UNDERGROUND CONSTRUCTION TECHNOLOGY
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PUSHING BOUNDARIES IN SMALL DIAMETER HARD ROCK MICROTUNNELLING

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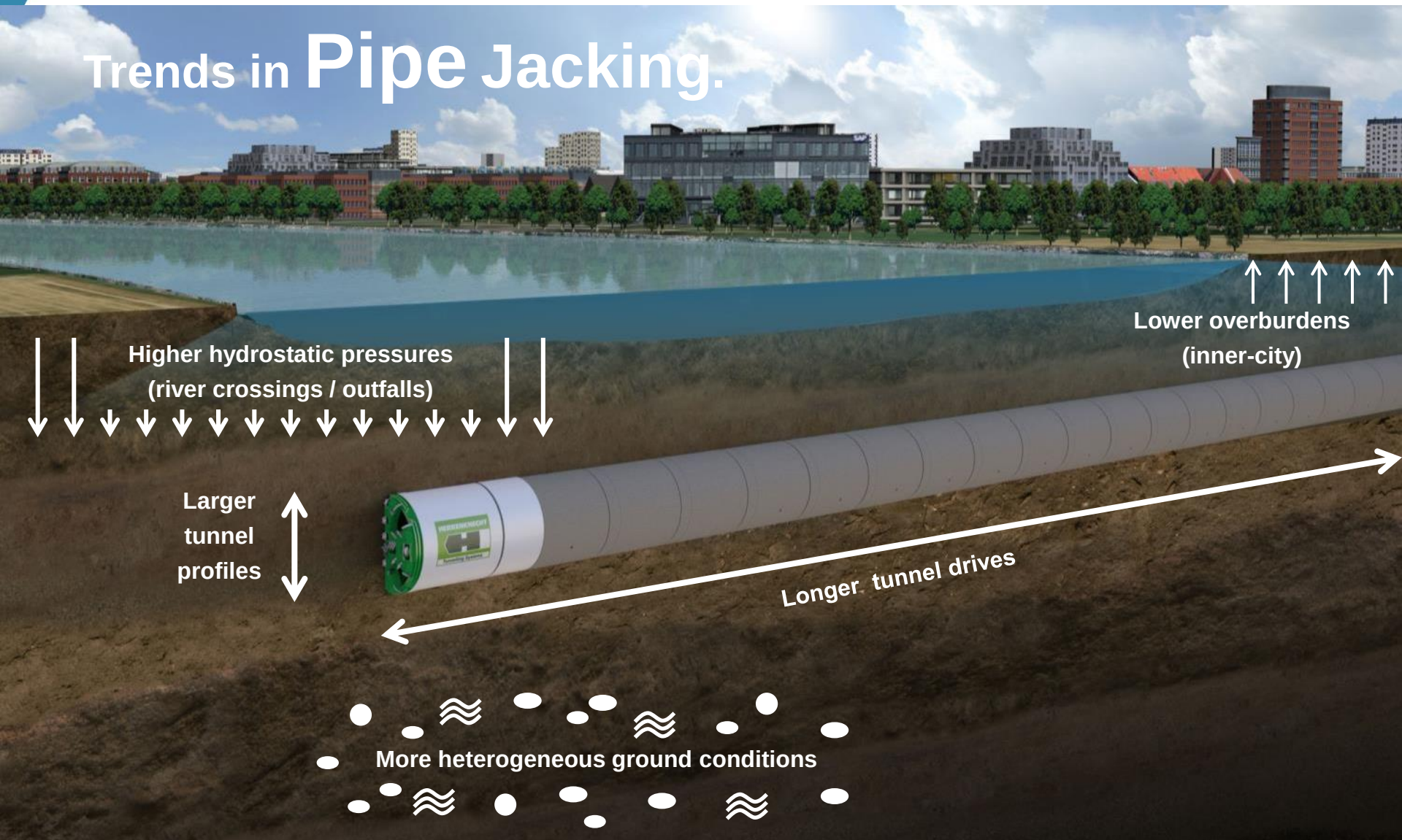
Nashville, July 2021

Microtunnelling in hard rock.

AGENDA

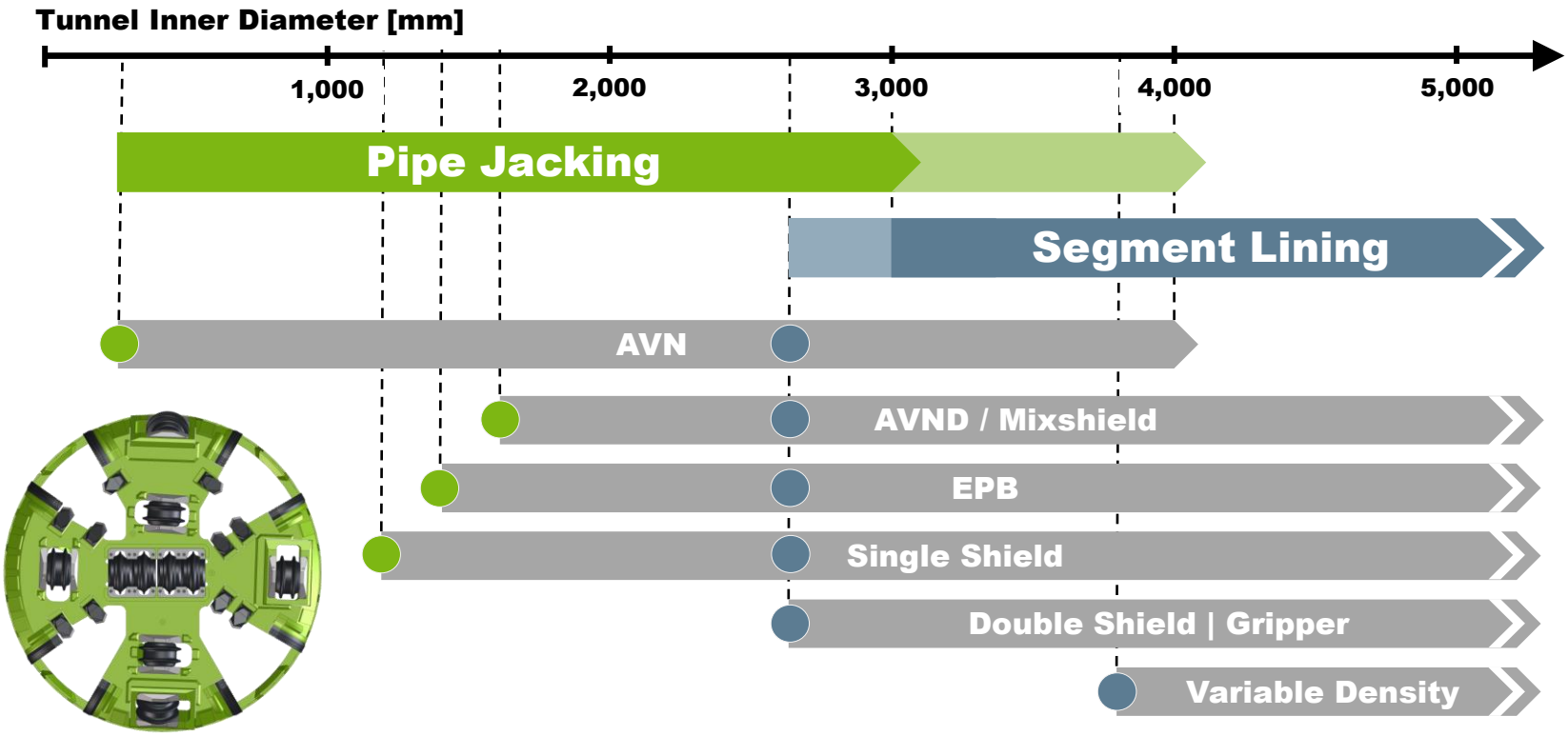
1. Introduction - Machine types and applicatons.
2. Rock investigation & Classification.
3. Machine- / Cutting Wheel- / Tool design for rock conditions.
4. Reference projects.
5. Outlook.

Trends in Pipe Jacking.



Small diameter tunnels.

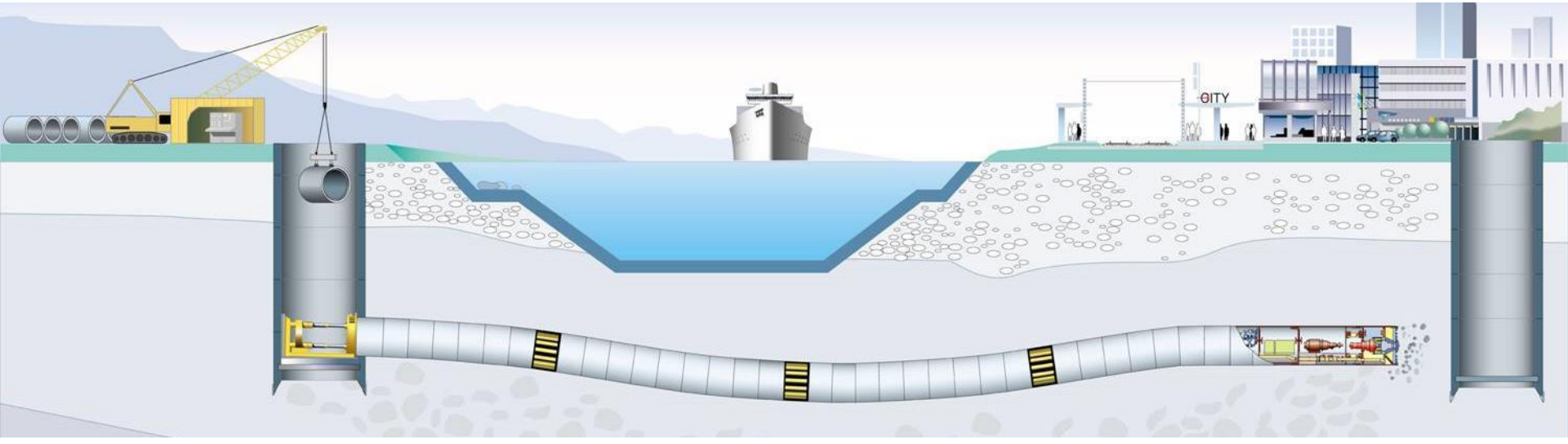
Machine Range.



Long-distance Pipe Jacking.

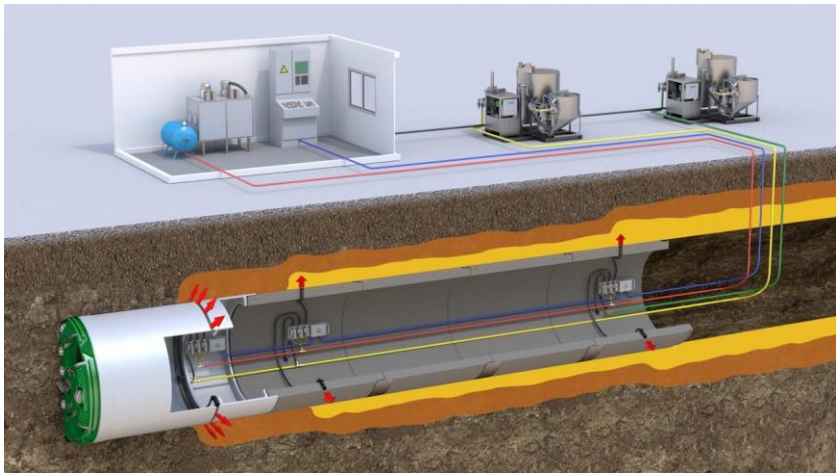
Increasing number of long distance projects on and offshore.

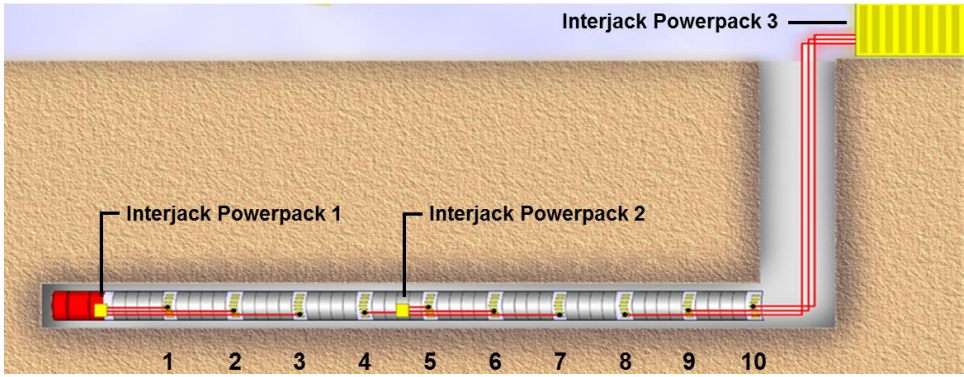
- More than 85 long-distance projects > 1,000m since early 1990s.
- 90% with Slurry machines (whereof 75% AVND technology)
- Europipe, Germany 1994: with 2.5km length still world record. ID 3000.
- Sochi 2013: 2km long outfall tunnel in the Black Sea. ID 2000.
- Mexico 2018: 2,246m Outfall for Pipeline. ID 2600.



Pipe Jacking Procedure.

Components for long-distance Pipe Jacking.





Bentonite lubrication system

- reduce skin friction
- Volume-control: adaptable bentonite distribution throughout a changing geology

Interjacking stations

- installed in regular intervals along the tunnel route
- To reduce jacking forces of jacking station in the lauch shaft
- Jacking cylinders are dismantled when tunnel is finisehd

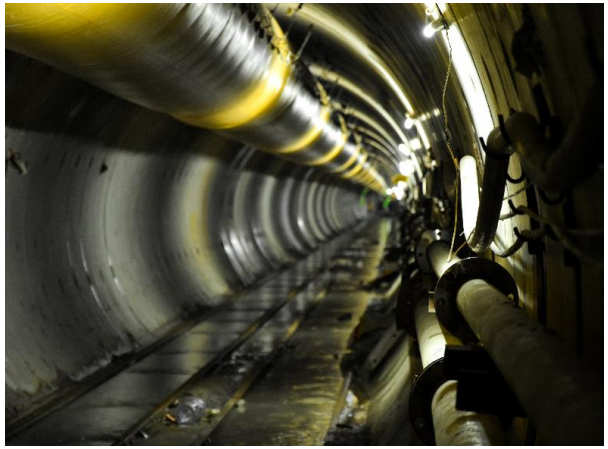
Long-distance Pipe Jacking.

Altamira Landfall, Sur de Texas – Tuxpan Pipeline.

- M-1275M, AVND2000, OD3200 (Pipe ID 2600)
- Tunnel length: **2.246m Sea Outfall**
- Geology: sand, silt, clay
- Groundwater pressure: up to 3 bar
- Contractor: Eurohinca
- End position reached: July 27th, 2018
- Best daily performance: 25,5m
- Best weekly performance: 111,2m

Small diameter tunnels.

Pipe Jacking vs. Segment Lining.

Pipe Jacking	Segment Lining
	
▪ Less joints per linear meter ▪ Less required personnel ▪ Remote-control → no personnel in tunnel → higher level of safety ▪ Smaller shafts required ▪ Lower lining costs	▪ Longer drive lengths possible ▪ Less shafts required ▪ Higher flexibility for tight curve drives ▪ Tunnel not moving → less friction → lower geological risk

Microtunnelling in hard rock.

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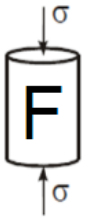
Geotechnical data.

Crucial for selection of appropriate machine concept.

Geotech investigation:

rock classification.



- **Unconfined Compressive strength (UCS)**
  measured in Mega Pascal (MPa); value for the axial force needed to break a rock.

- **Tensile Strength (TS)**
  Mega Pascal (MPa); value for the radial force needed to break a rock. In combination with the UCS, the rock can be classified as „brittle“ or „ ductile

- **Cerchar Abrasivity Index (CAI)**
  indication for the abrasivity of the rock. A steel needle is scratched over a rock specimen. The wear of the needle is measured to receive the CAI value (ranges from 0 to 6).

- **Rock quality Designation (RQD)**
  modified core recovery percentage, measures the length of sound rock pieces (> 100mm), gained in a core run.

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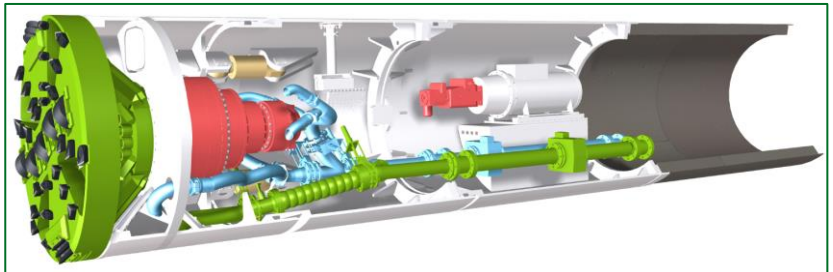
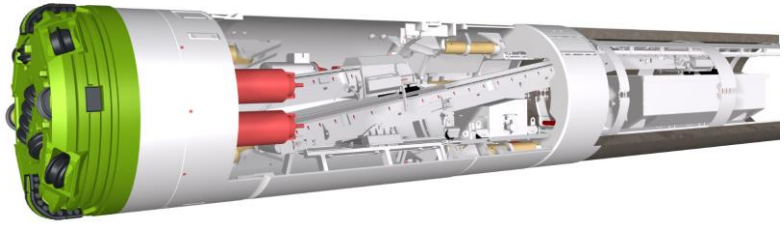
Small diameter tunnels.

Main Shield types.

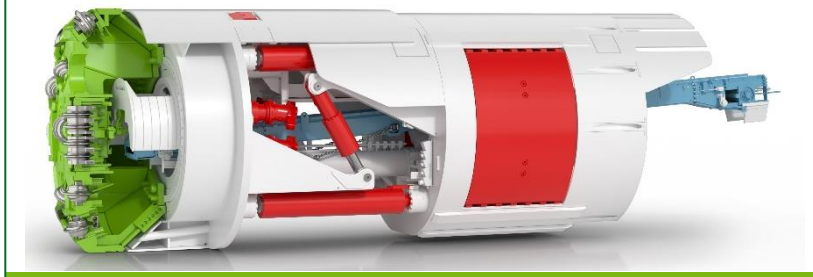


AVN | AVND
Cutting wheel: full face
Face support: slurry suspension
Muck transport: slurry circuit (separation needed)

EPB
Cutting wheel: full face
Face support: earth pressure
Muck transport: screw conveyor, belt, muck skip



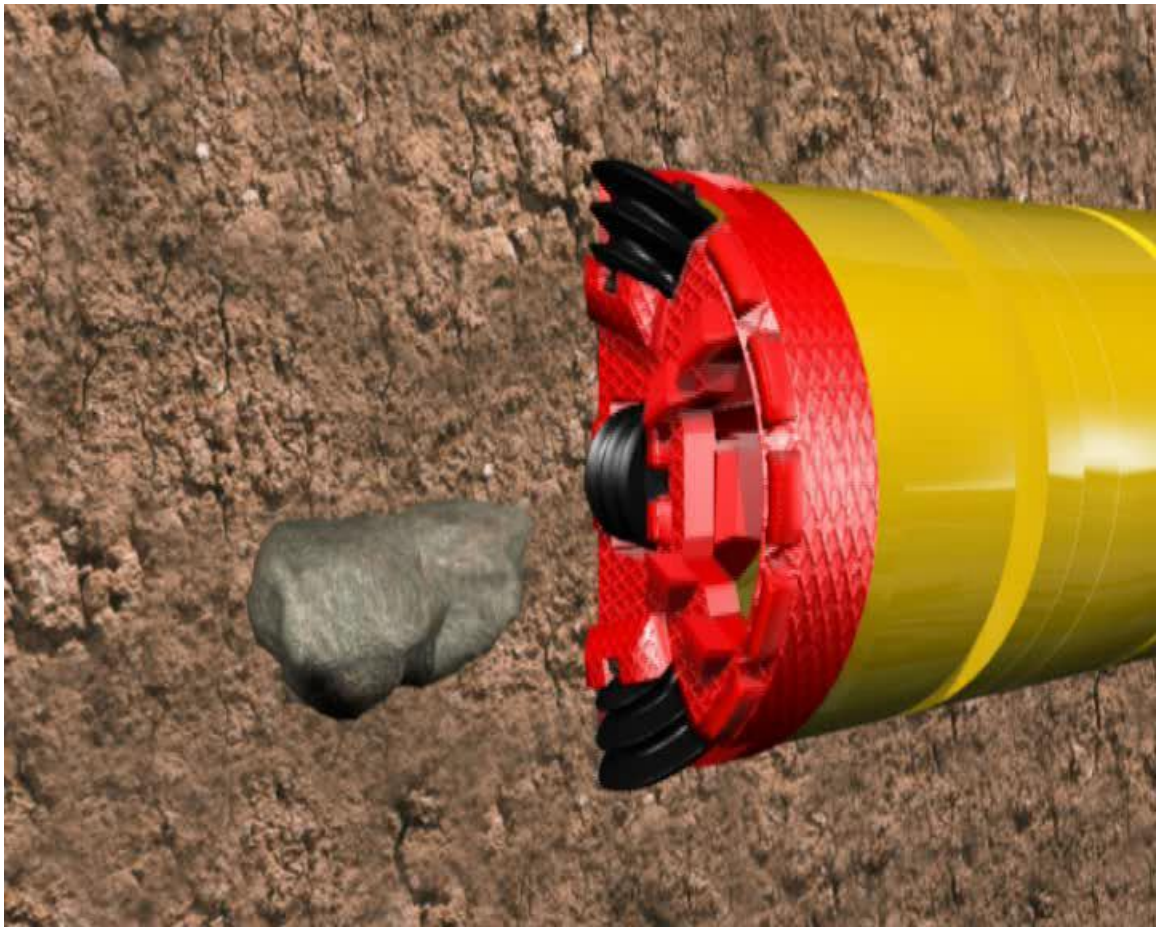
Shielded TBM
Cutting wheel: full face
Face support: mechanical by cutting wheel
Muck transport: conveyor belt, muck skip



Gripper TBM
Cutting wheel: full face
Face support: mechanical by cutting wheel
Muck transport: conveyor belt, muck skip

Cutting wheel / tools desing.

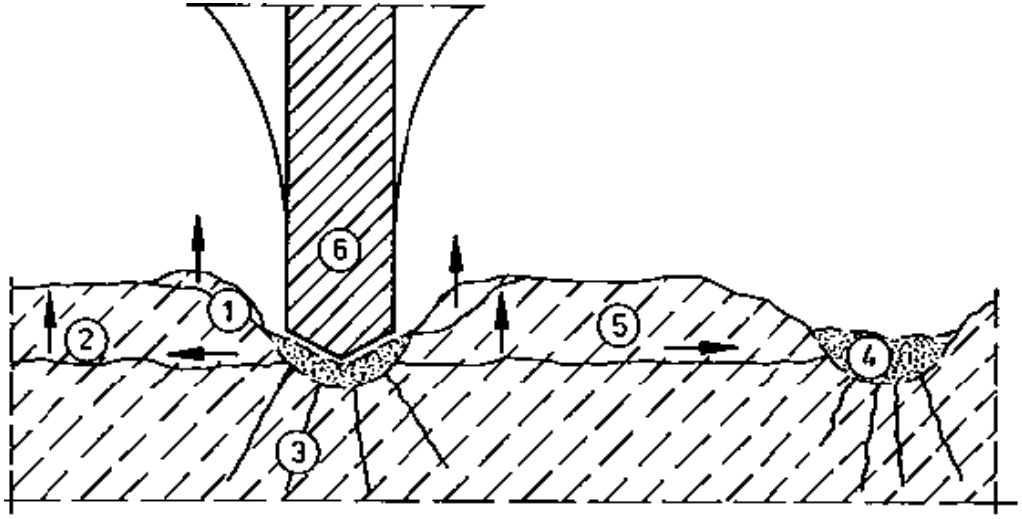
Cutting process.



Cutting wheel / tools desing.

Rock cutting/chipping process.

- The cutterhead of Hard Rock TBM´s are equipped with cutting discs.
- The cutting discs are pushed against the rock with up to 267kN per cutter ring
- Spalling caused by tension cracks
- Shear failure
- Formation of radial cracks under the discs



Disc Cutters

Type: Mono Block (>6“)

Standard (hardened) HD (Heavy Duty)	HF (Hard Facing)	TCI HF (Tungsten Carbide Inserts and Hard Facing)
		
Soft-hard rock / mixed ground gravel	Soft ground / gravel	Soft rock / mixed ground gravel

- The cutter ring can be optimized according to geological conditions

Disc Cutter

Type: Mono Block / TBM 1200 Pipe Jacking

Hard rock cutter heads.

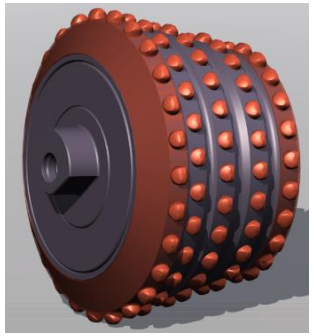
New cutterheads with TCI inserts.

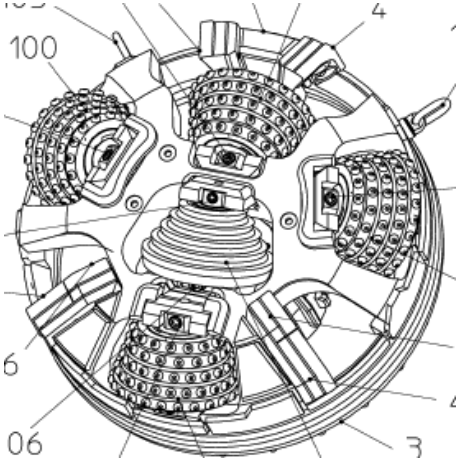
- For AVN 400 / 500 / 600 / 700
  - **suitable for retrofitting** of existing AVN machines (AVN 400 – AVN 700)
- Cutterhead equipped with **TCI cutter discs:**
  - high degree of wear-resistance for **longer drives**
  - for hard rock conditions with high compressive strengths **up to 150MPa**
  - with high **boulder cutting ability**

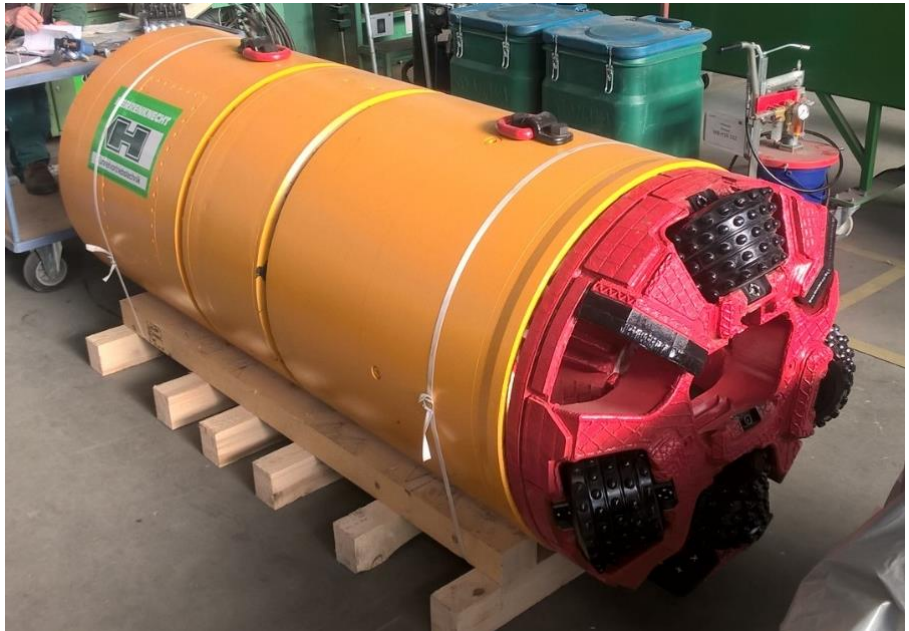
Microtunnelling in Hard Rock.

New AVN800 | OD975mm (38.4“).

- For **hard rock**, compressive strength: up to 200MPa **(29,000psi)** – 4 times
- Stronger main bearing **(89to)** – 3 times
- Extended **drive length:** 150-200m **(660ft)** – 2 times
- Increased **rotation speed** of cutting head: up to **30rpm** – 4 times
- **Torque** equal to current machine AVN800B
  - but more power **90kW** – 1.6 times
- TCI cutters



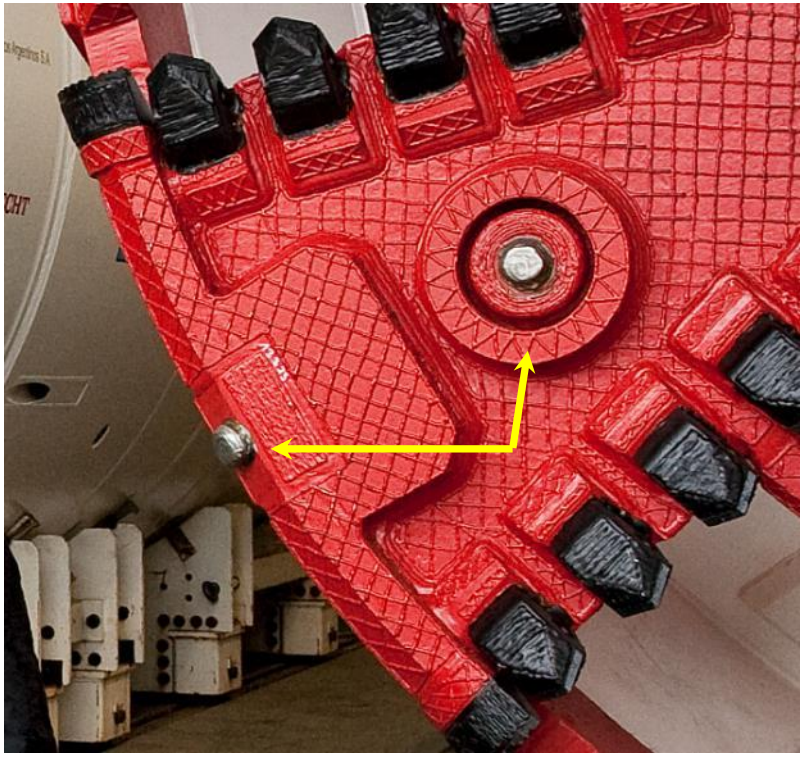




Hydraulic wear detection.

Integrated in steel structure of the cutter head.

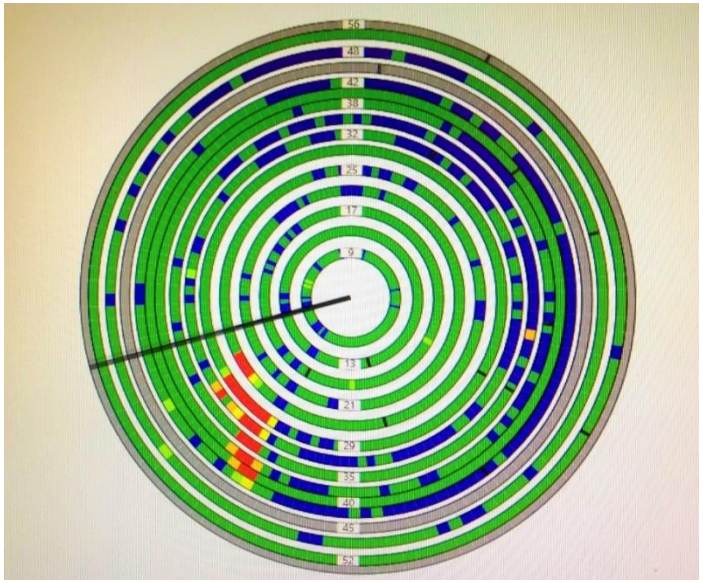
- M-1453M, M-1454M, EPB3600, OD4150

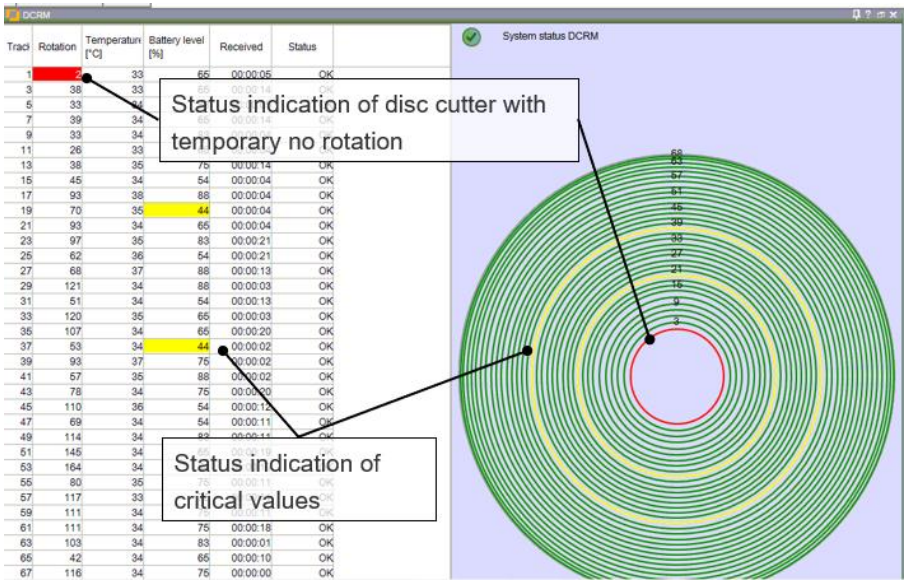


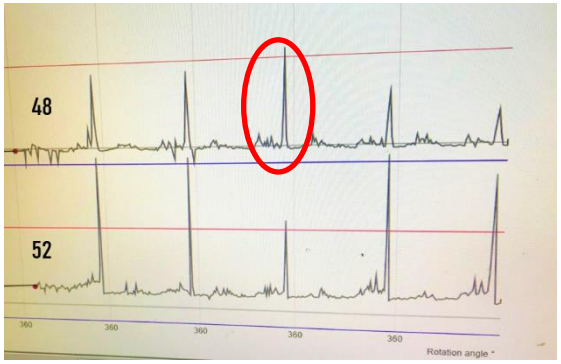
Large Diamter TBM‘s – Disc Cutter Monitoring systems.

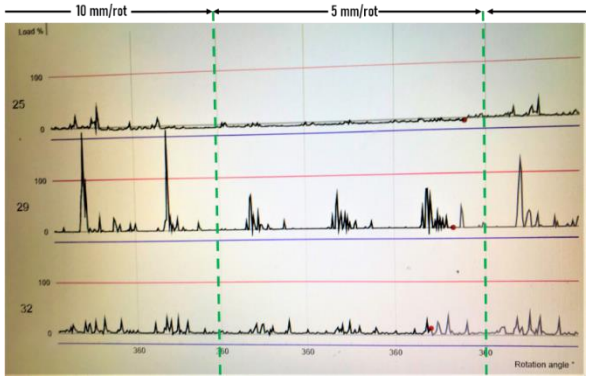
DCLM – Load Monitoring

DCRM – Rotation Monitoring



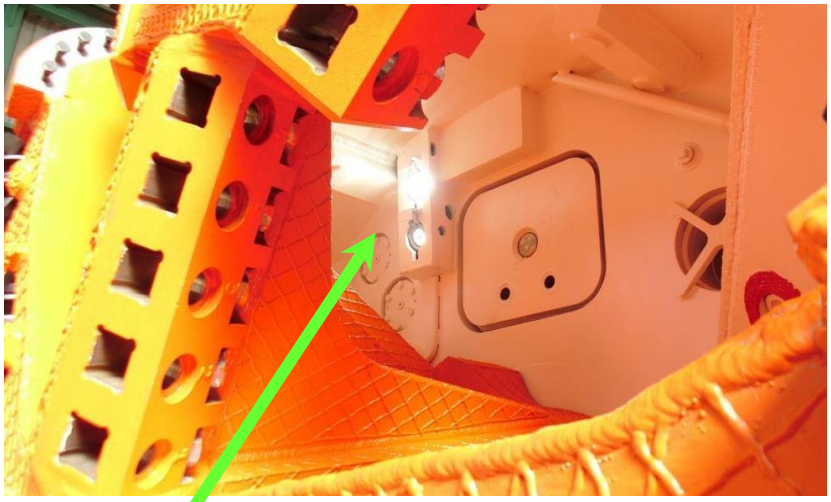






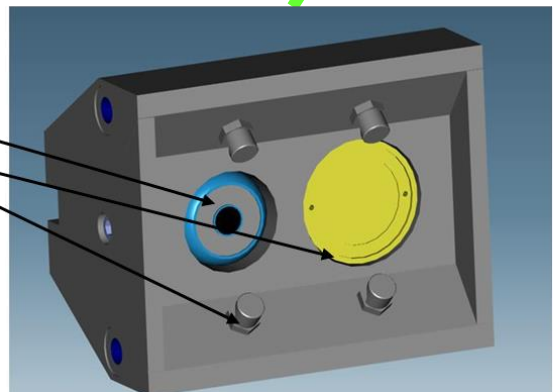
Camera system.

Provides insight to the excavation chamber.



Features

- Camera
- Light (LED)
- Cleaning nozzles



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New AVN800B Hard Rock – First Project Melbourne, Australia.

Contractor: Bothar Boring.

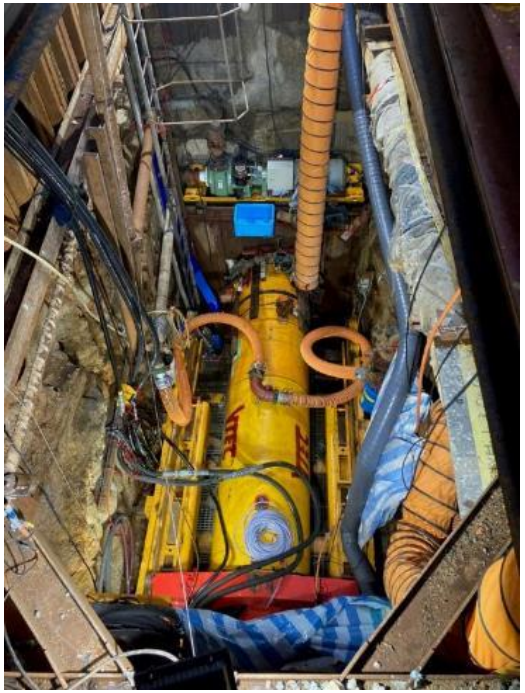
- M-2287M, AVN800B hard rock, April 2019
- Drive length: 40m, 100m
- **Geology:** blocky basalt, tuff
  - UCS: 185MPa
  - tensile strength: 15 MPa
  - Abrasivity: 3,3 CAI

Cutters after 140m of tunnelling

New AVN 800 Hard Rock.

Project Hong Kong.

- M-2496M, AVN 800 XC Hard Rock, OD 975 mm
- Location: Wan Chai, Hong Kong
- Project: installation of water main
- Drive length: 107m
- Curve radius: 153m
- Geology: rock grade II, granite
  - UCS **up to 200MPa**
- Client: Water Supplies Department of Hong Kong
- Contractor: VTEC



Outlook.

- Mechanised tunneling has become safer and faster compared to Drill & Blast operations in many areas.
- New cutting tool and wheel designs lead to faster installations.
- Wear protection and wear monitoring were key succes factors.
- New cutting tool designs open up the application range for smaller diamters and longer distances like the new AVN 800 Hardrock, Direct Pipe® and E-PowerPipe®.
- AI (Artificial Intelligence) has the potential to foster the development to safer, faster and more economical installations in the future.
- …

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