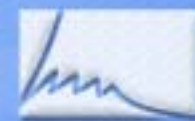




Soft Ground Tunneling with Tunnel Boring Machines

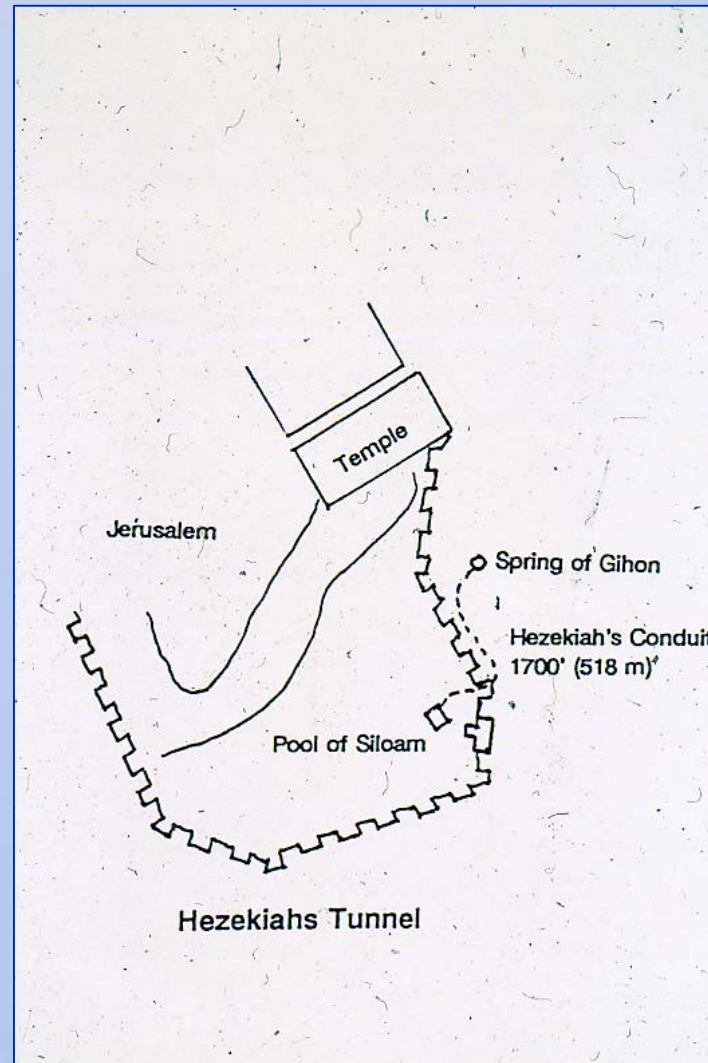
Jan 2009



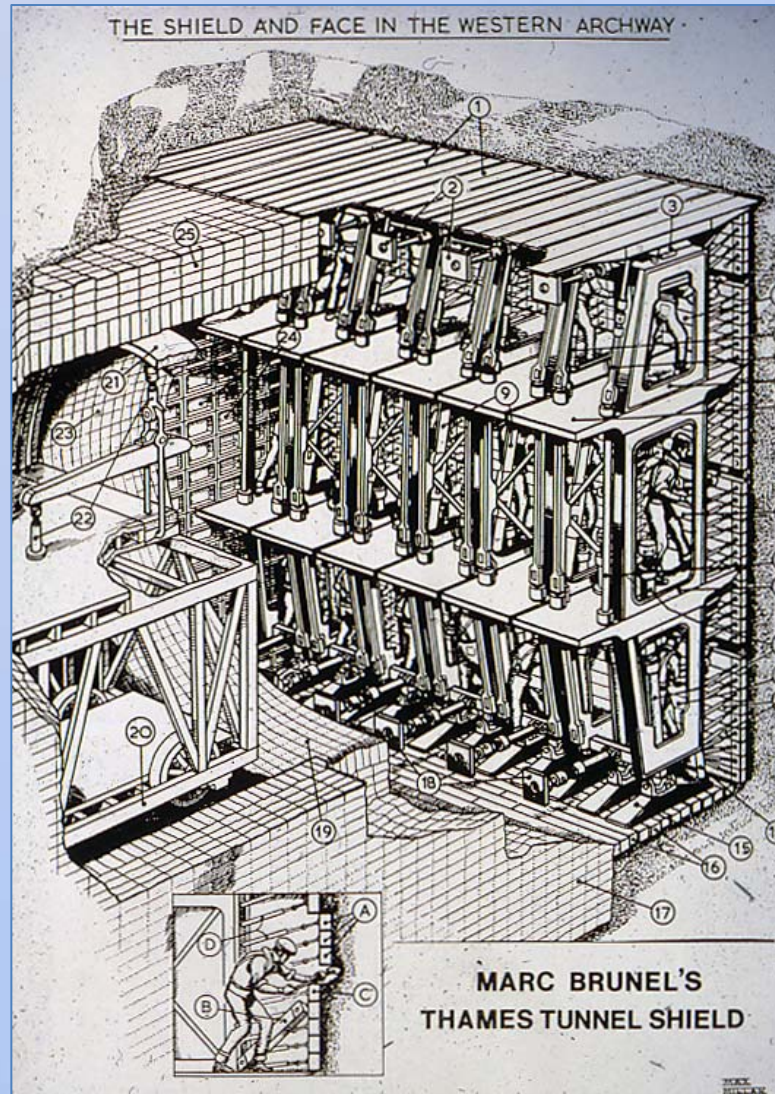
Hatch Mott
MacDonald

www.hatchmott.com

Hezekiahs Tunnel

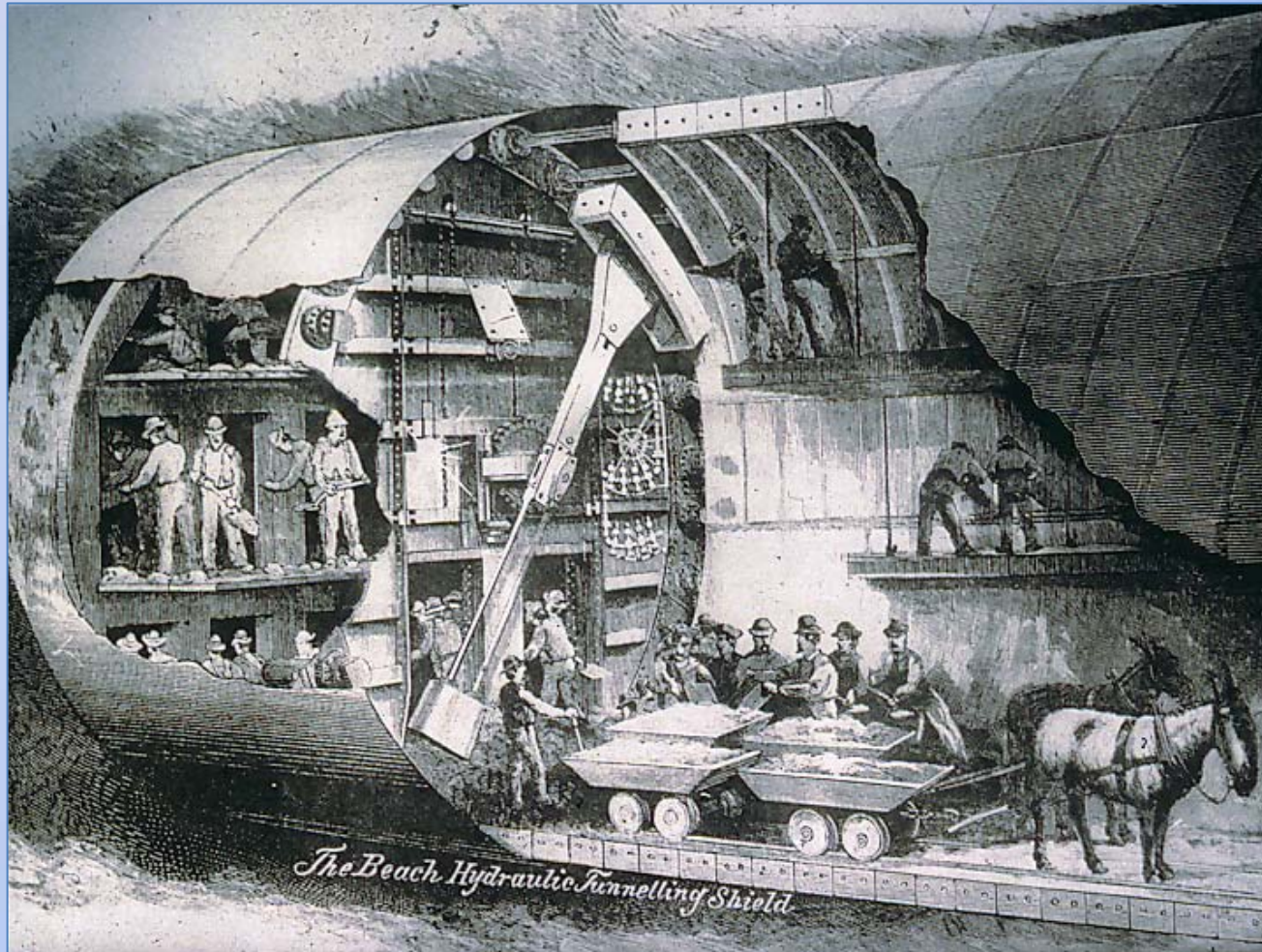


Brunel's Shield

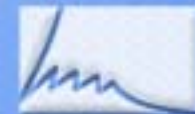


1825

St. Clair River Tunnel

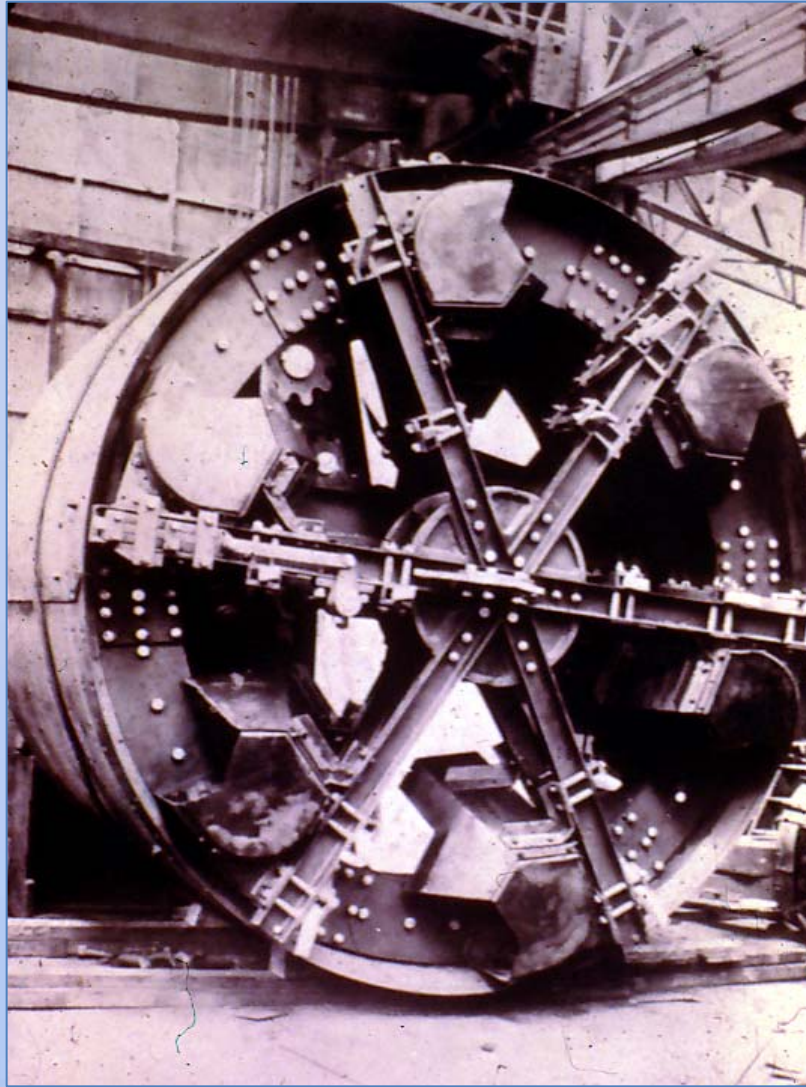


1880

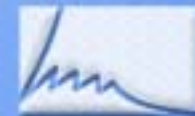


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Soft Ground TBM



Circa 1930's



Hatch Mott
MacDonald

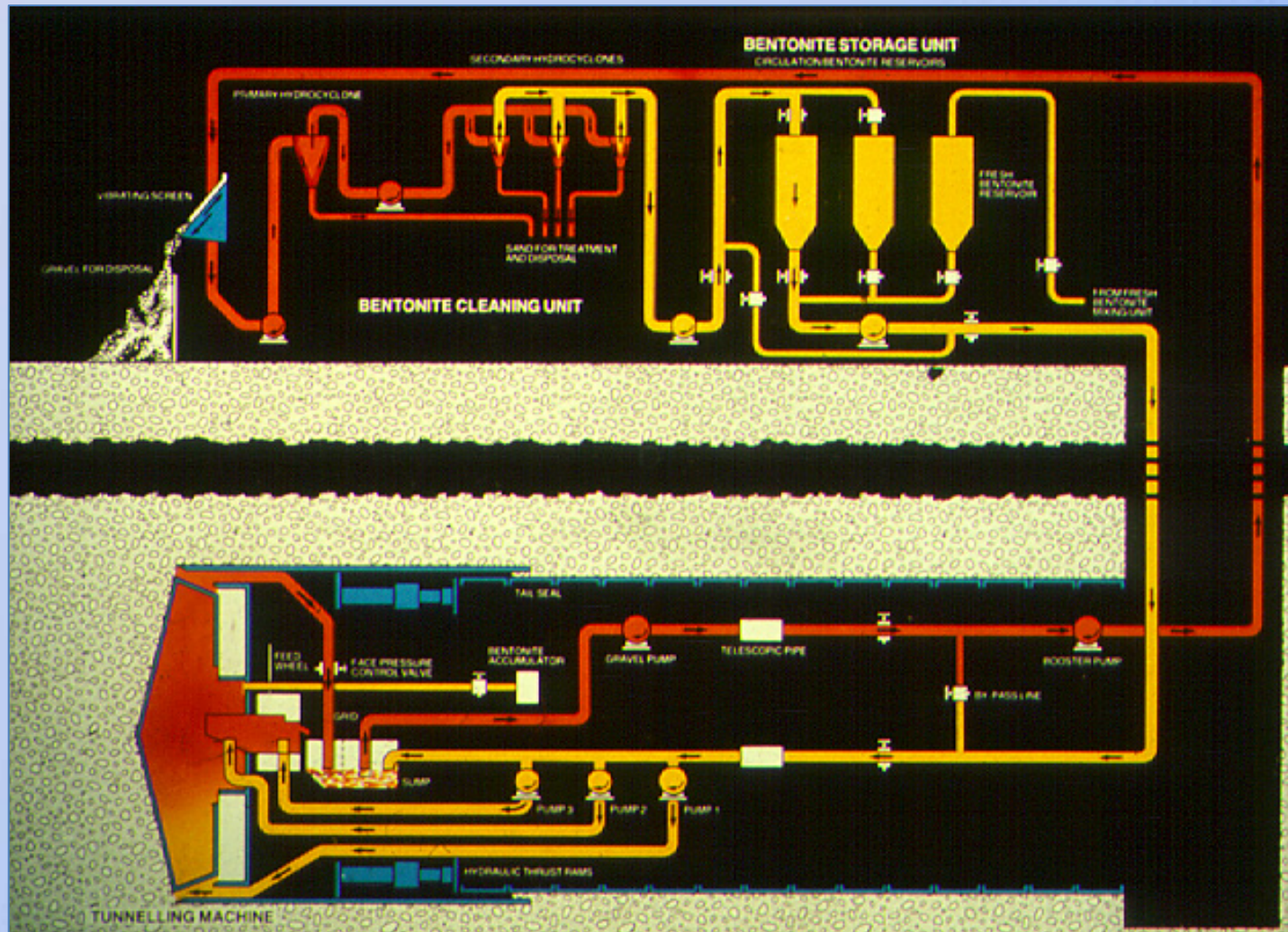
CLOSED FACE TBMs

- For use in poor ground conditions, sands, silts, soft clays below the water table
- Replaced the use of compressed air
- Controls the ground and protect the work force while installing the tunnel support.
- Two main types:
 - Slurry
 - Earth Pressure Balance

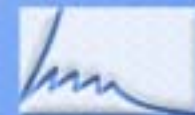
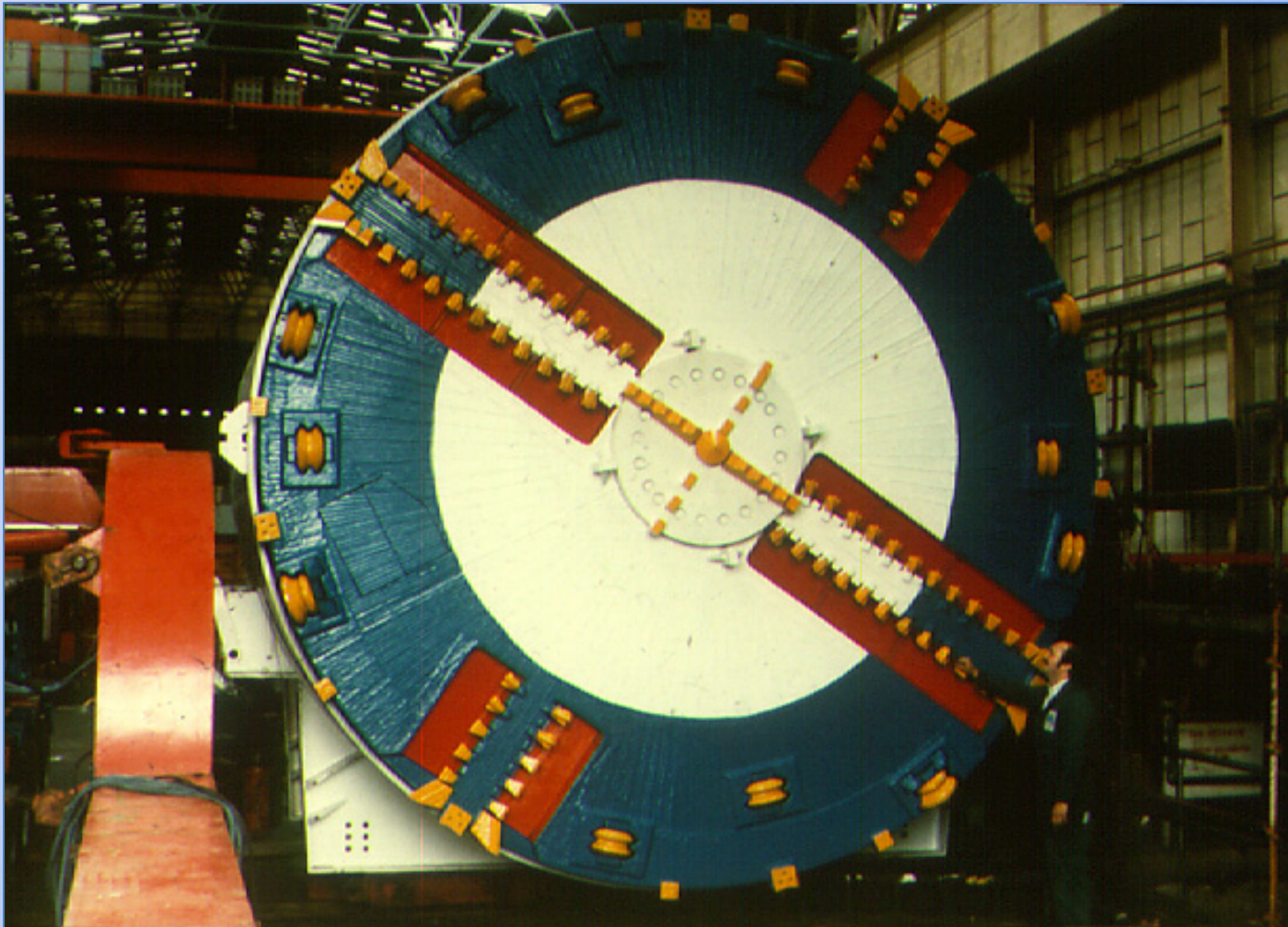
Slurry Machines

- Slurry Machines were initiated by John Bartlett's patent of 1964
- Developed for use in soft ground
- Mainly used in granular materials below the water table
- Face supported by a mixture of excavated material and bentonite slurry
- Excavated material transported in a slurry pipeline
- Separation plant required

Slurry Machine Circuit



Cairo Slurry Machine



Hatch Mott
MacDonald

Elbe Tunnel 14.2m Slurry Machine



Cutterhead
for the River
Elbe TBM,
manufactured
by Hoesch
Rothe Erde

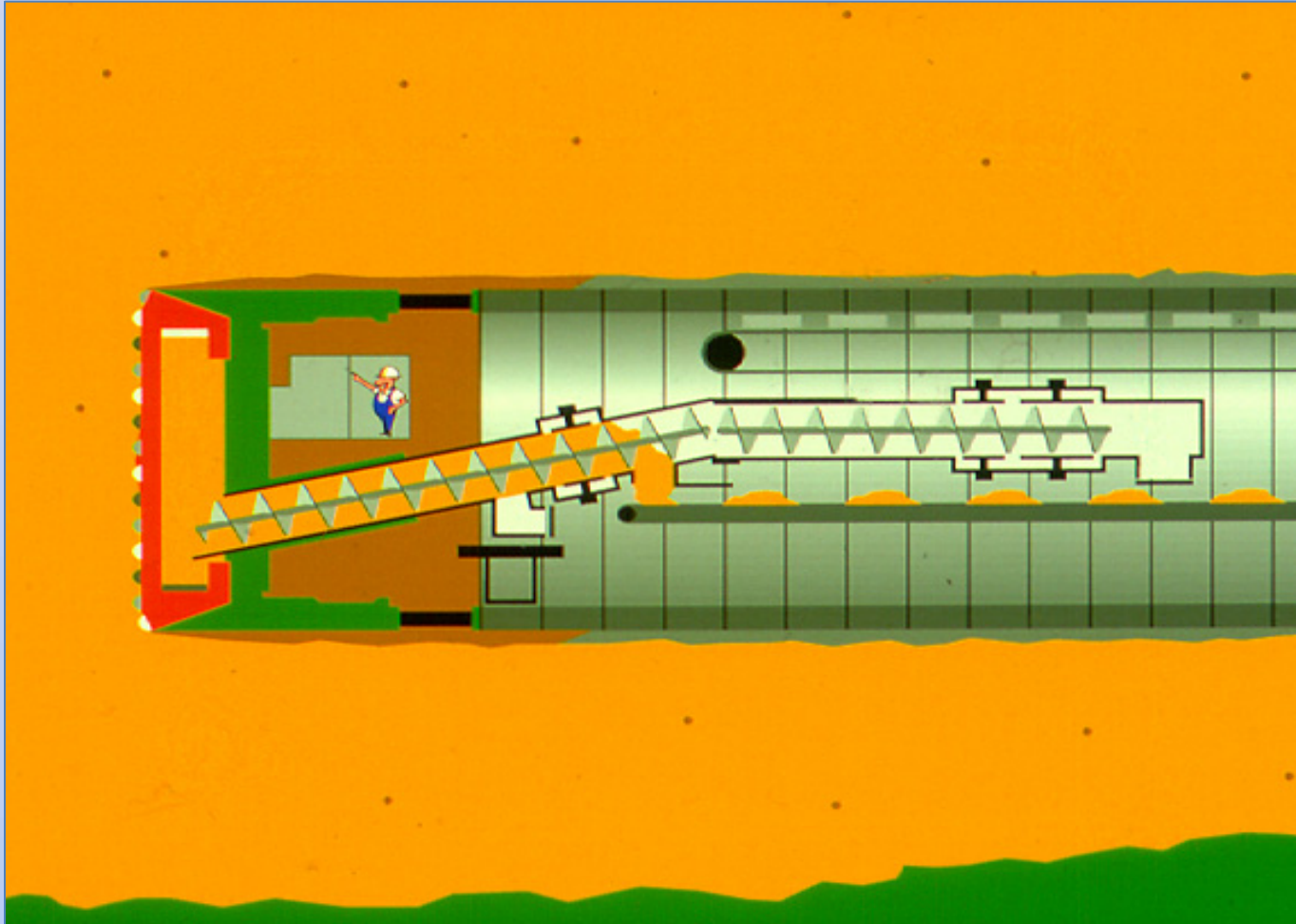
Separation Plant



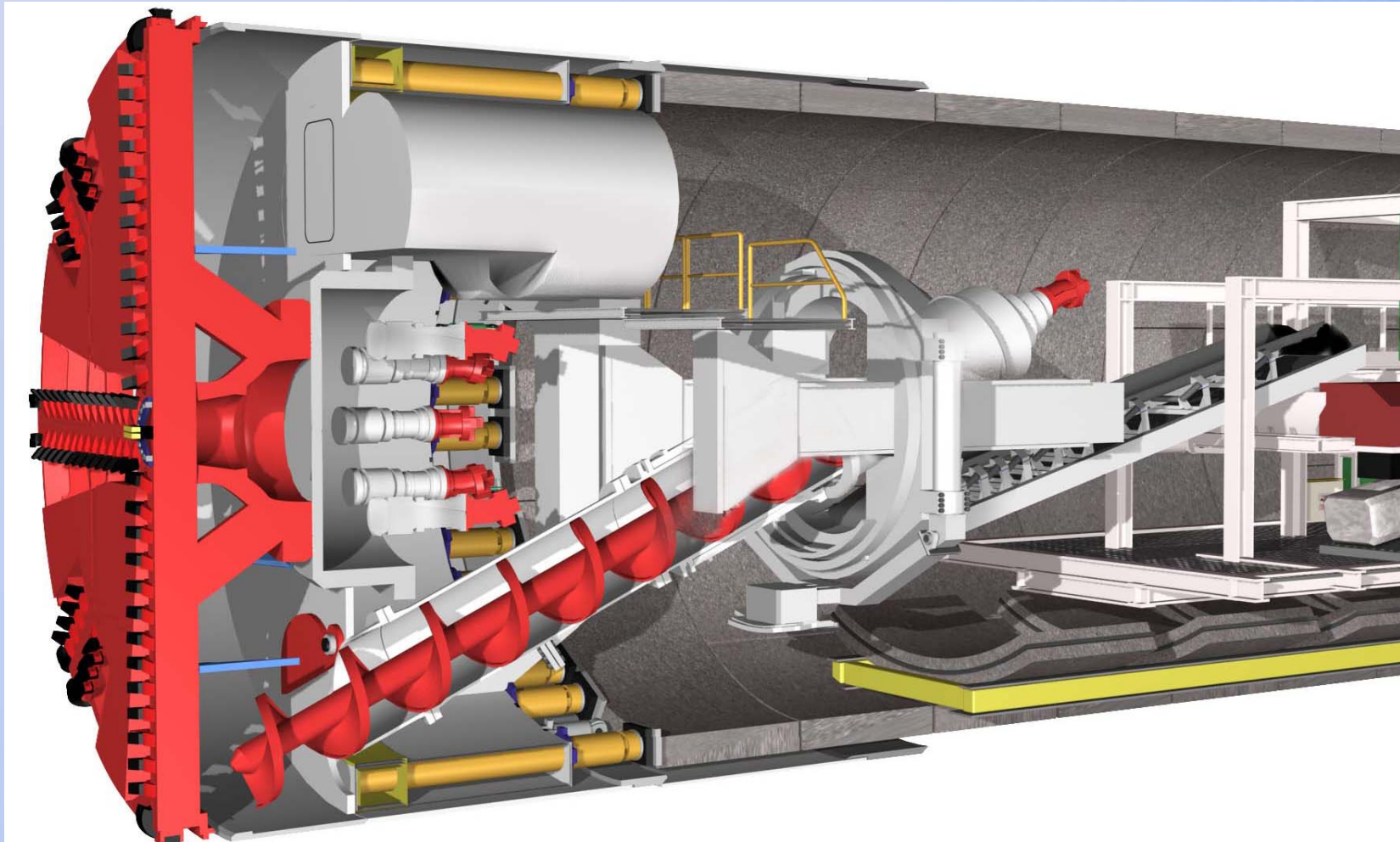
Earth Pressure Balance Machines

- Developed by Japanese in mid 1970's
- Needed to broaden the range of applicable ground conditions
- Much simpler than the Slurry Machine
- Face supported by conditioned excavated material
- Excavated material removed from the face with a screw conveyor and transported by train or conveyor.
- Has to some extent replaced the use of Slurry Machines

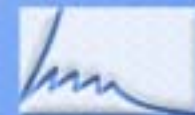
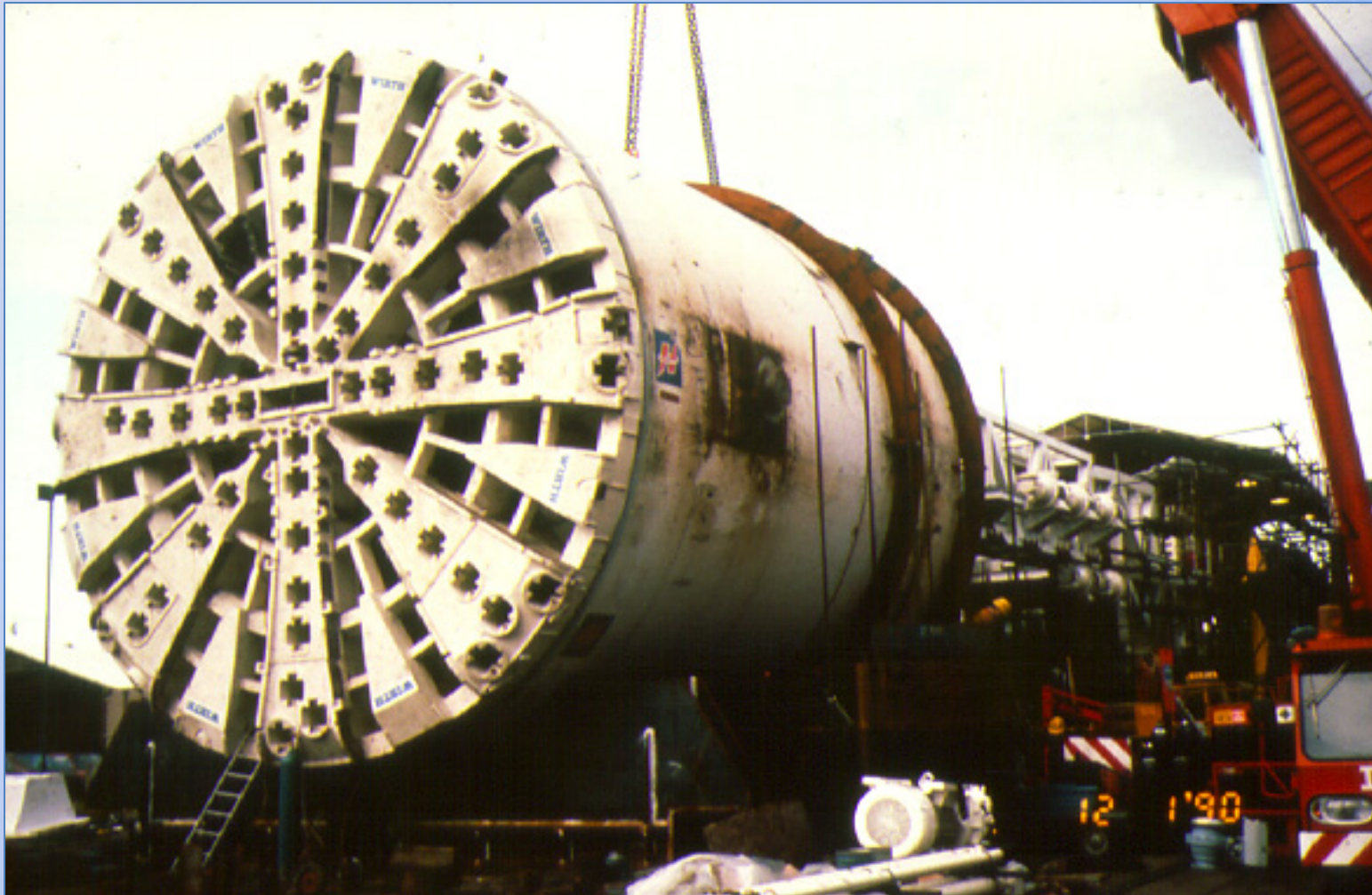
Diagram of EPBM



Typical Earth Pressure Balance TBM

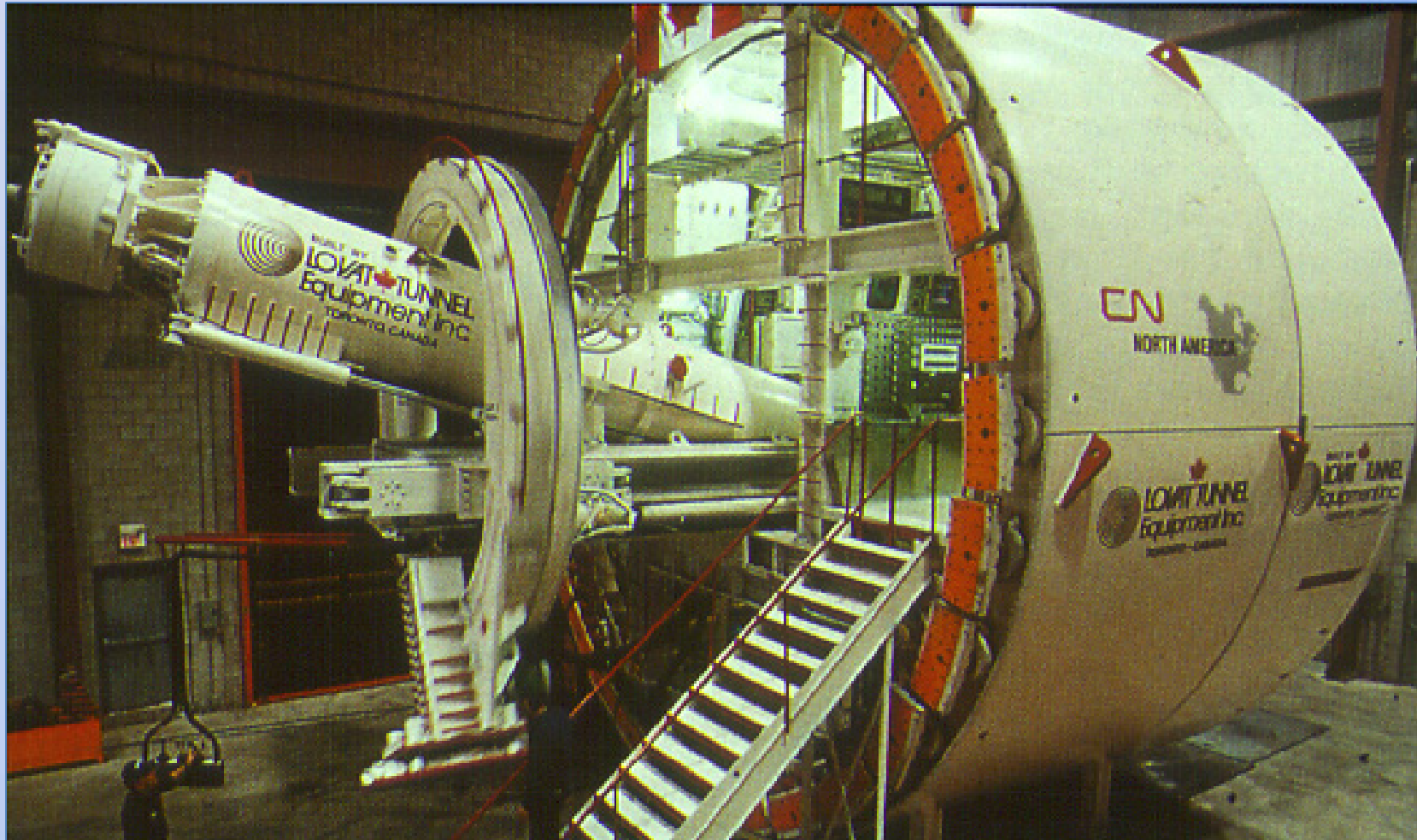


Storebaelt EPBM



Hatch Mott
MacDonald

St. Clair River Tunnel EPBM

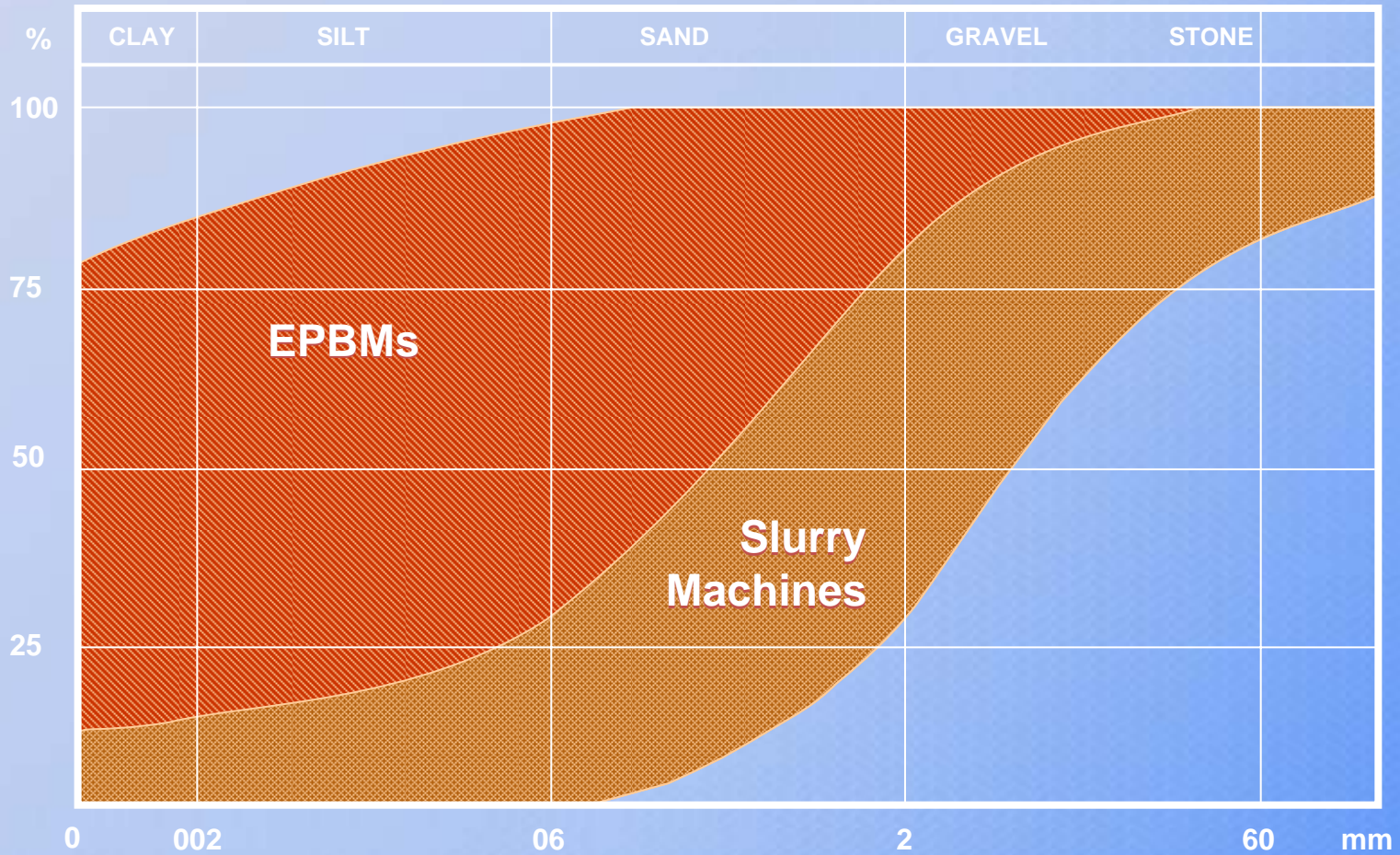


EPBM with Backup at Herrenknecht Factory



Soil Grading Curves

Range of Ground Conditions



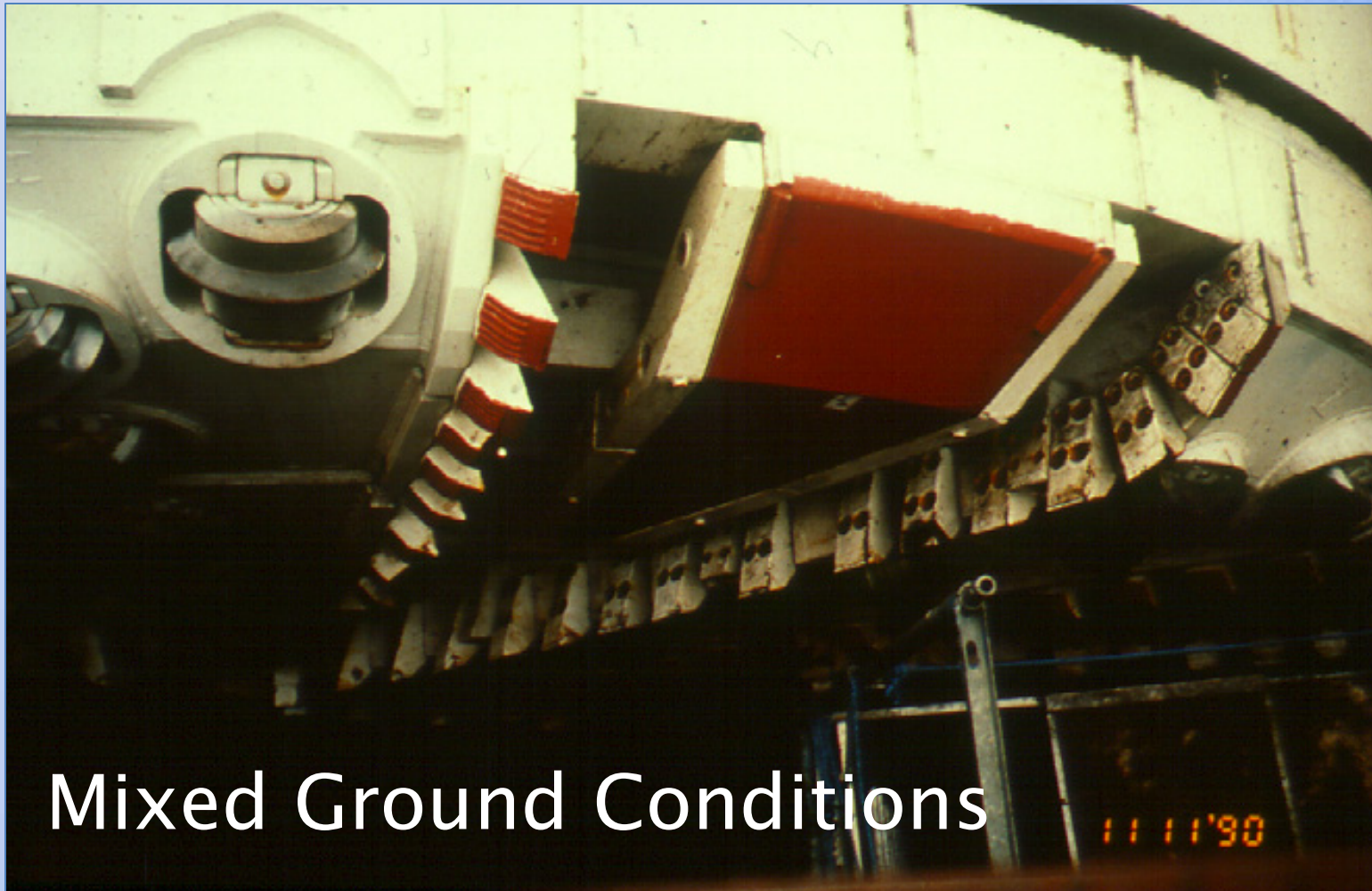
TBM - Key Components

- Cutter Head
 - Main Bearing
 - Head Access
- Muck Removal System
 - Screw conveyor to trains or conveyor
 - slurry line
- Push Rams
 - Sufficient to overcome:
 - Face pressure
 - Friction
- Tail Seals
 - Tail Grouting
- Tunnel lining
 - Erector system
 - Pre-cast concrete segments
 - Watertight Gaskets

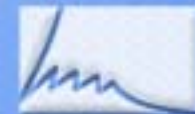
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Cutter Head



Mixed Ground Conditions



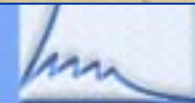
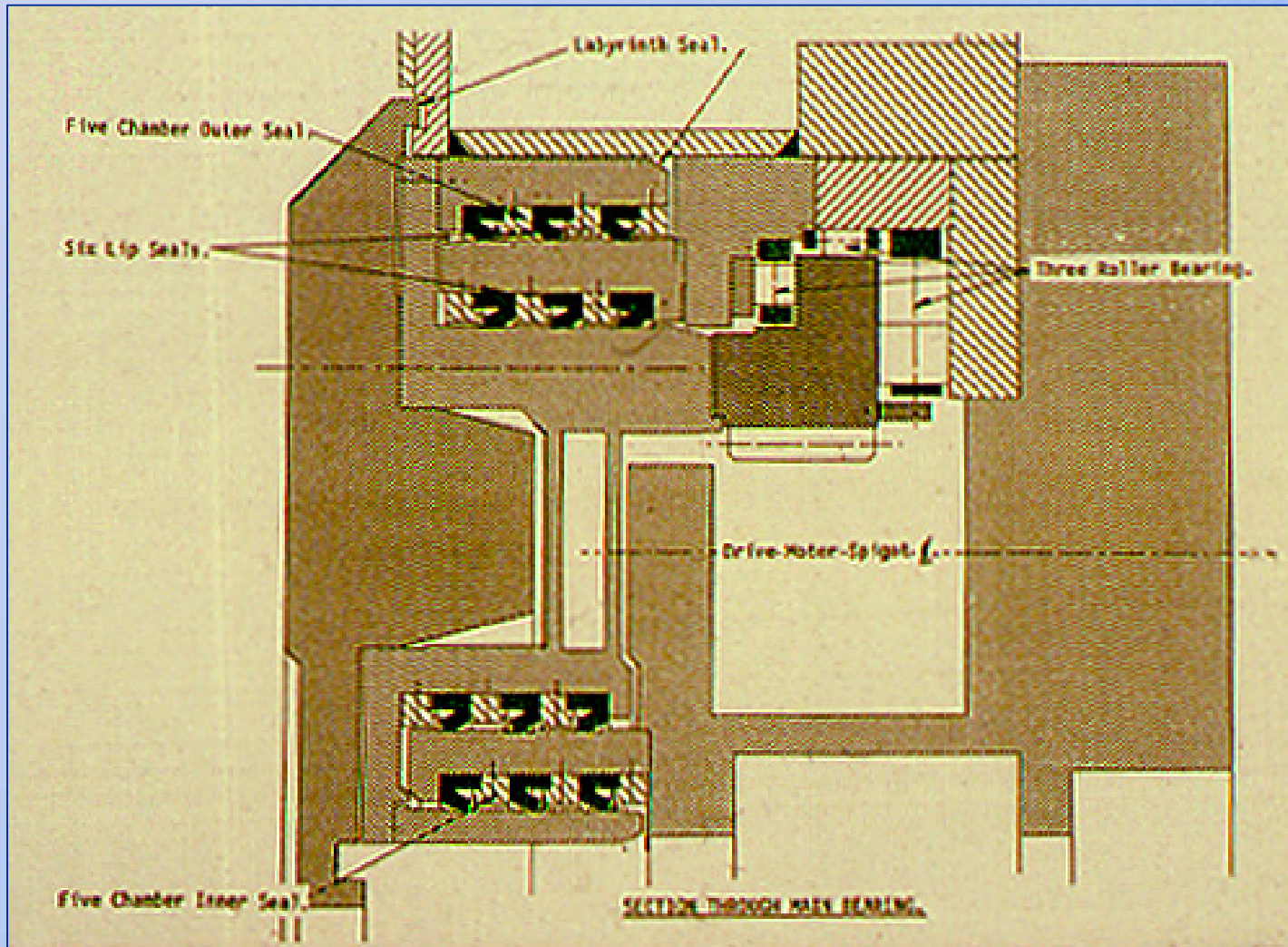
Hatch Mott
MacDonald

Channel Tunnel EPBM

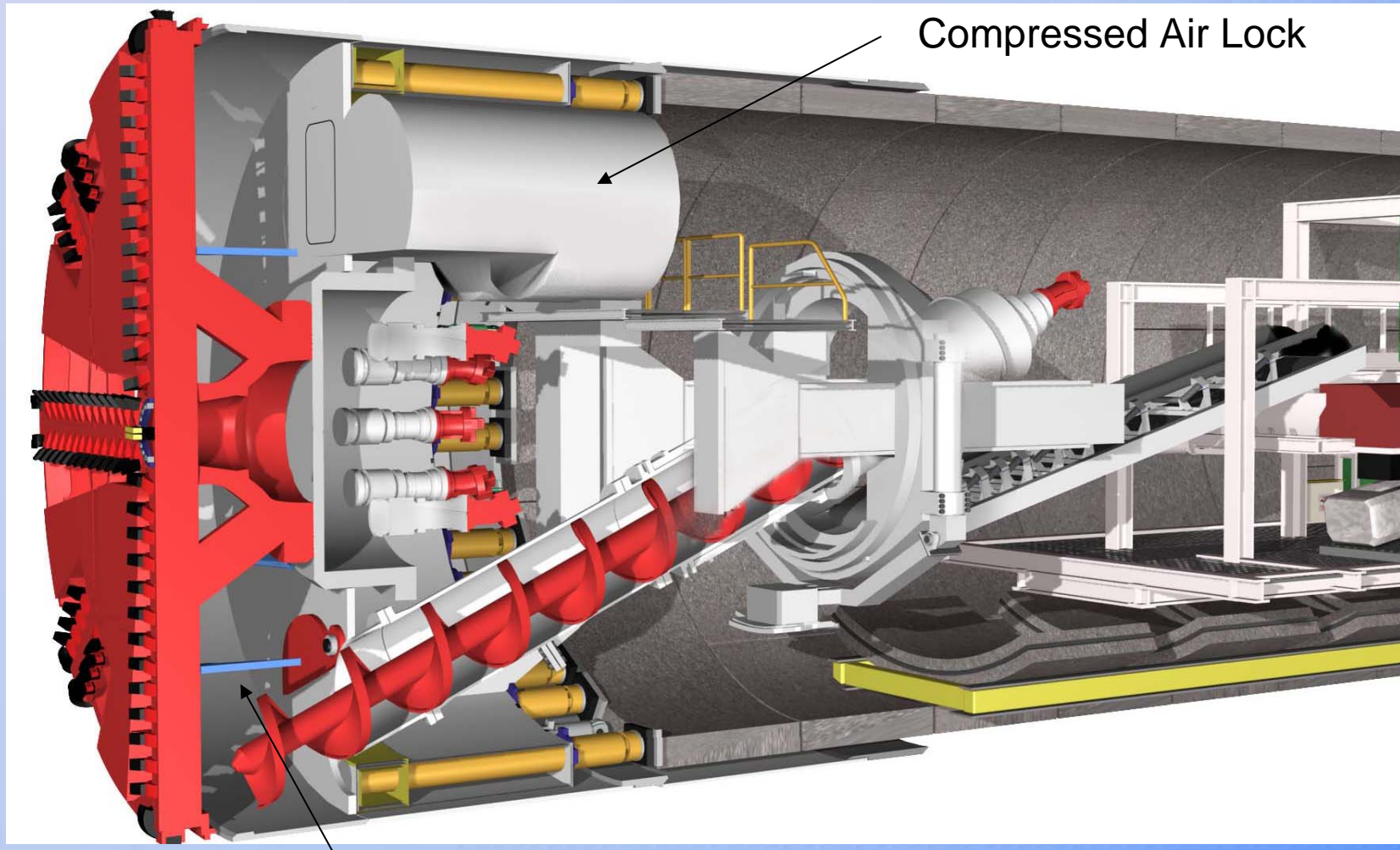


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Bearing Sealing System



Access to Chamber and Cutter Head



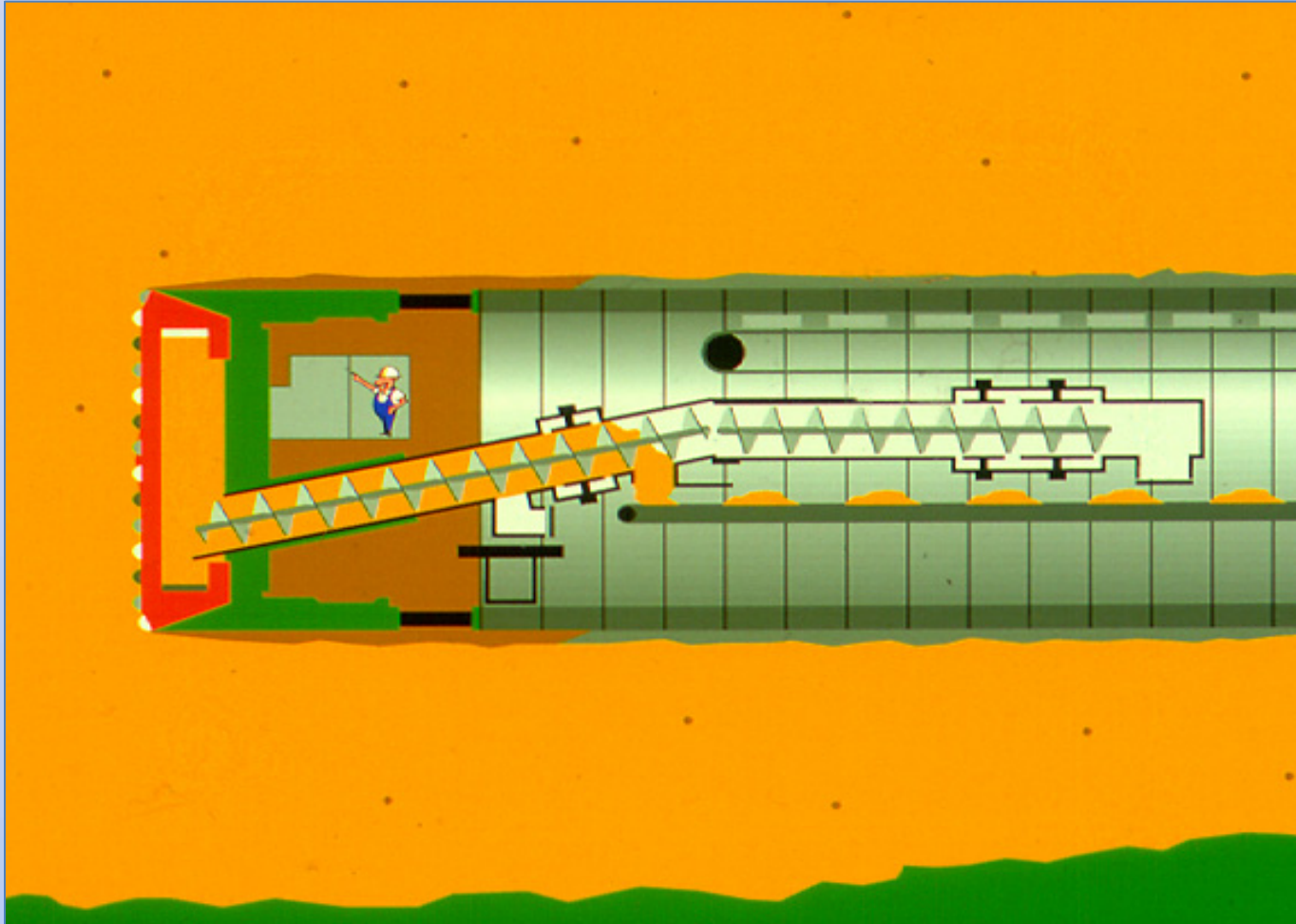
Compressed Air Lock

Pressurized Chamber

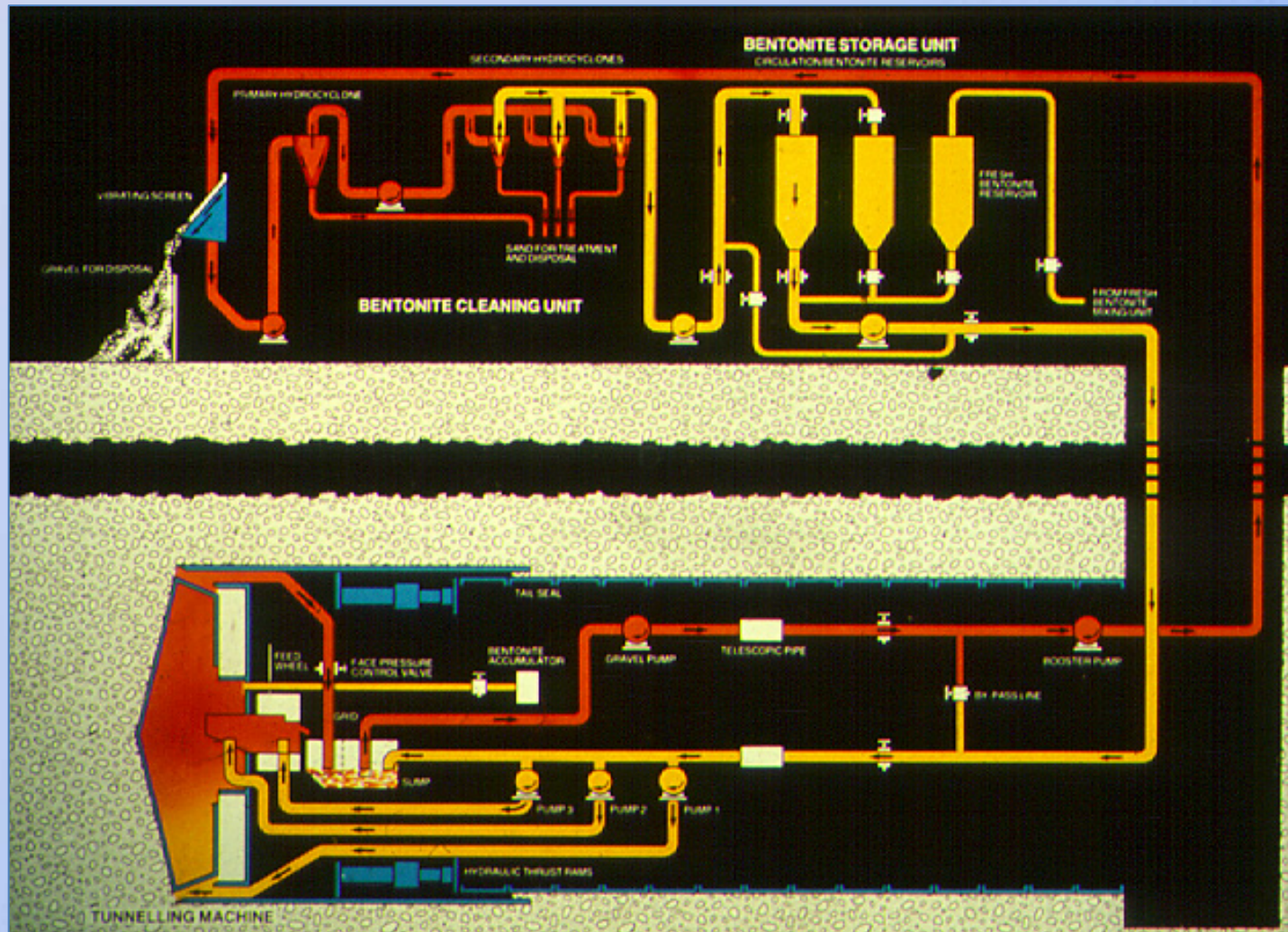
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Diagram of EPBM



Slurry Machine Circuit



EPBM Screw



TBM - Key Components

- **Cutter Head**
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Main Shove Rams



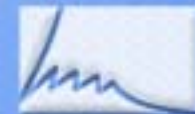
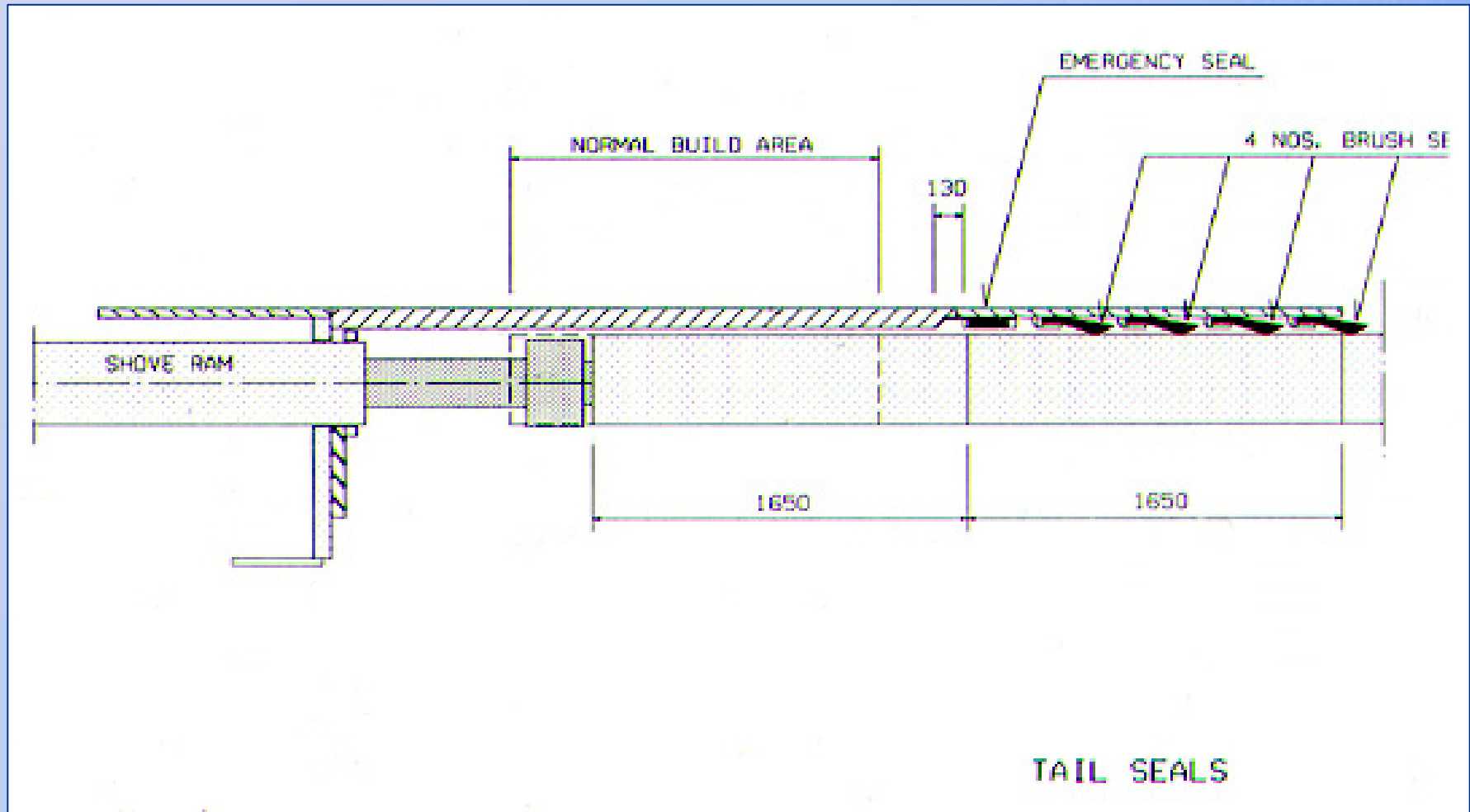
Total force for 49ft Diameter TBM

64 million lbs

TBM - Key Components

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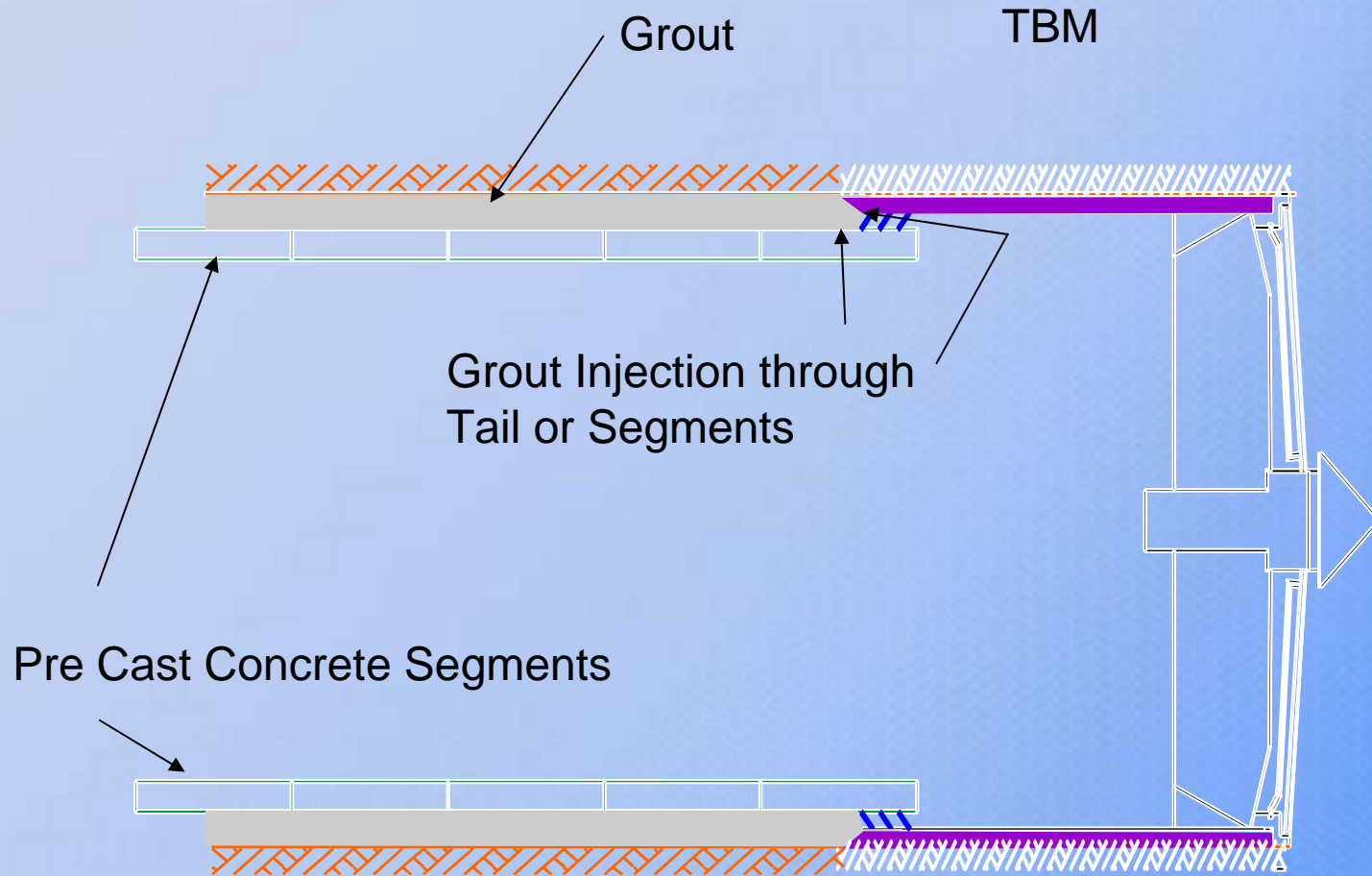
EPBM Tail Seal



EPBM Tail Seal



Tail Grouting



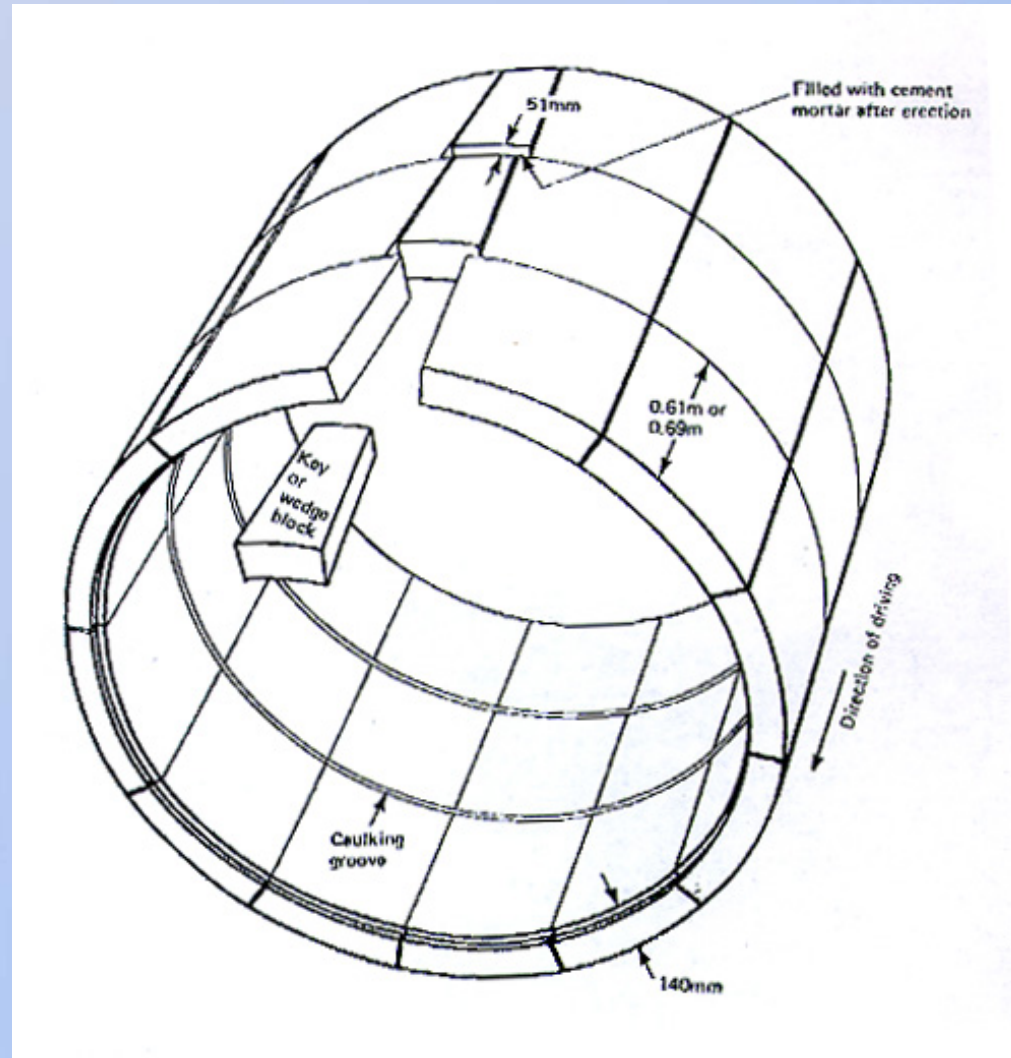
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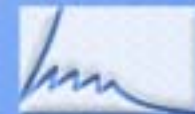
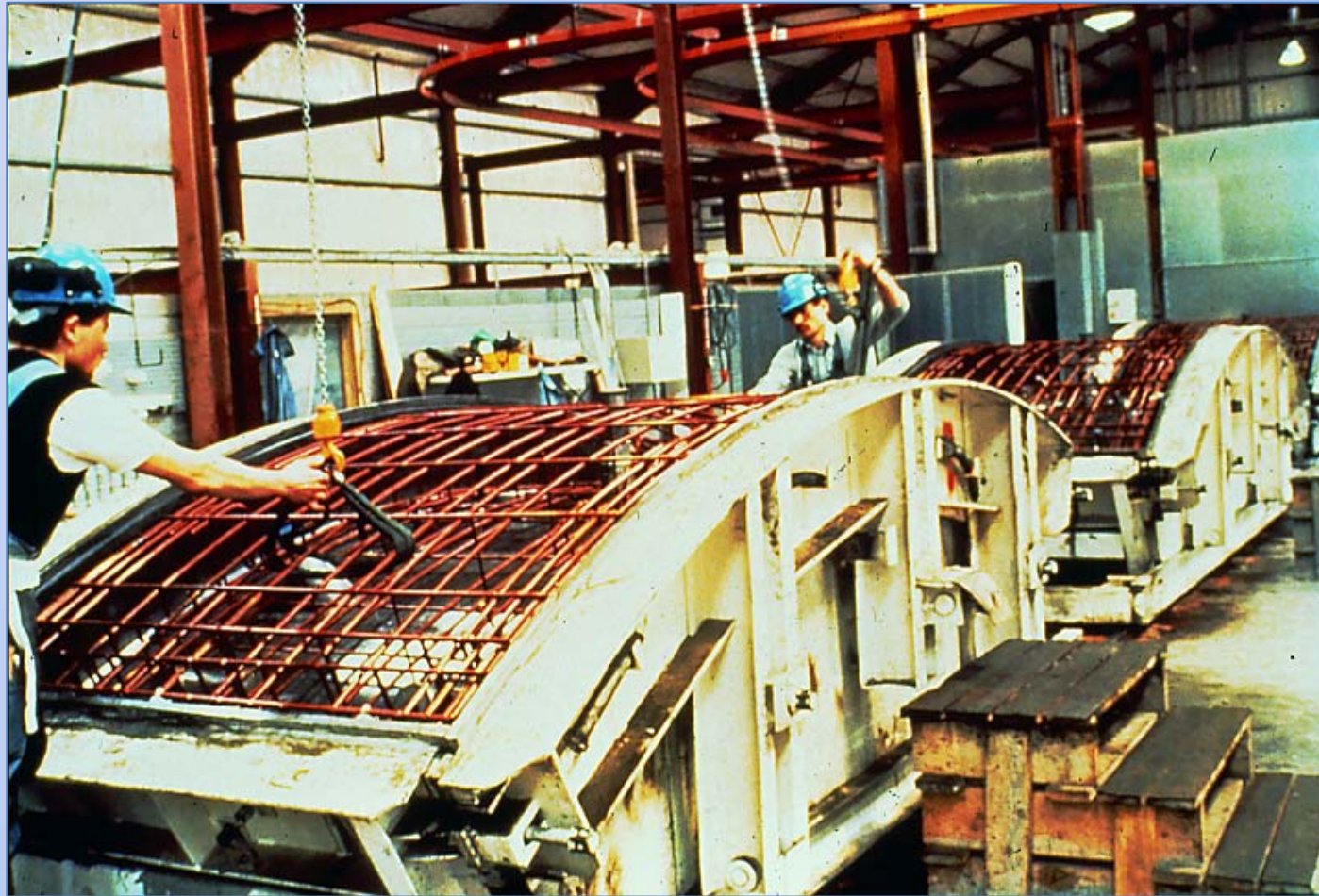
Use of Pre-Cast Concrete One-Pass, Gasketed, Lining

- Properly built linings can be 100% watertight
- Requires tapered lining to make sure gaskets meet on the circle joint between rings
- Requires high degree of accuracy of casting
- 100 year+ life can be obtained
- Manufacture near project site

Lining Assembly



Pre-Cast Segment Molds

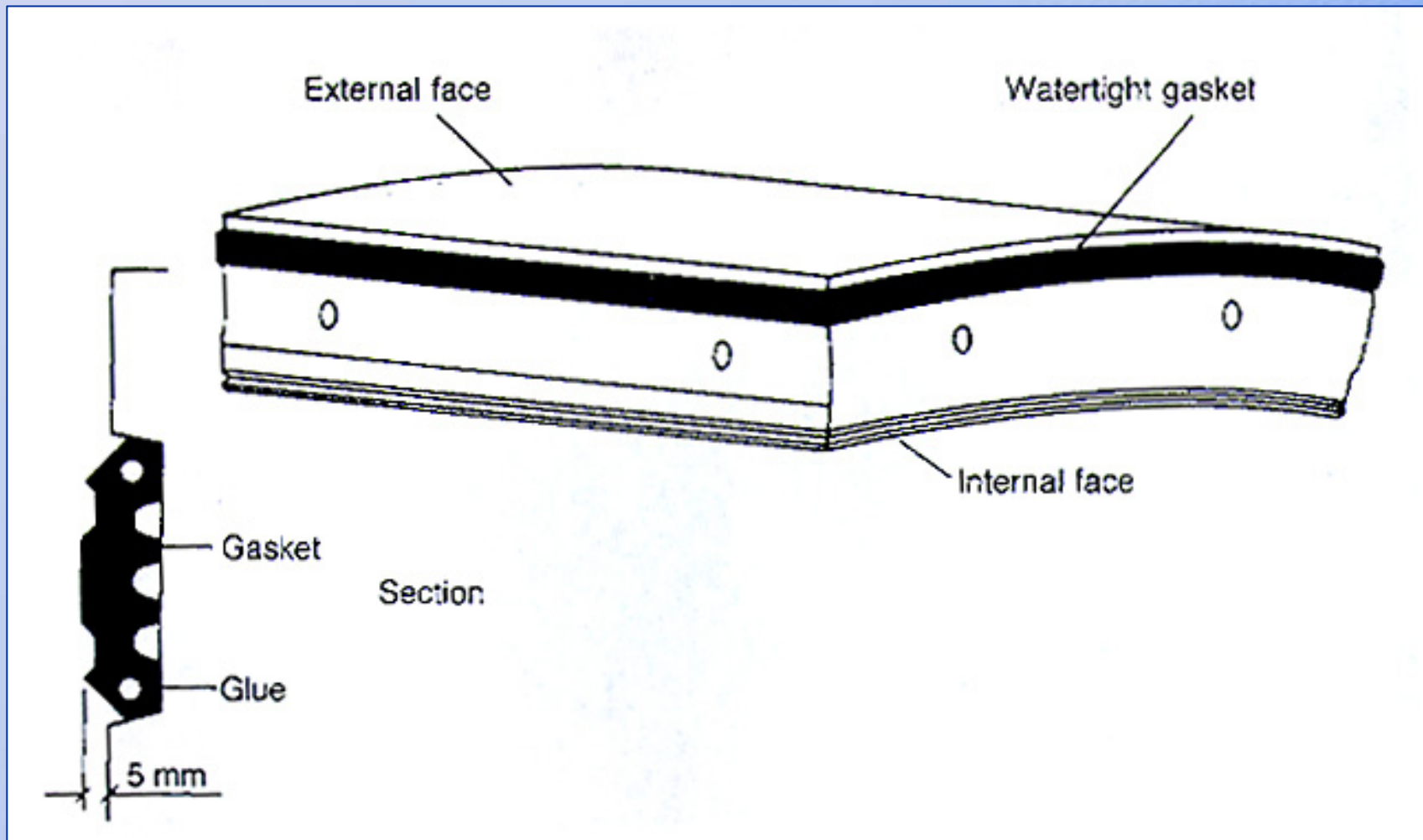


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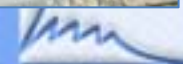
Channel Tunnel Segment Storage



Precast Concrete Segment



Installing the Gaskets



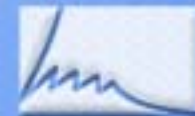
Hatch Mott
MacDonal

Transporting segments



Hatch Mott
MacDonald

Mechanical Segment Erector



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MacDonald

Vacuum Segment Erector



Completed One-Pass Lining



SETTLEMENT CONTROL

➤ Questions & Answers