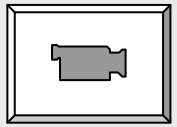
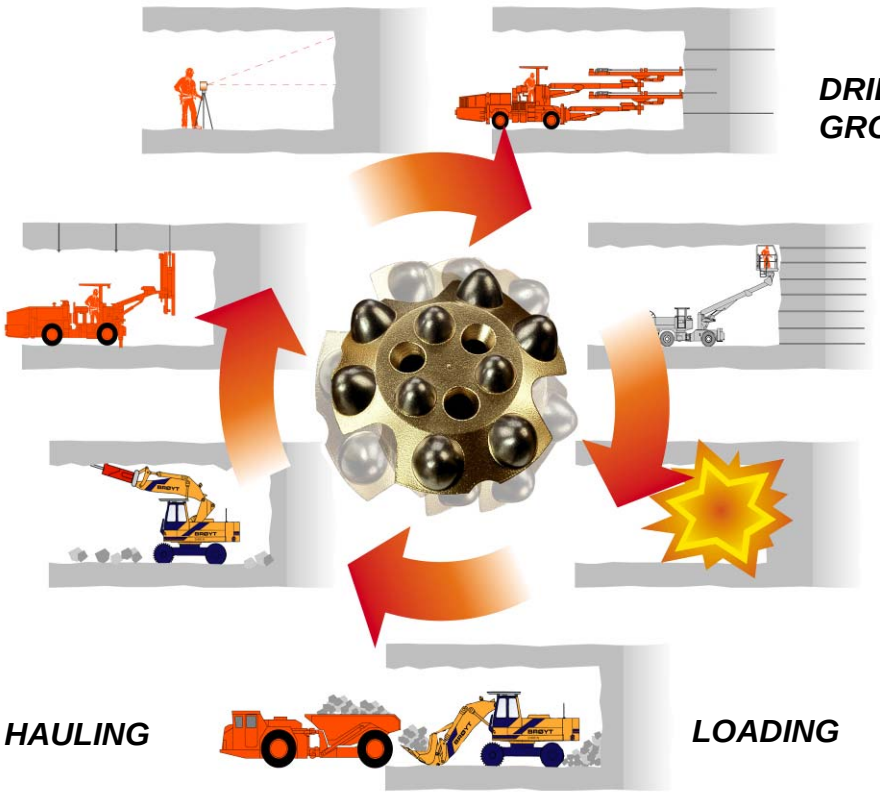
Metec 2009
Benefits of computerized drilling in drill and blast tunneling

Drill and Blast cycle





NAVIGATION & SURVEYING

DRILLING, PROBING, GROUTING

ROCK SUPPORTING

CHARGING

SCALING

BLASTING & VENTILATION

HAULING

LOADING

GENERAL FEATURES

- TDATA is an automatic control system for all drilling functions and boom positioning
- Available with 2-, 3- and 4-boom Sandvik DT jumbos
- Automatic drilling of a round with operator supervising the drilling
- TLOG data logging included
- VISUAL TUNNELING software for drill plan and curve design and reporting

MAIN COMPONENTS

Full graphic control panel

Multiprocessor control system for boom and drilling controls

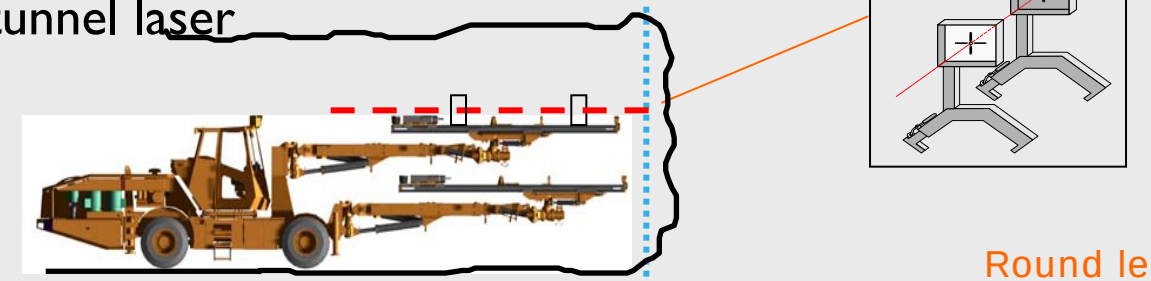
Software for designing and reporting

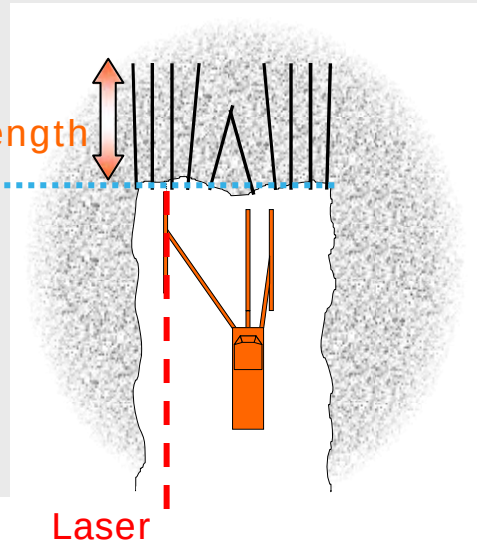
Boom control servo valves

Boom sensors

SETUP AND NAVIGATION 1/2

- Drill plan and curve table are selected from system memory
  - capacity for 50 drill plans and 20 curve tables
- Two targets are fixed to a feed rail and boom is driven to the reference line e.g. tunnel laser

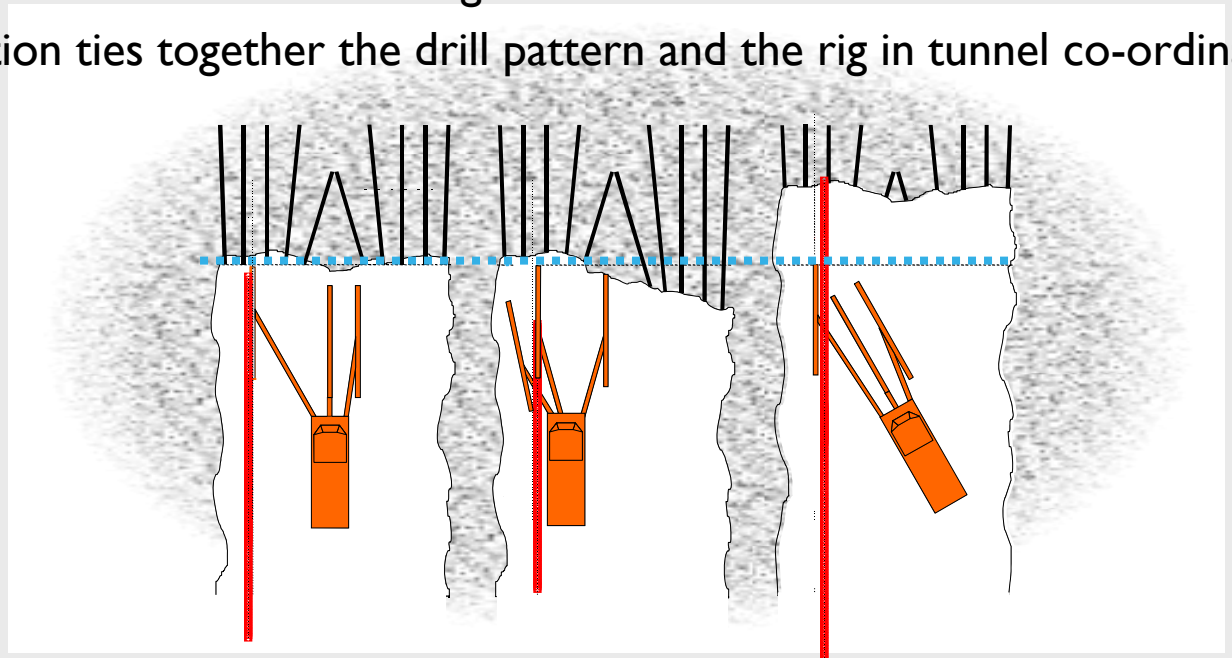




- Hole depth is calculated from navigation plane
  → straight round end
  Round length can be easily adjusted according to rock conditions before drilling starts

SETUP AND NAVIGATION 2/2

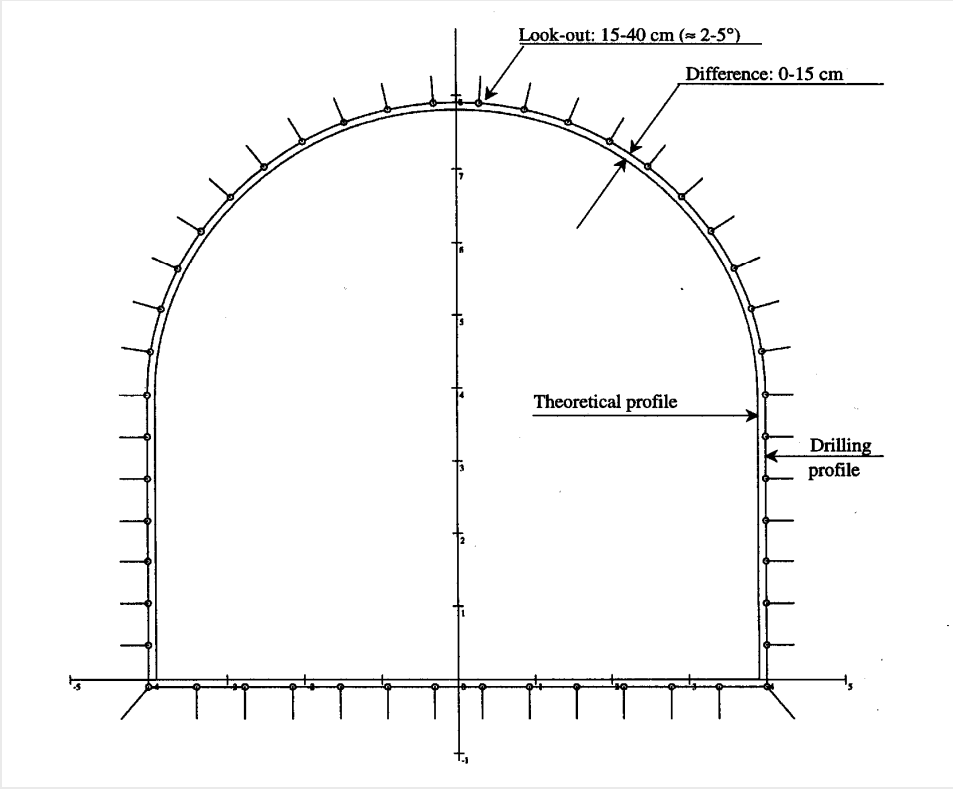
- Navigation eliminates the effects of carrier position and orientation
  - Any boom can be used for navigation
  - Navigation ties together the drill pattern and the rig in tunnel co-ordinate



Drilling accuracy

Drilling accuracy

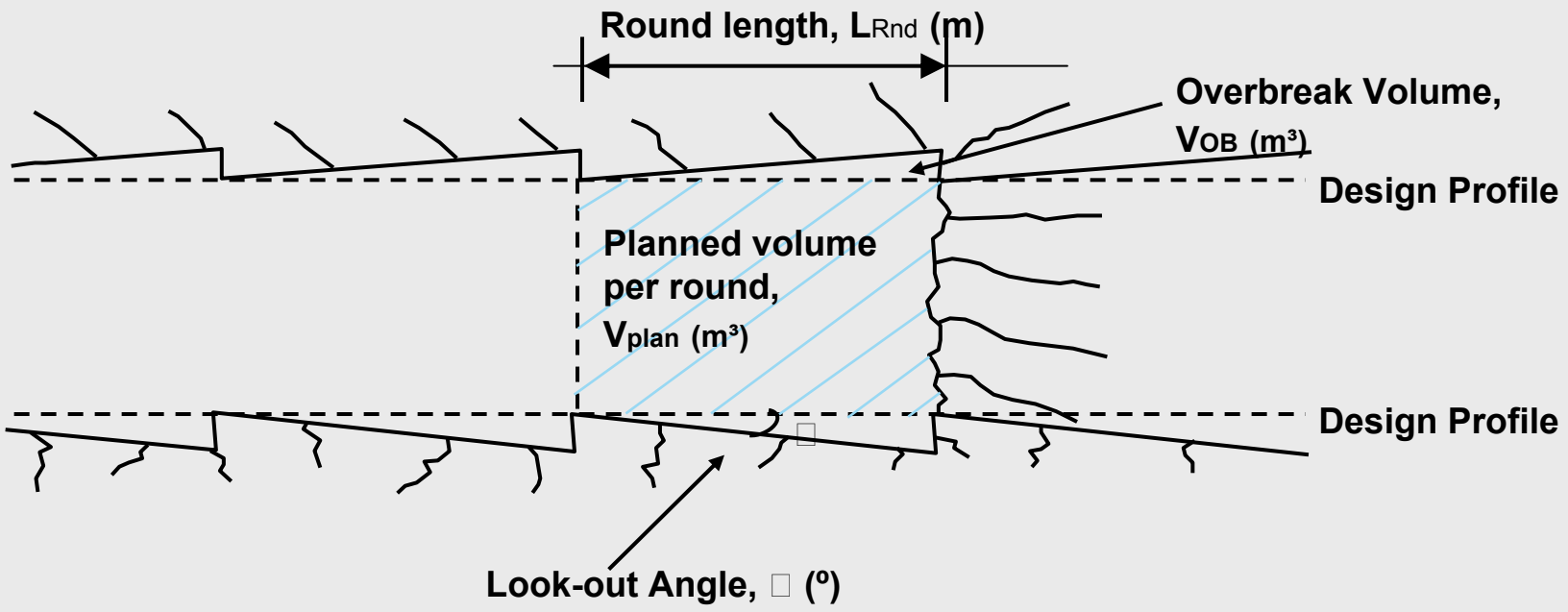
- **SOURCES OF DRILLING ERRORS**
  - Hole collaring position (incl. front stinger)
  - Hole direction (angles)
  - Hole length and hole deviation
  - Drilling pattern position and direction
  - Lost holes
- **MEDICINES**
  - Robust booms
  - Precise boom movements
  - Accurate parallel holding
  - Careful, smooth collaring
  - Drilling control system
  - Instrumentation
  - Straight hole drilling tools



Tunnel
profile quality

Tunnel profile quality

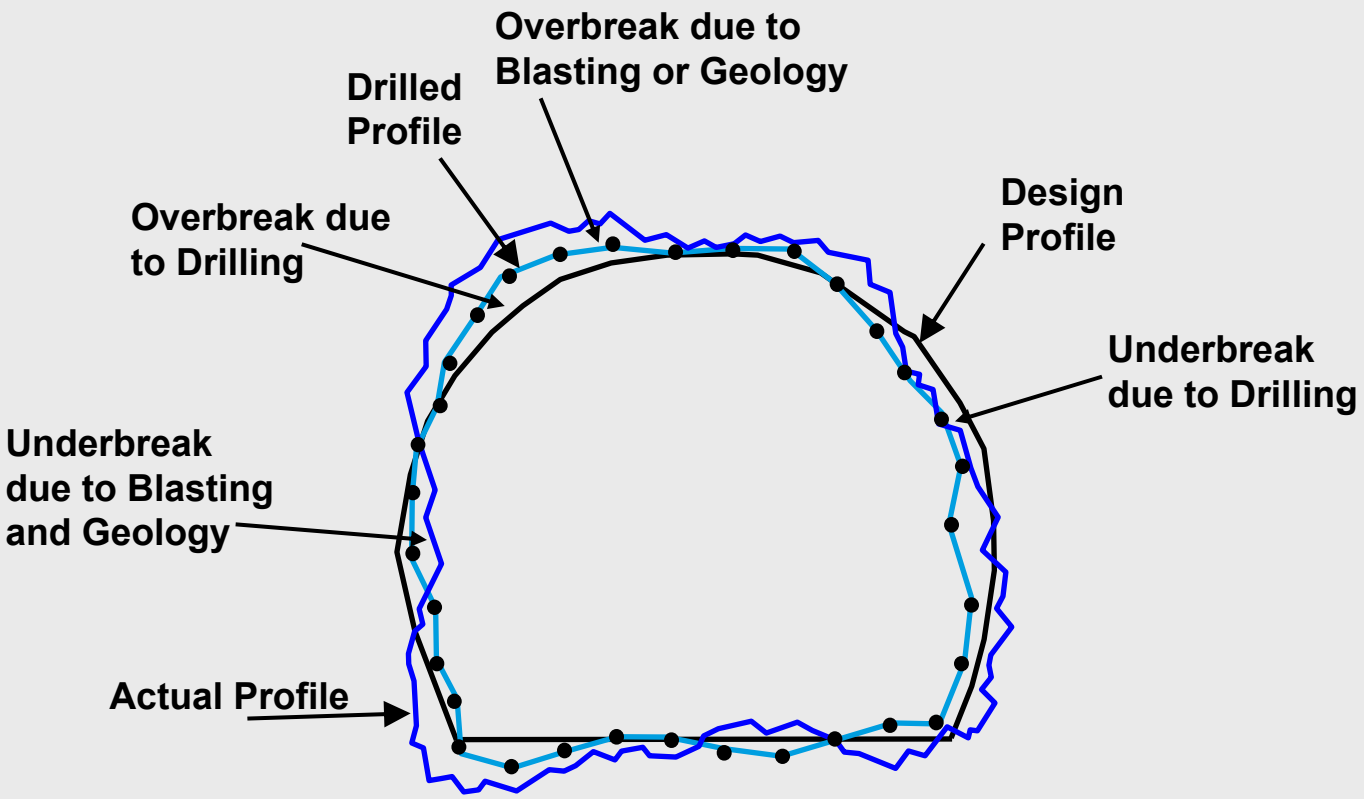
- **Definition of overbreak**



$$OB_{ave}\,(\%) = \frac{V_{OB}\,(m^3)}{V_{plan}\,(m^3)} \times 100$$

Tunnel profile quality

- **Causes of overbreak and underbreak**



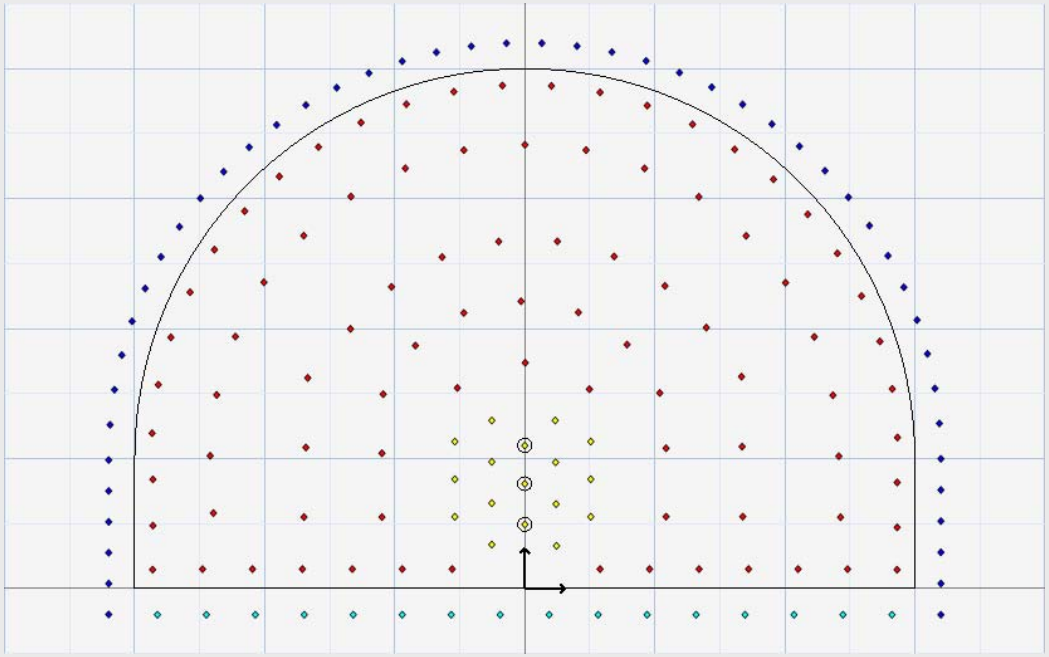
Tunnel profile quality

- Practical average overbreak results with computerized drilling jumbos and experienced excavation team

- **In favourable, good rock conditions** **10…15cm**
- **Typical results in fair rock conditions** **20…25cm**

Drilling
Profile quality

- Example:
  - 1000 m long D-shaped highway tunnel
  - Cross section 100 m^2
  - Planned excavation 100 000 m^3



Drilling
Profile quality

- Example:
  - 1000 m long D-shaped highway tunnel
  - Cross section 100 m^2
  - Planned excavation 100 000 m^3

LEVEL OF INSTRUMENTATION	NO INSTRUMENTATION	DATA CONTROLS
OVERBREAK	40 cm / 15 %	25 cm / 9.4 %
REAL CROSS SECTION	115 m^2	109 m^2
NUMBER OF HOLES	152	143
PULL OUT	88 %	95 %
SPECIFIC CHARGE	1.5 kg/m^3	1.3 kg/m^3
ADVANCE	234 m/month	259 m/month
EXCAVATION TIME	4.3 months	3.9 months
SHOTCRETE	50 mm	50 mm
UNEVENNESS FACTOR	1.35	1.15
REBOUND FACTOR	1.2	1.2

Example calculations shown more in detailed in A1.1 Instructions.

Drilling
Profile quality

- Example:
  - 1000 m long D-shaped highway tunnel
  - Cross section 100 m^2
  - Planned excavation 100 000 m^3

LEVEL OF INSTRUMENTATION	NO INSTRUMENTATION	iDATA CONTROLS
RELATIVE SAVINGS, EURO		
DRILLING	0	+ 2,158.-
EXPLOSIVES etc.	0	+ 51,107.-
LOADING & HAULING	0	+ 56,100.-
SHOTCRETE	0	+ 92,064.-
CONCRETE (OVERBREAK)	0	+ 841,500.-
TOTAL SAVING, EURO	0	+ 1,042,929.-
TIME SAVING, MONTHS	0	0.4

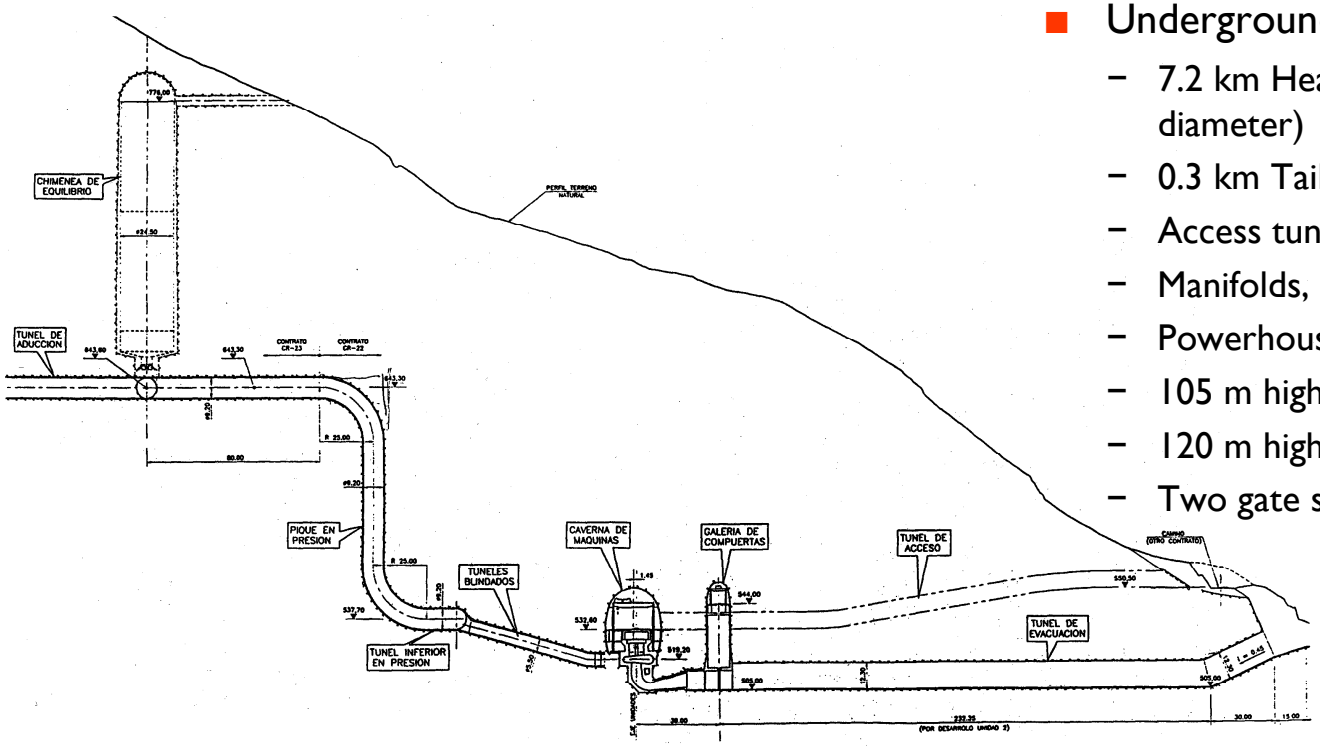
Example calculations shown more in detailed in A1.1 Instructions.

Worksite references

Worksite reference
Ralco - HEP

- Worksite
  - RALCO in Chile, 570 MW HE project
  - Contracts: CR22 - Headrace tunnel
    CR23 - Powerhouse cavern
  - Contractor: NECSO & Graña y Montero
  - Owner: Endesa Chile S.A.
  - Project value: 540 MUSD
  - UG excavation volume: 850.000 m^3
- Rock Conditions
  - Volcanic & magmatic rocks: andesite, breccia, basalt, gabbro, diorite, tonalite etc.
  - Fractured & weathered rock mass incl. high content of weak minerals

Main civil works



- Underground Excavation Works
  - 7.2 km Headrace Tunnel, Ø 9.8 m (excavation diameter)
  - 0.3 km Tailrace Tunnel, Ø 12.5 m
  - Access tunnels & adits
  - Manifolds, cable tunnels & draft tubes
  - Powerhouse: 26 m x 46 m x 110 m
  - 105 m high Penstock Shaft, Ø 9.8 m
  - 120 m high Surge Tank, Ø 25 m
  - Two gate shafts

Sandvik equipment

- 2 pcs of 3-boom DATASUPER 316-150
  - Computer controlled drilling
  - New generation drilling control
- 1 pc of 3-boom DATAMAXI 316 T
  - Computer controlled drilling
  - Old generation drilling control (-94)
- 1 pc of 2-boom PARA 206-90 Jumbo
  - TCAD instrumentation + basket boom
  - New generation drilling control
- 2 pcs of Commando 300 Trackdrills
  - Water flushing kit
- 1 pc of Ranger 500 Trackdrill
  - Water flushing kit
- 2 pcs of Rammer G 80 breakers

Headrace tunnel
Drilling

- 2 pcs of 3-boom DATASUPER 316-150
  - Face, bolt hole & injection drilling
- Tunnel Dimensions
  - 7.2 km long, circular shape Ø 9.8 m
  - Access from two adits
- Excavation Method
  - Full section in medium to good rock
  - Top heading + bench in bad rock
- Round characteristics
  - Round length: 1.0…4.0 m
  - Pattern: 118 pcs x ∅ 51 or 48 mm + 3 pcs x ∅ 102 mm
  - Drilling cycle time: 2.5…3.0 h

Headrace tunnel
Performance

- Working Time Arrangements
  - 2 x 12 hours shift per day
- Daily Advance per heading
  - One round per shift blasted => 2 rounds per day
  - 8 m per day in medium to good rock
  - 2 m per day in bad rock

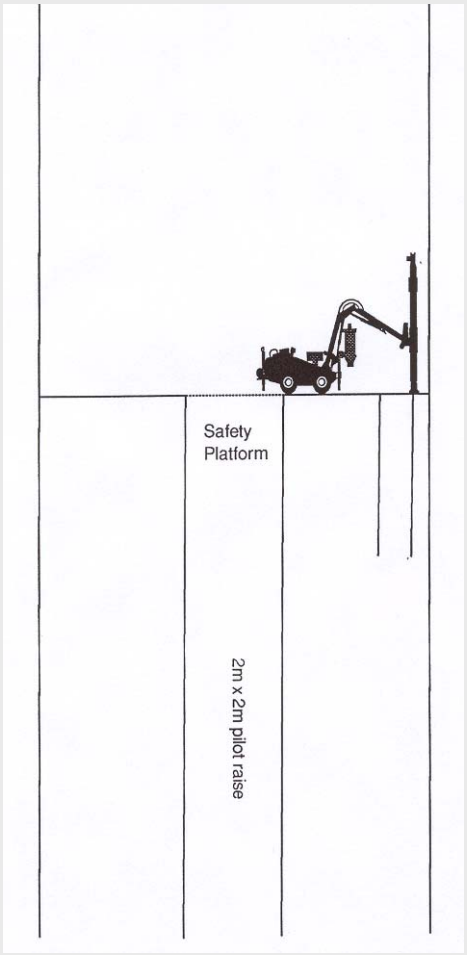
Powerhouse
complex & tailrace

- 1 pc of 3-boom DATAMAXI 316 T
  - Face & bolt hole drilling
- 1 pc of 2-boom PARA 206-90 + basket
  - Face & bolt hole drilling
- 1 pc of Ranger 500
  - Bench drilling with vertical holes in the powerhouse cavern, bench height: 5m
  - Anchor hole drilling (long bolts)
- 2 pcs of Commando 300
  - Bolt hole drilling in the powerhouse cavern

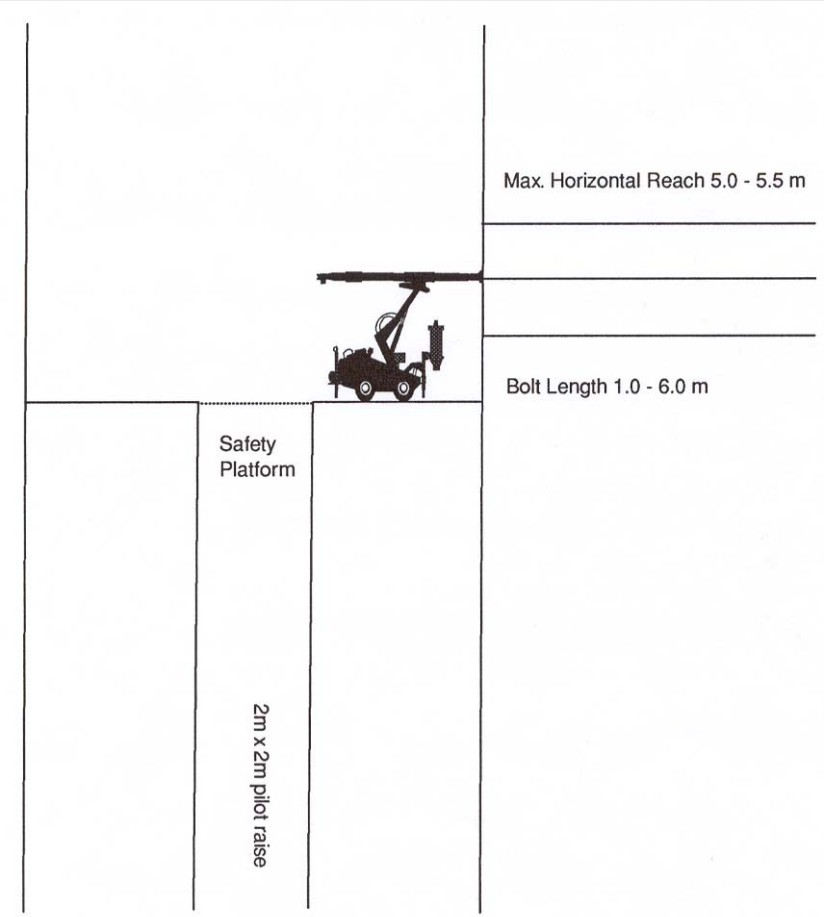
Shaft excavation
Method

- Excavation of 2 m x 2 m pilot raise with Alimak Raise Climber
- Enlargening of the shaft
  - 1-2 pcs of Commando 300 for drilling, bench height: 3 m
  - 1-2 pcs of small excavators for loading blasted muck into pilot raise
  - Secondary loading below the raise
  - Units lifted up/down with 10 ton winch
  - Alimak used for workers transportation
- Supporting of the shafts
  - 3 m long, resin grouted bolts (Commando 300)
  - 150 mm thick shotcrete layer
  - Concrete lining

Shaft excavation
Drilling



Shaft excavation
Bolting



- Drilling of the bolt hole
- Manual installation of resin cartridges
- Installing bolt utilizing feed and rock drill of Commando 300
- Mixing resin components utilizing rotation motor of HL 300 and special tool between shank / bolt
- Pretensioning bolt by tightening the nut

Sandvik rock tools
drill steel life

UNIT	DRILLED METERS	SHANK LIFE, drm	ROD LIFE, drm	COUPLING LIFE, drm	BIT LIFE, drm
Datasuper 1 (new generation drilling control system)	220.284	7.596	3.338	5.123	1.288
Datasuper 2 (new generation drilling control system)	198.036	8.251	1.722	3.047	615
Para 206 (new generation drilling control system)	127.515	9.809	2.024	2.965	759
Datamaxi (old generation drilling control system)	50.896	3.181	1.184	2.213	653
Commando 1	32.804	2.982	994	1.491	576
Commando 2	42.640	2.665	948	1.254	422
Ranger 500	25.726	3.675	953	1.225	476

* All values include breakage & loss of steel caused by improper operation or accident

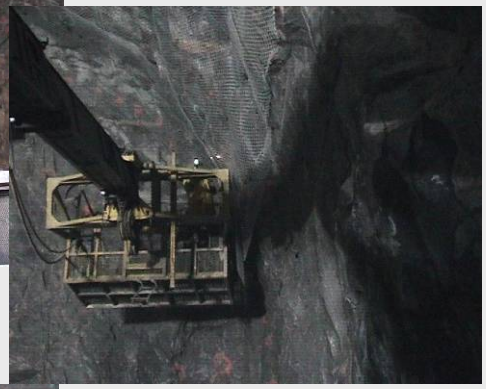
Full service contract

- Manpower and Service Tools
  - 1 x supervisor + 1 x technical secretary
  - 12 x servicemen for mobile equipment
  - 1 x serviceman for Rock Tools
  - 1 x drill master (6 months start-up)
  - Tools, service containers & vehicles
- Contract including
  - Fixed operational costs for spare parts, maintenance & drilling tools for drilling units
  - Parts consignment stock for BrØyt & Rammer
  - Equipment availability guarantee: 90 % for 1st year, 85 % for following years
- Taking care of
  - Preventative maintenance
  - Parts supply
  - Drill steel & bit servicing
  - Inventory control & cost collection
  - Invoicing and payment follow-up

Worksite reference – Toulnustouc HEP

- Worksite
  - 526 MW Toulnustouc Hydropower Project in Quebec Canada
  - Contract: 8.3 km long Headrace tunnel
  - Excavation volume: 1.4 Mm^3
  - Contractor: EBC Inc.
  - Owner: Hydro-Quebec
  - Contract value: 70 million$
- Tunnel dimensions
  - Cross section: 134.3 m^2
  - Horseshoe: h=11.86m x w=13.4m (now)
  - Circle Top: h=13.0m x w=11.0m (in the beginning)
  - New shape optimized hydraulic properties of tunnel, pullout length, fragmentation and blast vibrations

Method



- Full section
  - Round length: ~ 5.7m (pull % ~97-98 %)
- 3-front excavation
  - 3 faces in operation simultaneously
- Excavation sequence
  - Bolting (drilling & installation)
  - Screening (wiremesh)
  - Drilling (and primary manual scaling)
  - Charging
  - Blasting and ventilation
  - Primary mechanical scaling
  - Loading and hauling
  - Final mechanical scaling
  - Final manual scaling
  - Geological surveying

Main tunneling equipment

- 3 pcs of Axera T12 DATA-315 jumbos
  - Face drilling and bolt hole drilling
  - TF 500 x 20' feeds + ∅ 46 mm rods
  - TBB 5E basket boom
  - TDATA control system
- 1 pc of Caterpillar 988 G loader
  - 6.5 m^3 bucket
  - 1 pc of Cat 988 F as a backup unit
- 8 pcs of Caterpillar 773 trucks
  - 50 ton dump box
- 3 pcs of Caterpillar 235 excavators
  - Mechanical scaling
- Several lifting vehicles
  - Bolt & wiremesh installation
  - Charging
  - Manual scaling

Bolting

- Axera T12 DATA-315 jumbo
  - Bolt hole drilling with 2 or 3 drilling booms
  - Bolt installation from basket
- Lifting vehicle
  - Bolt installation
- Bolting characteristics
  - Mechanical anchor bolts: 4m long (sometimes 6m long)
  - Hole size: 51mm
  - Number of bolts: 10 pcs per round (average)
- Bolting cycle
  - Bolt hole drilling: 20 min
  - Bolt installation: 40 min
  - Total cycle: 60 min

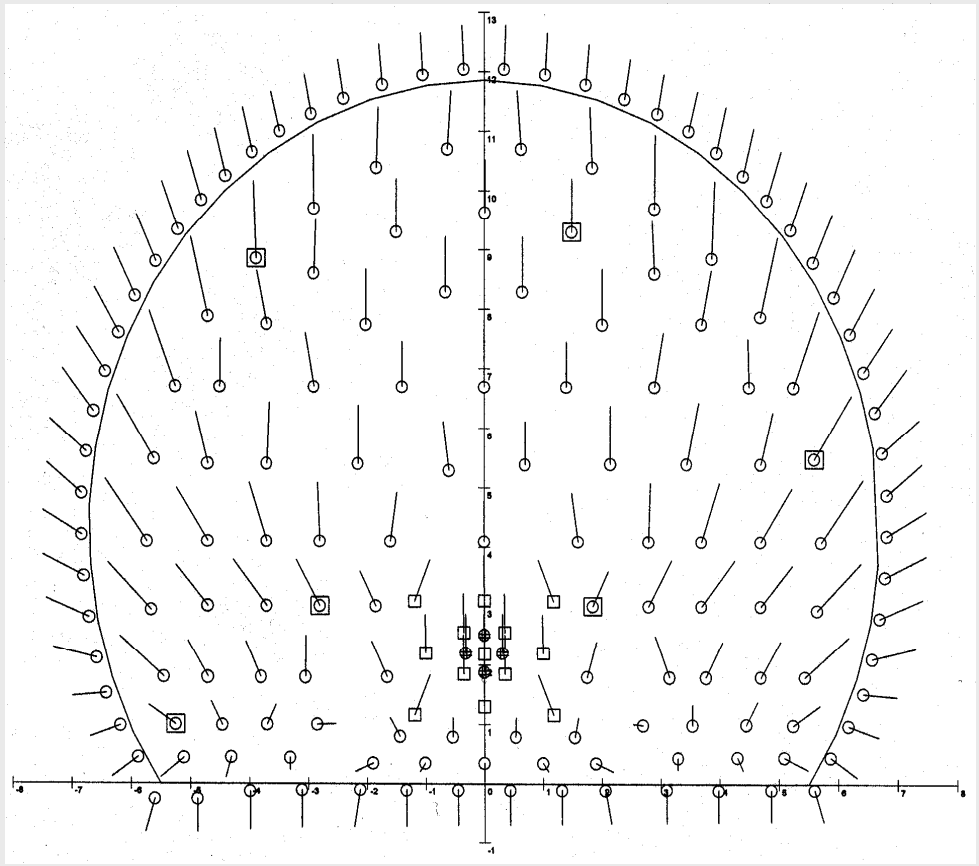
Screening

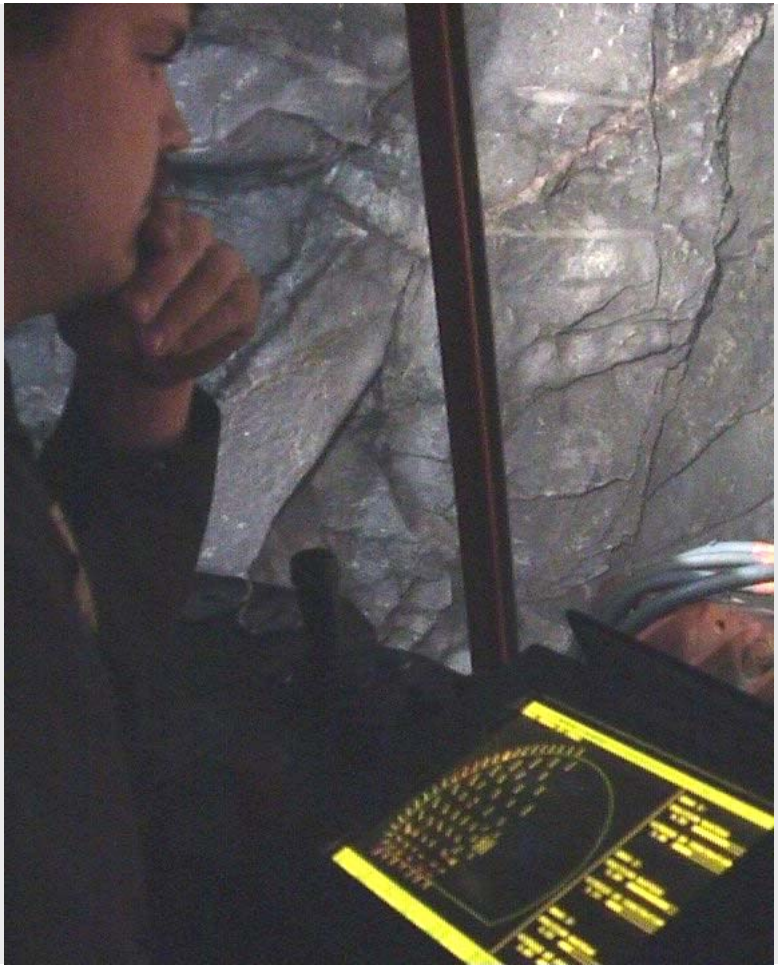
- Method
  - 10m x 3m wiremesh sheets
  - Installation after bolting (Hydro Quebec request)
  - 80 x 1m long installation pins per round (hole Ø 35 mm)
- Equipment
  - Installation: 2 x lifting vehicle
  - Drilling: 1 stoper per lifter
- Screening cycle
  - Installation: 60 min
  - Drilling of pins: 120 min
  - Total cycle: 180 min

Drilling

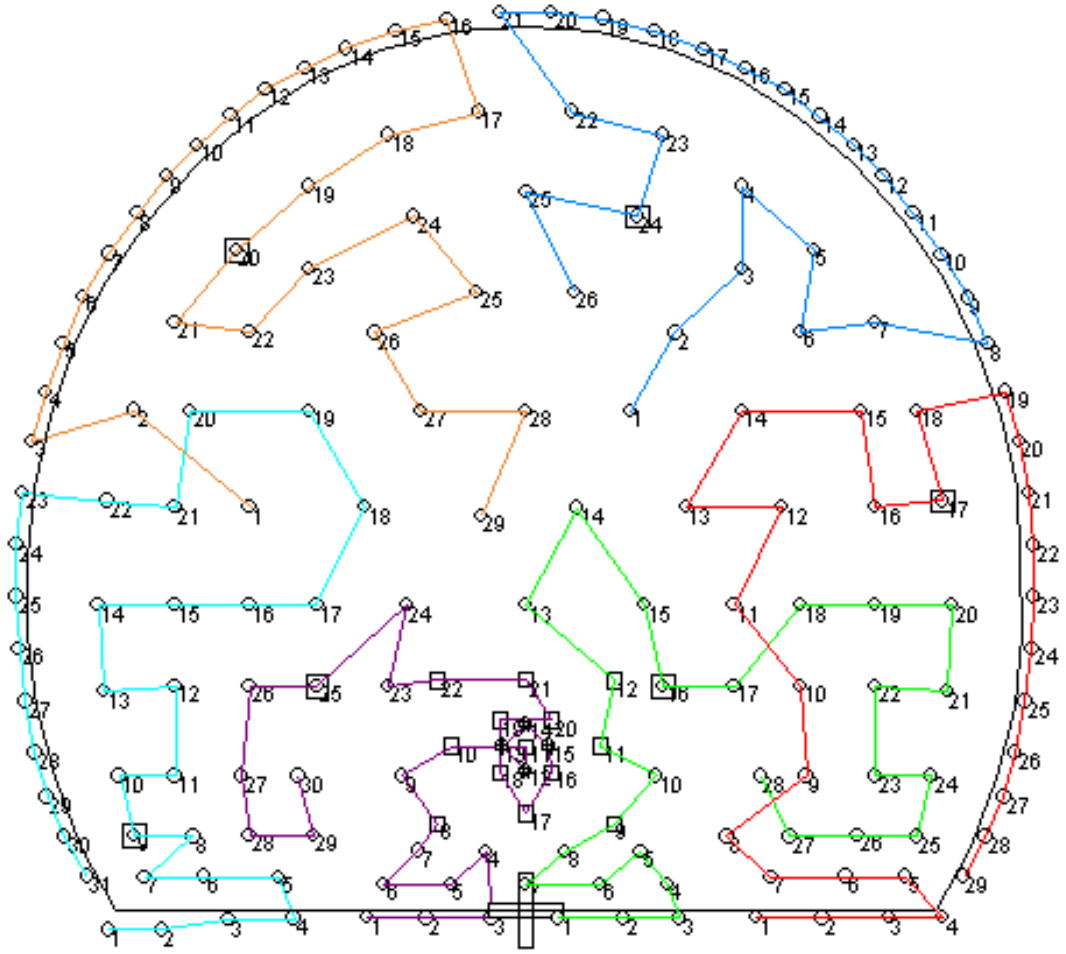
- 2 pcs of Axera T12 DATA-315 jumbos
  - 2 computerized drilling units are used for face drilling side by side
  - 95 % of the holes are drilled in AUTOMATIC drilling mode
- Round characteristics
  - Round length: 5.7m (pull % ~ 97-98 %)
  - Hole size: 57mm (earlier 51 & 54mm)
  - Number of holes: 172 + 4 pcs
  - All profile holes can be seen after blasting
- Drilling cycle
  - Rock type: very hard granite gneiss - uniaxial compressive strength ~ 250 MPa
  - Net penetration rate: 1.5-2.0 m/min
  - Total cycle: 180 min

Drilling
Drill plan



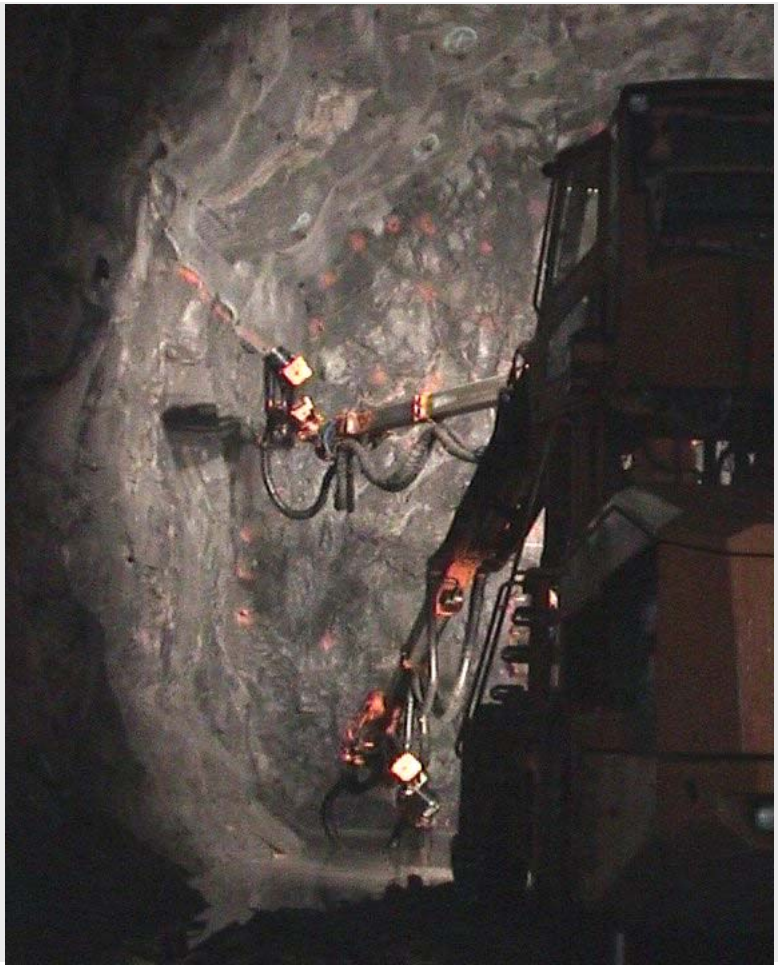


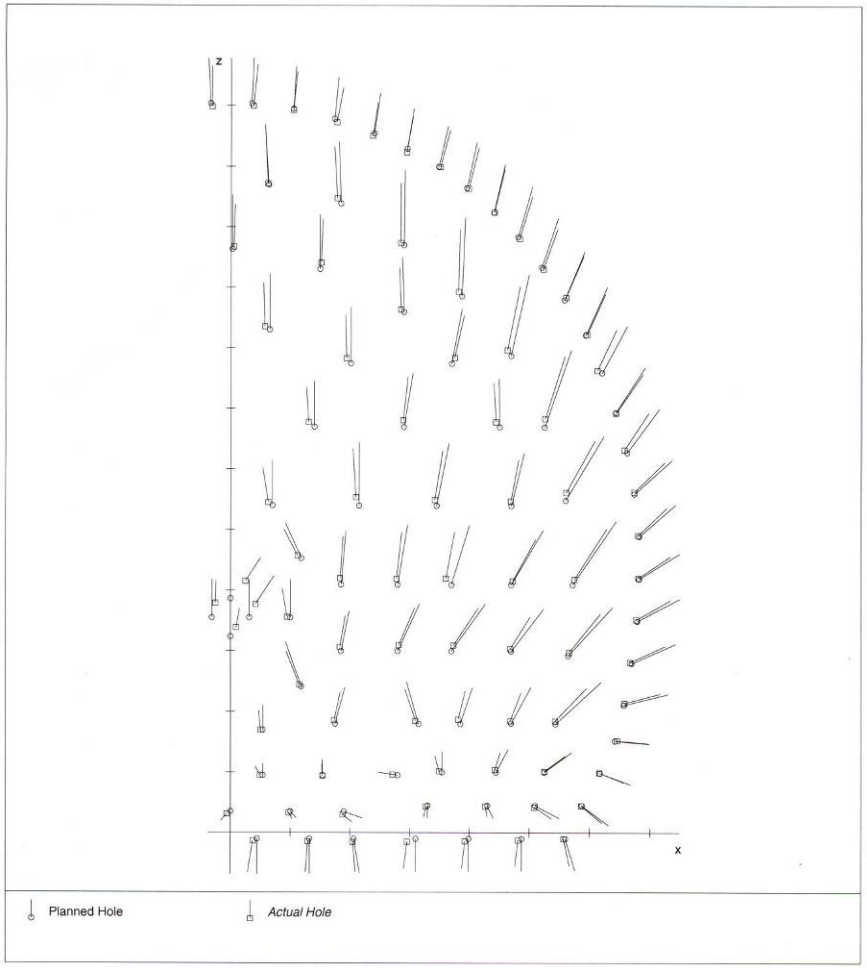
Drilling
Boom sequences



Drilling

Planned vs. actual holes





Charging

- 3 pcs of lifting vehicles + anfo-platform
  - Mechanized charging
  - 2 workers per lifter
- Charging characteristics
  - Field holes: anfo
  - Profile holes: smooth blasting tubes
  - Non-electric detonators
- Charging cycle
  - Total cycle: 110 min

Loading and Hauling

- 1 pc of Caterpillar 988 G loader
  - 6.5 m^3 bucket
  - 1 pc of Cat 988 F as a backup unit
- 8 pcs of Caterpillar 773 trucks
  - 50 ton dump box
- Loading & hauling characteristics
  - Trucks turn inside tunnel very close to the face
  - Dumping into trucks from the side
  - Four buckets per truck
- Loading & hauling cycle
  - Loading cycle time / truck: 2-2.5 min
  - Turning & reversing time: 0.5-0.8 min
  - Waiting time per truck: 0-1.0 min
  - Loading & hauling capacity: 425 loose-m^3 / hour => Total cycle: 170 min

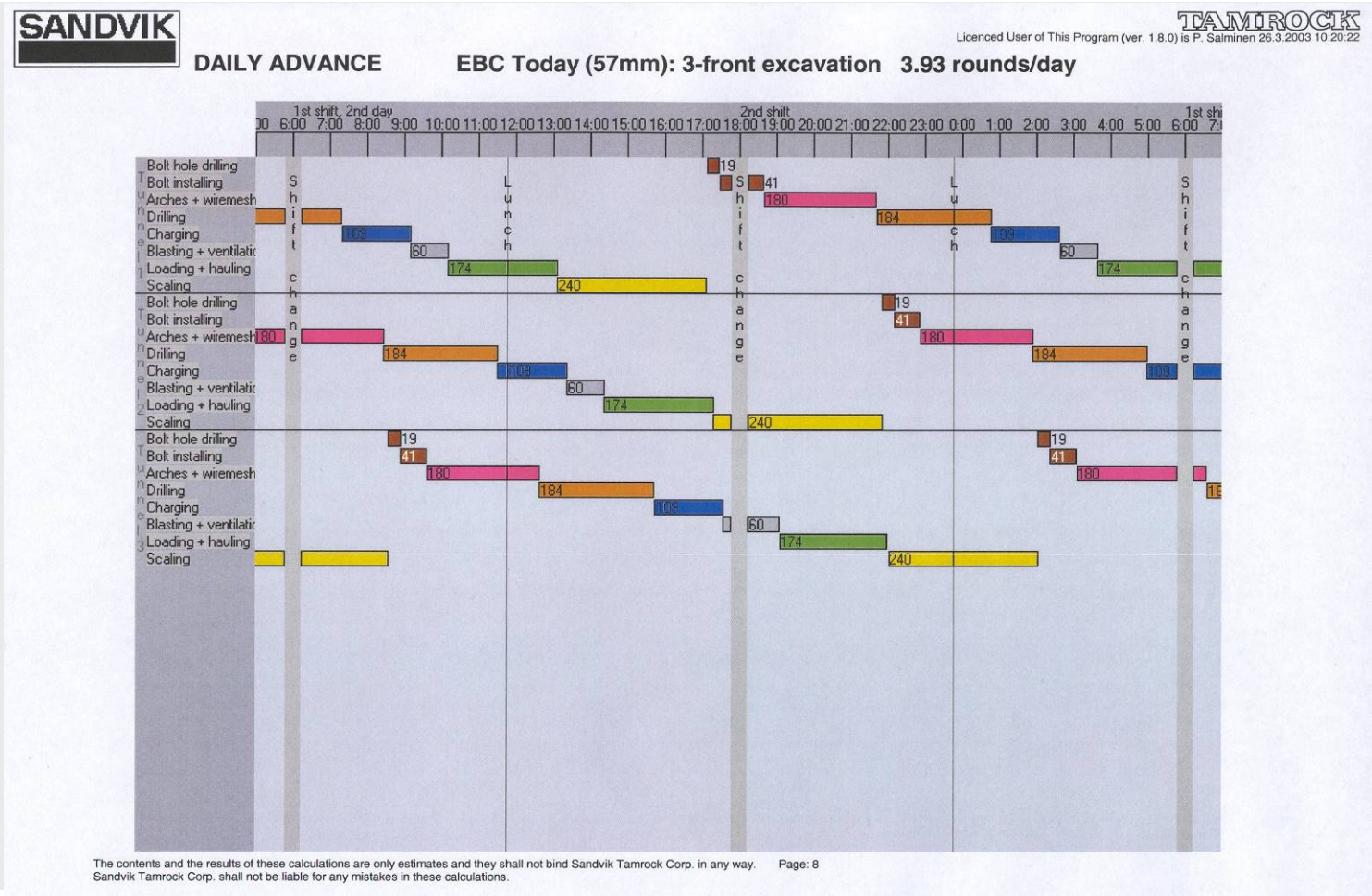
Scaling

- Method (four different stages)
  - 1st manual scaling from jumbo basket (during or after drilling)
  - Primary mechanical scaling on top of the muckpile (before mucking)
  - Final mechanical scaling for tunnel walls (after mucking)
  - 2nd manual scaling (before bolting)
- Equipment
  - Scaling bars + jumbo basket boom
  - Cat 235 excavator + 2 picks in bucket
- Scaling cycle
  - Manual scaling: 80 min (w/o 1st manual scaling, which is incl. in drilling cycle time)
  - Mechanical scaling: 170 min
  - Total cycle: 250 min

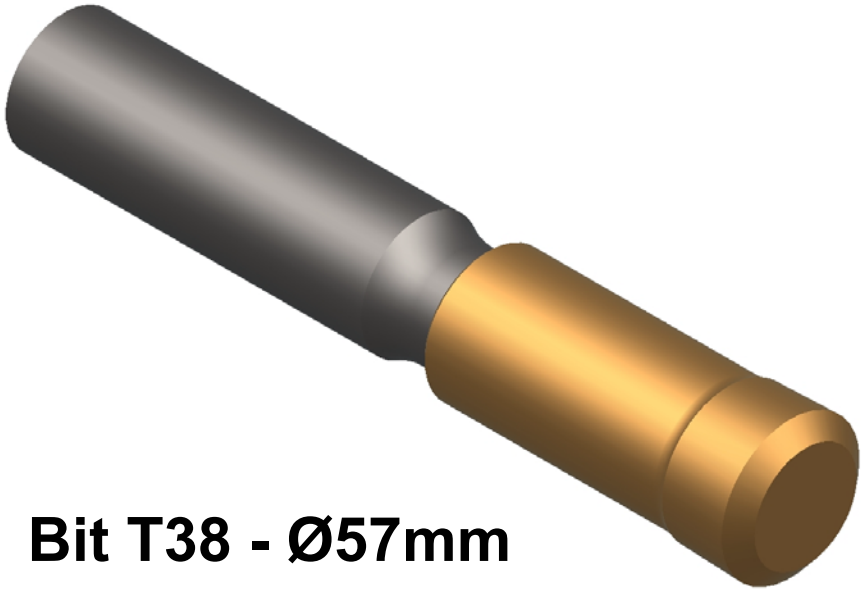
Performance

- 3-front excavation
- Working time arrangements
  - 2 x 12 hours shift per day
  - 5.7 days per week
- Daily advance
  - Average round cycle time: 16.7 hours
  - 4 rounds per day => 23 m per day
- Long-term performance
  - Average weekly result: 20 rounds per week => 114 meters per week
  - Best weekly result: 23 rounds per week => 131 meters per week

Performance
daily advance



Drill steel life



Bit T38 - Ø57mm

Rod T38-round46mm-T38

- Rock type
  - Very hard granite gneiss ~ 250 MPa
- Sandvik Drilling tools
  - Shank (T38): 7304-7585-01
  - Coupling (T38): 7314-3652
  - Rod (T38-round46-T38): 7324-8561-20 => excellent hole straightness !
  - Bit (T38 / Ø57mm): 7514-5357-S45
  - Reaming bit (Ø102mm): 7723-4802-S45
  - Pilot adapter (R35): 7823-5647
- Service life
  - Shanks: 6000 drm
  - Rods: 3000 drm
  - Bits (Ø57mm):
    - **average 420 drm**
    - **max. life 600 drm**
    - **regrinding interval 60 drm**