Rock Disintegration Techniques

Thermal Spalling

Heat

700-1100°F

Spall

Molten Rock

2000-4000°F

Vapor

Fusion & Vaporization

Fractures

Force

Powdered Zone

Mechanical Breakage

Reactive Chemical

Chemical Reaction
# Rock Drilling Energy Requirements

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Temperature °C</th>
<th>Specific Energy J/CC</th>
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</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>Ambient</td>
<td>100</td>
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<tr>
<td>Thermal Spalling</td>
<td>600</td>
<td>1500</td>
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<tr>
<td>Melting</td>
<td>1100-3000</td>
<td>5000</td>
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<tr>
<td>Vaporization</td>
<td>8000-20,000</td>
<td>12,000</td>
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</tbody>
</table>
Combination
Conventional - Novel Drills
Kerf Cutting Mechanism

Combination Drilling Systems

Conventional

Cratering & Indexing

Rock

Combination Novel-Conventional

large Fractures

Novel Breakages
Kerf Index Distance in Rock Volume Removed

Energy-75 ft. lb.  Optimum Indexing

3/16” DIE Indiana Limestone

Single Crater
Novel-Mechanical Tunnel Boring machine

- Laser Beam
- Laser Beam Grid
- Novel Rock Slotting Device
- Thrust Cylinder
- Telescoping Legs
- Muck Deflectors & Buckets
- Conventional Rock Crushing
Tunnel Kerfing System

Geometry

Kerf

Annular Rock Protrusion

R = Radius To ITH

Kerf = 1 Ton

No. of Kerfs = N

N = 4
Rock Melting and Vaporization Drills
(1100 to 3000°C)
LANL Subterrene
LANL Subterrene
Russian Rock Melting Generator (VNIIBT)
Russian Rock Melting Generator
Electric Arc Drill

- Roller
- Nozzles
- Electrode
- Arc
Electric Arc Drill

- Insulation
- Molten Rock
- Arc
- Rock
- Center Electrode
- Incandescent Shell (Electrode)
Combination Electric Arc - Roller Cone Drill

- Conductor Cable
- Gas - Filled Chamber
- Electrodes
- Feed off and Gas Pressure Source
Plasma Drill

Gas (Helium or Argon)

Drilling Fluid

Reamer

Plasma

Electric Cable

Electric Arc
Electron Beam
Pulsed Electron Beam

Electron Burst
9 MV
45 kA
0.16 μs

= 64 kJ

64 cm²

Rock
Pulsed Electron Beam
Laser Drill (Gladstone)

- Electric Cable
- Electric Arc
- Coherent Light Beam
- Lens
- Reamer
- Crystal or Gas
- Drilling Fluid
Laser Drill

Electric Cables

Drilling Fluid

Ruby Crystal

Reamer

Electromagnet
Interaction of a Focused Laser Beam with Rock

- Focused Laser Energy
- Intensity Profile of Focused Laser Beam
- Gas Jet Assist ($\text{CO}_2\text{N}_2$)
- Radiated Heat Loss
- Reflected Energy
- Ejected vapor and Melt
- Convective Heat Loss
- Vapor
- Melt
- Heat - Affected Rock Zone (Heat Conduction)
- Solid Rock
Cross Section of Laser Kerfed Rocks
Deep Laser Kerfs Cut in Dolomite with 5 kw Laser

Rocks sectioned at right angle to kerf mirror focal length - 20.5 in.
No Jet
See table I for test conditions

<table>
<thead>
<tr>
<th>Test No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
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<tr>
<td>39</td>
</tr>
<tr>
<td>40</td>
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</tbody>
</table>
Thermal Spalling Drills
(600 to 800°C)
Jet-Piercing Drill

- Oxygen
- Water
- Fuel
- Reamer

Burner Assembly
Flame Drilling

Diagram showing the process of flame drilling, with labels for oxygen, fuel, water, reamer, burner assembly, rotary piercing, and churn piercing.
Rocket Exhaust Drill

- Nitric Acid
- Gasoline
- Water
- Rocket Motor
- Reamer
Electric Disintegration Drill

- Drilling Fluid
- Electric Current
- Electric Cable
- Heating Zone
- Cooling Zone
Electric Disintegration Drill
Electric Disintegration Drill
Electric Boulder Breakage
Electric Mining Technique
High-Frequency Electric Drill

- Drilling Fluid
- Electrode
- Electric Cables
- Electric Current
Terra-Jetter Drill

- Liquid Nitrogen
- Steam
- Detritus
Induction Drill

- Induction Coil
- Flux Lines
- Electrical Cables
- Drilling Fluid
- Reamer
- Induction Heating
Mechanical Destruction Drills
Turbine Bit

- Nozzle
- Diamond Cutter Wheel
- Turbine Buckets
Implosion Drill

- Hollow Sphere
- Collapsing Sphere
- Nozzle
- Shock Wave
Spark Drilling Mechanism

- Electrode
- Insulator
- Spark
- Chips
- Rock
- Shock Wave
Tangential Spark Drill

- Cathodes (Insulated)
- Circulation Port
- Anodes
- Spark-Over In Liquid
Spark Drilling Mechanism
Radial Spark Drill

- High Voltage Leads
- Water Inlet
- Exit for Water and Crushed Rock
- Rotating Center Electrode
- Teeth of Bit
Sandia Spark Drill
Electrohydraulic Rock Crusher

- Rock Inlet
- Spark
- Electrode
- Insulation
- Water
- Rock
- Perforated Bottom
- Electrode
Spark Percussion Drill

- Electric Cables
- Spark Gap
- Drilling Fluid
- Piston
- Seals
- Splines
Russian Explosive Capsule

Liquids (Explosive Mixtures)

Detonator

Fins

Diaphragm

Percussion Pin
Soviet Liquid Explosive Drill

- Two Stage Piston
- Oxidizing Agent
- Chemical Initiator
- Fuel
- Fuel Pipeline
- Initiator Pipeline
- Oxidizer Pipeline
- Flushing Fluid
- Detonation Chamber
Exxon Explosive Drill
AAI Explosive Drill
AAI Explosive Capsule
Explosively Drilled Hole in Granite
Explosively Drilled Hole in Limestone
REAM Cannon
REAM Projectile Drill
REAM 57-mm and 90-mm Projectiles
REAM Tunnel in Granodionite
Ultrasonic Drill

Electric Cables
Magnetostrictive Core
Emitter

Drilling Fluid
Coil
Abrasion and Cavitation
Sandia Chain Drill
Sandia Replaceable Cutter Head Bit
Sandia Replaceable Cutter Head Bit
Sandia Replaceable Cutter Head Bit
High Pressure Jet Bit

Nozzle

High Velocity Jets
Exxon Jet Bit
Exxon Jet Drilling

Drilling Rate (ft/hr)

Nozzle Pressure - PSI

- Berea Sandstone
- Indiana Limestone
- Carthage Marble
Exxon Jet Drill
Exxon Jet Instrumentation
Exxon Jet Pumps
Exxon Jet Bits
Exxon Jet Roller Bit Test

500 PSI
18 FT/HR

2300 PSI
38 FT/HR

NOZZLE PRESSURE

DRILLING RATE
Project Review

Conventional Coiled Tubing

High Pressure Motor

High Pressure Bit
High Pressure Drilling Mechanism

- Bit
- PDC Cutter
- Jets
- Rock Ledges
High Pressure Motor

10,000 psi
High Pressure Jet-Drilling Rates

Jet Drilling Rate (ft/in)

- **Texas Cream Limestone**: 1500 ft/in
- **Leander Limestone**: 780 ft/in
- **Glacier Bluff Dolomite**: 255 ft/in
- **Pecos Red Sandstone**: 68 ft/in

Note: (WOB=1000 lbs)

- **Bit Weight = 2000 lbs**
  - Green = 10,000 psi
  - Red = 1,000 psi

- **Texas Leander Glacier Pecos**
CT High Pressure Jet Drilling Rate

- Red Sandstone 3-1/8” Bit: 1600
- Rotary: 150
- Conventional: 300
- High Pressure: 1600
Motor Field Test
Field Drilling Rates

- 3 3/8” Motor
- 4 3/4” Bit
- Dolomite
- 1600-1900 ft
Gulf Abrasive Jet Drill
Terra Drill Projectile Drill
Terra Drill Projectiles
Terra Drill System
Terra Drill Drilling Rate

8" diameter - 60 RPM
Madera Limestone

Terra-drill

3 Cone Rotary Rock bit

RATE - in feet per hour

WEIGHT ON BIT - in 1000s of pounds
Terra Drill Prototype
Terra Drill Prototype
Terra Drill Experiments
Chemical Drills
Russian Chemical Drill

- Compressed Gas
- Fluorine
- High Velocity Jets Dissolve Rock
- Firing Leads
- Explosively Opened Seal
- Alloy Catalyst
McCullough Chemical Drill

- FIRING LEADS
- COMPRESSED GAS
- EXPLOSIVELY OPENED SEAL
- HALOGEN FLUORIDE
- ALLOY CATALYST
- HIGH VELOCITY JETS
- DISSOLVE ROCK
Novel Drill Conclusions

- High Energy Consumption
- Ability to Focus Power
- Combine Novel / Mechanical Drills
- Will Be Used In Future
Advanced Directional Drilling System
(Maurer Engineering Inc., 1978)

- Automatic Rig
- Pipe Reel
- On-Site Computer
- Relay Satellite
- Headquarters
- Reelable Pipe
- Receiver/Transmitter
- Processing and Control
- Survey Package
- Sensors
- Retractor
- Thruster
- Motor
- High Speed Bit
- Steering Sub
Rig Automation
Automated Offshore Rig
Arctic Drilling Rig
Automated Land Rigs
Russian Advanced Drilling Studies

Volume 1: Novel Drills
Volume 2: Advanced Downhole Motors
Volume 3: Advanced Drill Bits
Volume 4: Horizontal Drilling
Volume 5: Directional Drilling
The End
Russian Rock Melt Lining System

Dr. Alexander Gusman
Dr. Michael Gelfgat
Rock Melt Lining Technology

1. Sliding Packer
2. Centralizer
3. Heat insulator
4. Heat generator
5. Cable
6. Drillpipe
7. Drilling Console
8. Kelly with cable
9. Current collector
10. Swivel
11. Control unit
12. Additional transformer of variable power
13. Power transformer
14. High Voltage Switchboard

Top of the insulating stratum

Bottom of the insulating stratum

NPO « BUROVAYA TEKHNika » VNII GT
Rock Melt Lining Technology
Project Manager Dr. Alexander Gusanan
Russian Rock Test Stand
Rock Melting Power Supply
Russian Rock Melting Generator (VNIIBT)
Russian Rock Melting Generator
Russian Molten Rock Liner
Slit for Measuring Temperature
Ryrometer Temperature Measurement
The End
Advanced Geothermal Turbodrill (AGT)

- Bearing Pack
- Speed Reducer
- Turbine
Planetary Gears

- Sun Gear
- Ring Gear
- Planet Gears
Turbodrill Drill Stand
Drilled Rock Sample
Peak Drilling Rates

- Conventional: 76
- TUBODRILL: 207
Advanced Geothermal Turbodrill (AGT) Field Test
12 1/4” Carbide Roller Bit
Texas Pink Granite

Drilling Rate (ft/hr)

Rotary: 42
LANL Turbodrill: 45
AGT Turbodrill: 92