Drill a borehole of $\varnothing 114\text{mm}$ using the rotary vibrating drill head,
2. Insert the $\varnothing 60,3\text{mm}$ co-axial heat exchanger,
3. Cementing and removing the drill string.

Specially developed grout:

- Fill borehole at 50% before inserting the heat exchanger,
- Give time to pull back drill string before hardening,

<u>Soil</u>	<u>Unconsolidated and soft rock</u>	<u>Medium to hard rock</u>
<u>Drilling fluid</u>	Water	<u>Compressed air</u>
<u>Drill bit</u>	To <u>loose</u> Open crown	<u>Fixed</u>
<u>Sites</u>	Molinella Udine	Firenzuola <u>Asfeld</u> <u>Greystones</u>
<u>Advantages</u>	High energy <u>extraction</u>	
	<u>No need for casing</u>	Reduce <u>compressor size</u> <u>Reduced drill bit wear</u>

A COMPACT, VERSATILE DRILLING MACHINE FOR INNOVATIVE DRILLING METHODS IN URBAN AREAS

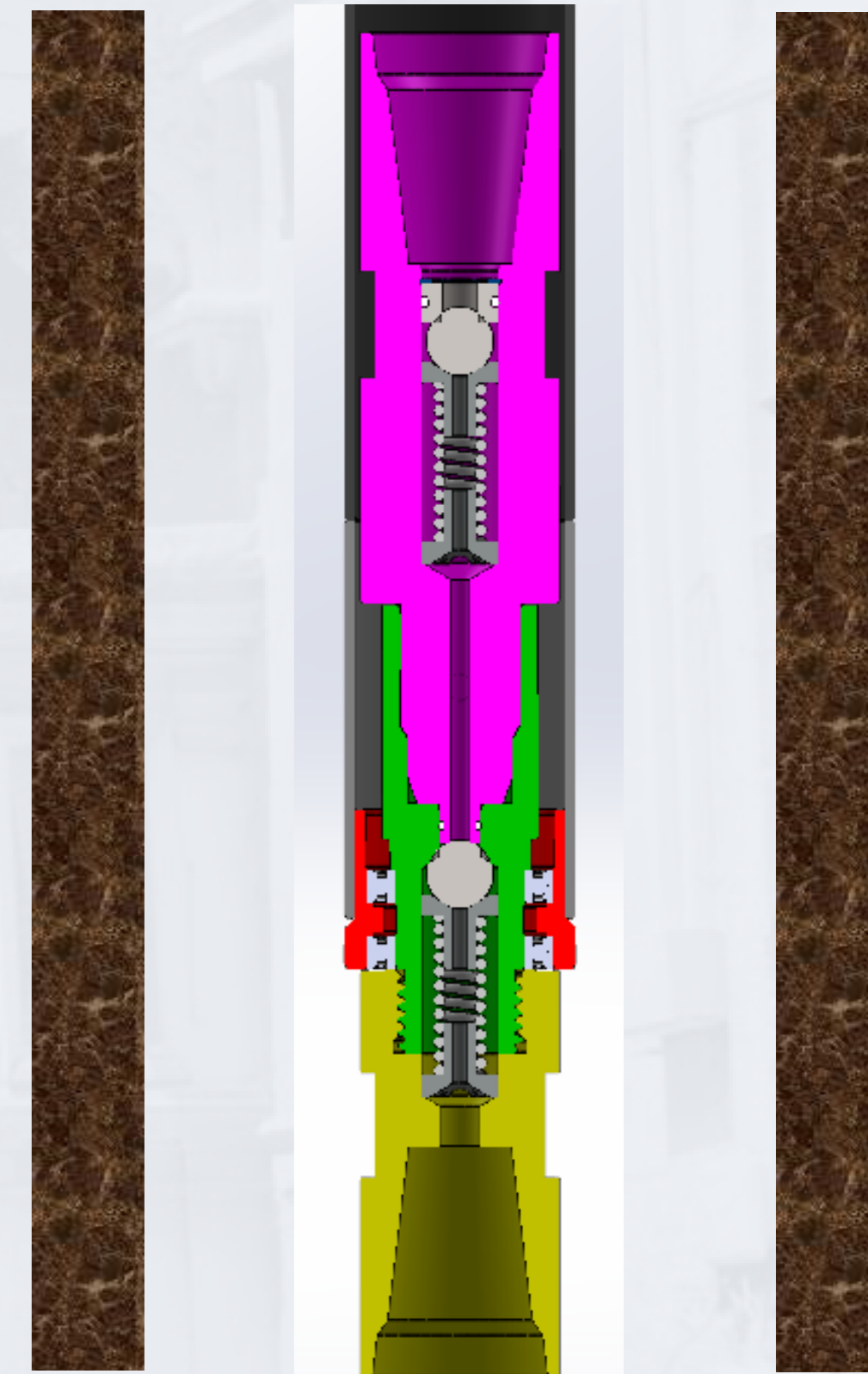
The Hydra-RED drilling method for co-axial Borehole Heat Exchangers

A rotating drill bit assembly (DBA) to lose is driven by the drill strings, from the drill rig:

- The external pipe of the co-axial heat exchanger is fixed to the DBA and is entrained into the soil,
- As the DBA advances in the soil, new drill shafts and external pipe are mounted.

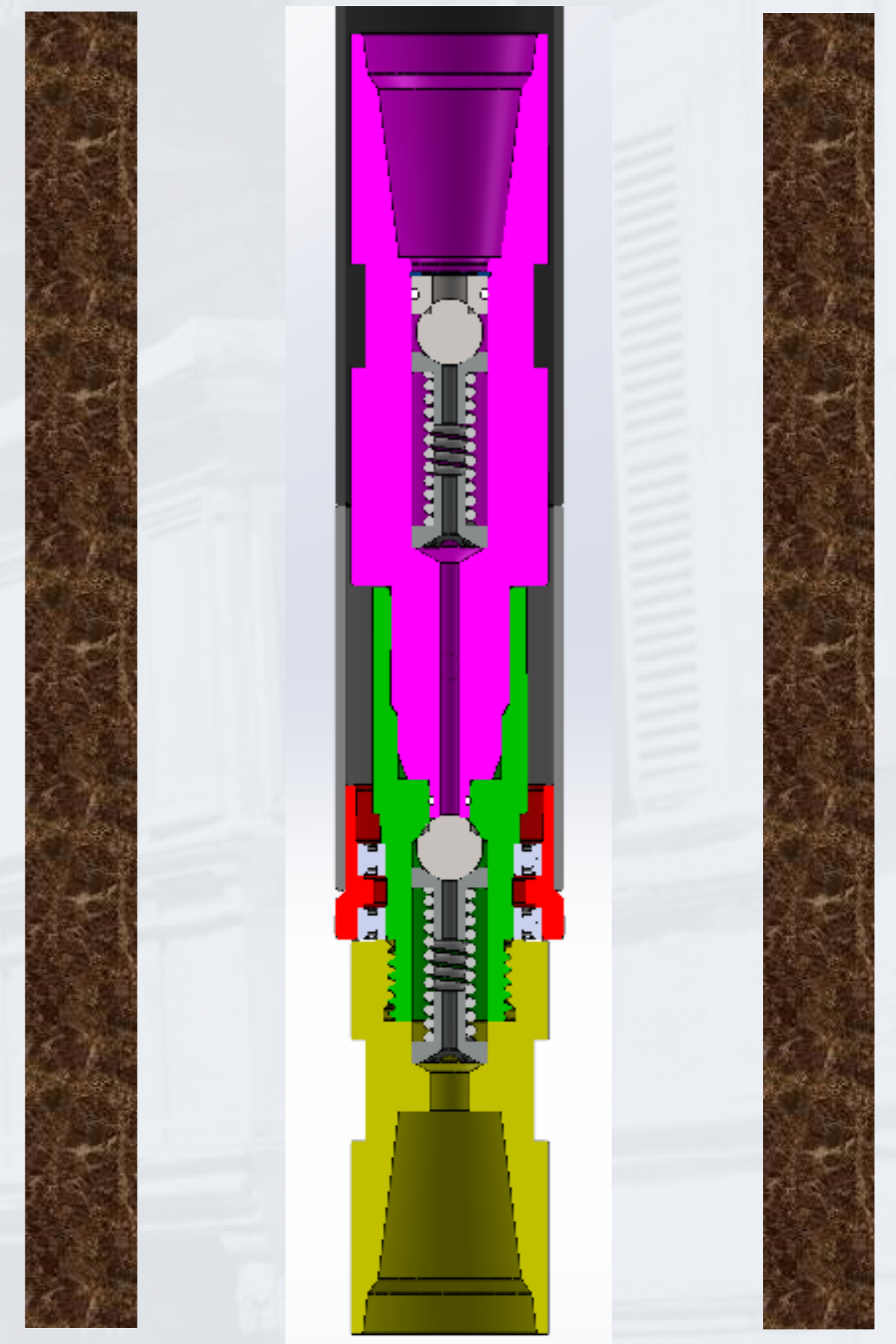
External pipe connections are:

- Hydra-lock (snap-ring + O-ring),
- Press fit,
- Welded,
- Water + additives are fed to the DBA through the drilling strings,
- The DBA is equipped with non-return valves,
- The DBA can be equipped with different drilling tools in function of soil type (blade bit, roller bit, PDC, etc.),
- The DBA can be with bearings in case of low friction soil or without bearings in case of high friction soil,



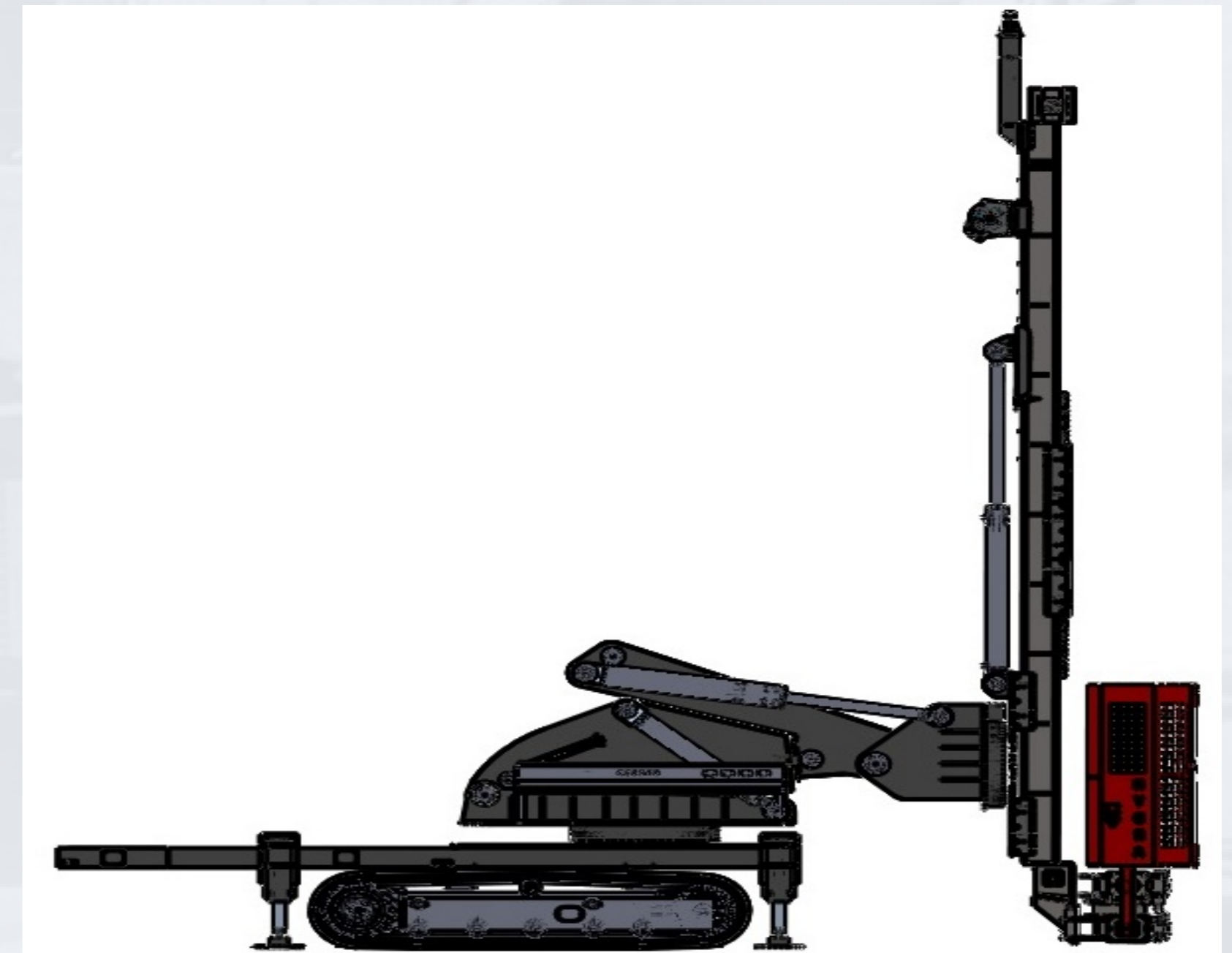
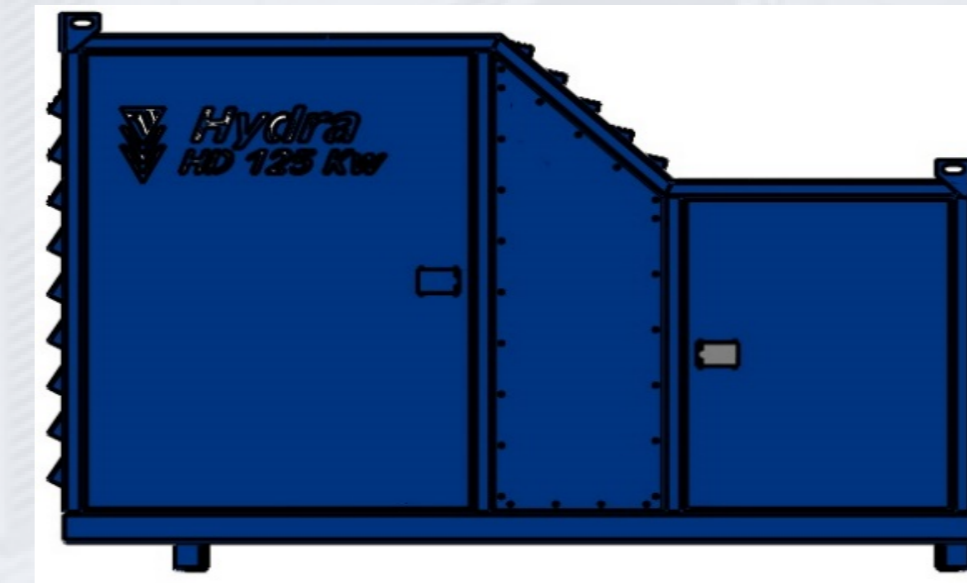
The Hydra-RED drilling method for co-axial Borehole Heat Exchangers

- When drilling depth is reached (80m, 100m, 120m) the borehole wall is flushed with water,
- Then grout (highly conductive, corrosion protective) is introduced until it is coming out at the top,
- Drill strings are removed and cleaned,
- Closing of the bottom hole of DBA:
 - Insert special design plug using the drill strings,
 - Drop 0,5m of specially designed grout,
- Insert the inner plastic pipe and mount the BHE head,



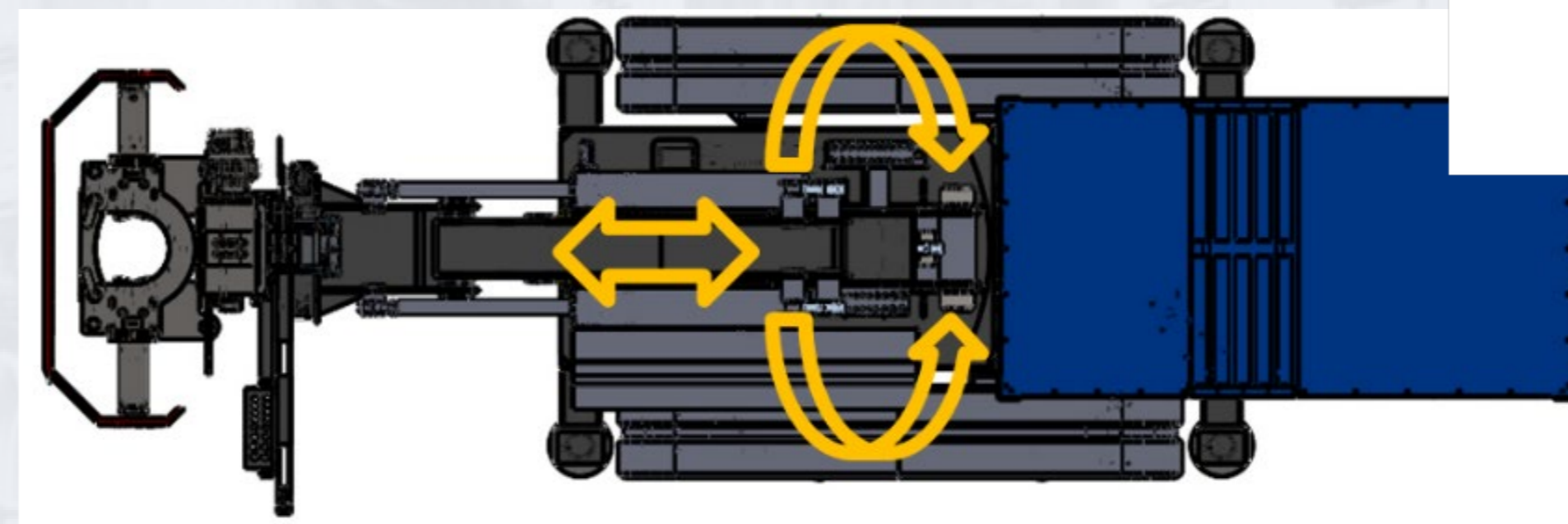
Features of the versatile and compact drill rig and accessories

- Machine brand and model: Hydra Joy3 P,
- Hydraulic power pack:
 - Diesel Engine 125kW,
 - Tier 4B emission levels (N45 ENT HW20),
 - HI-eSCR High efficiency selective catalyst reduction (patented) system
 - Responds to pollution barriers in built environment,
 - Dismountable power pack -> low levels of dust, noise, pollutants in the working area and possibility to drill in indoor environments,



Features of the versatile and compact drill rig and accessories

- Drilling mast movements: allow to drill multiple boreholes without moving the rig and to drill multiple inclined boreholes under an angle of 10-20°C. One disadvantage is the lower rigidity between the mast and the frame.
 - Rotation of the frame: 180° to left and to right,
 - Extension of the mast: 1,5m from the undercarriage,
 - Rotation of the mast: to the left and to the right,



Features of the versatile and compact drill rig and accessories

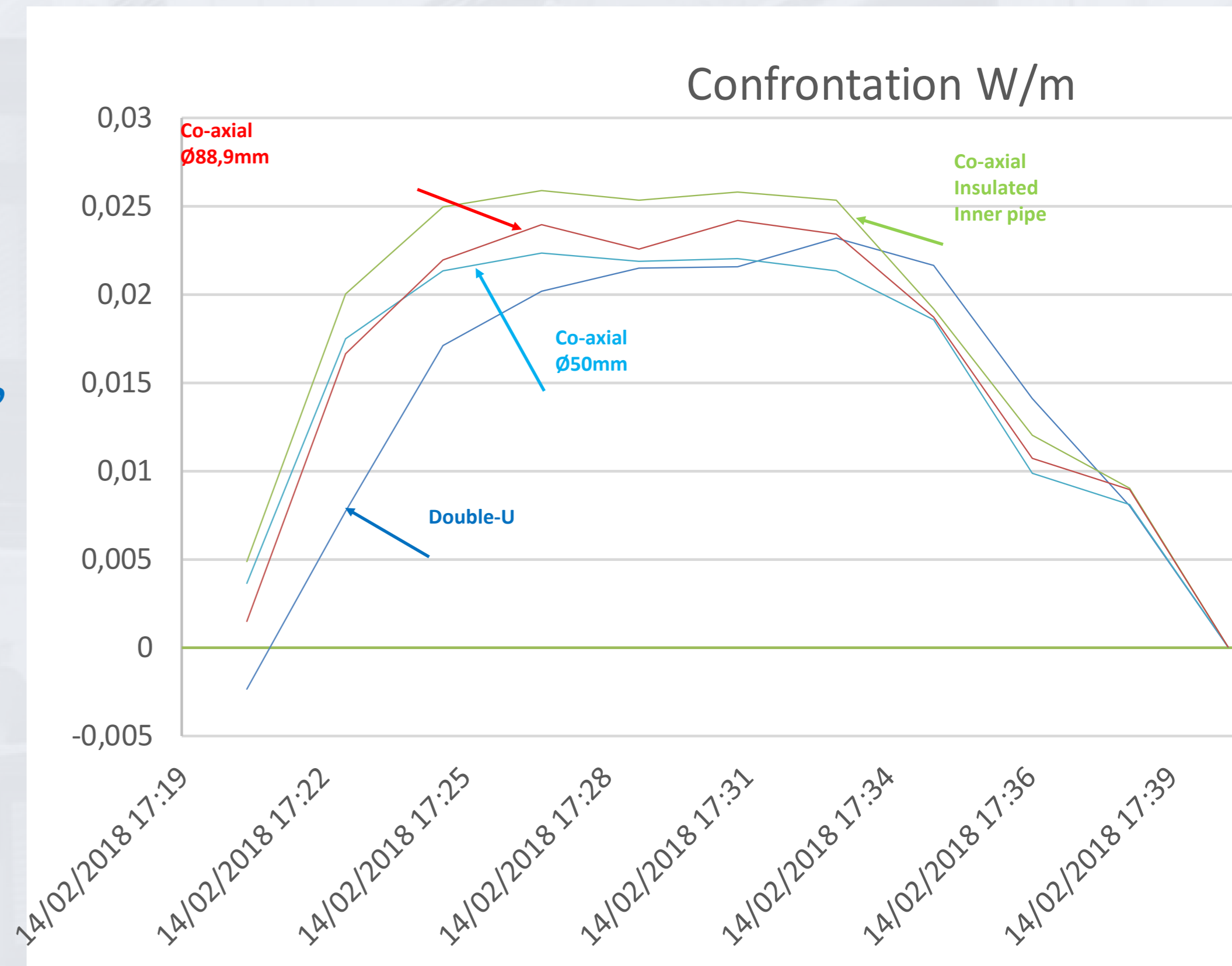
- Semi-automated feeder for rods handling: a magnet mounted on a support in turn mounted on an excavator can mount and dismount the rods
 - Reduces the rod mounting and dismounting times,
 - Reduces labour intensity and eventually number of operators,
 - Increase safety of operations (operate rig from excavator, hold rods even if power cuts of),



Features of the versatile and compact drill rig and accessories

Advantages:


- Patented in Italy n°102018000011157,
- No need to use casing to stabilize the borehole:
 - Use smaller compact rigs,
 - Lower investments and maintenance costs,
 - Higher accessibility in built environment (increased market),
- Shorter installation times:
 - Potential to install 2 boreholes/day,
- Higher energy extraction yields (proven in Cheap-GSHPs project):
 - 20-30% less meters to install,
 - 80m are equivalent to 100m Double-U probes,
 - No permit needed in Italy if depth \leq 80m,
- Possibility to install up to 4 inclined BHE's on one spot,
- Lower quantity of grout needed (\varnothing 100mm vs \varnothing 152mm),



THANK YOU

Luc Pockelé

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