Metec 2009
Benefits of computerized drilling in drill and blast tunneling
Drill and Blast cycle

- Navigation & Surveying
- Rock Supporting
- Scaling
- Hauling
- Loading
- Charging
- Drilling, Probing, Grouting
- Blasting & Ventilation
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
- Boom control servo valves
- Software for designing and reporting
- Multiprocessor control system for boom and drilling controls
- Boom sensors
SETUP AND NAVIGATION

- 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
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**

\[ OB_{ave} (\%) = \left( \frac{VOB (m^3)}{V_{plan} (m^3)} \right) \times 100 \]
**Tunnel profile quality**

- **Causes of overbreak and underbreak**

  - Overbreak due to Drilling
  - Overbreak due to Blasting or Geology
  - Underbreak due to Drilling
  - Underbreak due to Blasting and Geology
  - Drilled Profile
  - Design Profile
  - Actual Profile
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 m²
- Planned excavation 100 000 m³
Example:
- 1000 m long D-shaped highway tunnel
- Cross section 100 m²
- Planned excavation 100 000 m³

<table>
<thead>
<tr>
<th>LEVEL OF INSTRUMENTATION</th>
<th>NO INSTRUMENTATION</th>
<th>DATA CONTROLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVERBREAK</td>
<td>40 cm / 15 %</td>
<td>25 cm / 9.4 %</td>
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<tr>
<td>REAL CROSS SECTION</td>
<td>115 m²</td>
<td>109 m²</td>
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<tr>
<td>NUMBER OF HOLES</td>
<td>152</td>
<td>143</td>
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<tr>
<td>PULL OUT</td>
<td>88 %</td>
<td>95 %</td>
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<tr>
<td>SPECIFIC CHARGE</td>
<td>1.5 kg/m³</td>
<td>1.3 kg/m³</td>
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<tr>
<td>ADVANCE</td>
<td>234 m/month</td>
<td>259 m/month</td>
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<tr>
<td>EXCAVATION TIME</td>
<td>4.3 months</td>
<td>3.9 months</td>
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<tr>
<td>SHOTCRETE</td>
<td>50 mm</td>
<td>50 mm</td>
</tr>
<tr>
<td>UNEVENNESS FACTOR</td>
<td>1.35</td>
<td>1.15</td>
</tr>
<tr>
<td>REBOUND FACTOR</td>
<td>1.2</td>
<td>1.2</td>
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Example calculations shown more in detailed in A1.1 Instructions.
## Drilling

### Profile quality

**Example:**
- 1000 m long D-shaped highway tunnel
- Cross section 100 m²
- Planned excavation 100 000 m³

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<th>LEVEL OF INSTRUMENTATION</th>
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</thead>
<tbody>
<tr>
<td>RELATIVE SAVINGS, EURO</td>
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<tr>
<td>DRILLING</td>
<td>0</td>
<td>+ 2,158.-</td>
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<td>EXPLOSIVES etc.</td>
<td>0</td>
<td>+ 51,107.-</td>
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<tr>
<td>LOADING &amp; HAULING</td>
<td>0</td>
<td>+ 56,100.-</td>
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<tr>
<td>SHOTCRETE</td>
<td>0</td>
<td>+ 92,064.-</td>
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<td>CONCRETE (OVERBREAK)</td>
<td>0</td>
<td>+ 841,500.-</td>
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<td>TOTAL SAVING, EURO</td>
<td>0</td>
<td>+ 1,042,929.-</td>
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<tr>
<td>TIME SAVING, MONTHS</td>
<td>0</td>
<td>0.4</td>
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</tbody>
</table>

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 m³

- **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
- 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 Ø 51 or 48 mm +
  - 3 pcs x Ø 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

<table>
<thead>
<tr>
<th>UNIT</th>
<th>DRILLED METERS</th>
<th>SHANK LIFE, drm</th>
<th>ROD LIFE, drm</th>
<th>COUPLING LIFE, drm</th>
<th>BIT LIFE, drm</th>
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<tbody>
<tr>
<td>Datasuper 1 (new generation drilling control system)</td>
<td>220.284</td>
<td>7.596</td>
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<td>Datasuper 2 (new generation drilling control system)</td>
<td>198.036</td>
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<td>Para 206 (new generation drilling control system)</td>
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<td>Datamaxi (old generation drilling control system)</td>
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<td>Commando 1</td>
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<td>Commando 2</td>
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<td>1.254</td>
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<tr>
<td>Ranger 500</td>
<td>25.726</td>
<td>3.675</td>
<td>953</td>
<td>1.225</td>
<td>476</td>
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* 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 Mm³
  - Contractor: EBC Inc.
  - Owner: Hydro-Quebec
  - Contract value: 70 million$

- **Tunnel dimensions**
  - Cross section: 134.3 m²
  - 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 + Ø 46 mm rods
  - TBB 5E basket boom
  - TDATA control system
- 1 pc of Caterpillar 988 G loader
  - 6.5 m³ 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
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
1 pc of Caterpillar 988 G loader
- 6.5 m³ 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-m³ / 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
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