Advanced Directional Drilling System
(Maurer Engineering Inc.)

- 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
Rock Disintegration Techniques

- **Thermal Spalling**:
  - Heat: 700-1100°F
  - Spall

- **Fusion & Vaporization**: 2000-4000°F

- **Mechanical Breakage**: Force

- **Chemical Reaction**: Reactive Chemical
# Rock Drilling Energy Requirements

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

Combination Drilling Systems

Conventional

Cratering & Indexing

Rock

Combination Novel-Conventional

large Fractures

Novel Breakages

Rock
Kerf Index Distance in Rock Volume Removed

3/16” DIE Indiana Limestone

Energy-75 ft. lb.

Optimum Indexing

Single Crater

Crater Volume (In.3) vs. Index Distance (In.)
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

\( R = \text{Radius} \)
To ITH

Kerf = 1 Ton

No. of Kerfs = \( N \)

\( N = 4 \)

Face

Section
Rock Melting and Vaporization Drills

(1100 to 3000°C)
LANL Subterrene
LANL Subterrene
LANL Subterrence

- Extrusion Tube
- Water
- Cooling Water
- Tungsten or Iridium Wire
- Extrudite
- Gas
- Electrical Cable
- Boron Nitride
- Tungsten Shoe
- Molten Rock
Russian Rock Melting Generator (VNI BT)
Russian Rock Melting Generator
Electric Arc Drill

- Roller
- Nozzles
- Electrode
- Arc
Electric Arc Drill

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

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

Gas (Helium or Argon)

Drilling Fluid

Reamer

Plasma

Electric Cable

Electric Arc
Electron Beam Drill

- Electric Cables
- Vacuum
- Deflector Coil
- Seal
- Anode
- Drilling Fluid
- Cathode
- Focus Grid
- Focus Lens
- Electron Beam
Electron Beam
Electron Beam
Pulsed Electron Beam

Electron Burst
9 MV
45 kA
0.16 μs

= 64 kJ

64 cm²

Rock
Pulsed Electron Beam
Laser Drill

- Electric Cables
- Drilling Fluid
- Ruby Crystal
- Electromagnet
- Reamer
Interaction of a Focused Laser Beam with Rock

Focused Laser Energy

Intensity Profile of Focused Laser Beam

Gas Jet Assist (CO$_2$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>
</tr>
<tr>
<td>39</td>
</tr>
<tr>
<td>40</td>
</tr>
</tbody>
</table>
Thermal Spalling Drills
(600 to 800ºC)
Jet-Piercing Drill

- Oxygen
- Water
- Fuel
- Reamer
- Burner Assembly
Flame Drilling

Diagram showing the process of Flame Drilling, involving oxygen, fuel, and water. The diagram illustrates the reamer, burner assembly, and the movement between rotary piercing and churn piercing.
Rocket Exhaust Drill

Nitric Acid → Gasoline

Water

Rocket Motor

Reamer
Electric Disintegration Drill

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

- Drilling Fluid
- Electrode
- Electric Current
- Electric Cables
Terra-J etter Drill

Liquid Nitrogen

Steam Detritus
Microwave Drill

- Electric Cables
- Waveguide
- Reamer
- Drilling Fluid
- Magnetron
- Electromagnet
Induction Drill

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

- Nozzle
- Diamond Cutter Wheel
- Turbine Buckets
Implosion Drill

Collapsing Sphere

Shock Wave

Hollow Sphere

Nozzle
Spark Drilling Mechanism

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

Cathodes (Insulated)

Anodes

Circulation Port

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

- Electrode
- Insulation
- Rock Inlet
- Water
- Rock
- Perforated Bottom
- Electrode
- Spark
Electrohydraulic Rock Splitter

- Electrode
- Insulation
- Water
- Spark
- Boulder
Spark Percussion Drill

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

- **Choke**
- **Nozzle**
- **Explosive Capsule**
Russian Explosive Capsule

- Liquids (Explosive Mixtures)
- Fins
- Detonator
- 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
Sandia Chain Drill
Sandia Replaceable Cutter Head Bit
Sandia Replaceable Cutter Head Bit
High Pressure Jet Bit

Nozzle

High Velocity Jets
Exxon Jet Bit
Exxon Jet Drill
Exxon Jet Instrumentation
Exxon Jet Bits

DIAMOND

DRAG

ROLLER
Exxon Jet Roller Bit Test

NOZZLE PRESSURE

500 PSI

18 FT/HR

2300 PSI

38 FT/HR

DRILLING RATE
Erosion Drilling Test No. 8

Graph showing the comparison of well depth versus rotating time for conventional bits (2000 PSI) and erosion bits (10,000 - 15,000 PSI).
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)

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

1500
(WOB=1000 lbs)
780
910
68
142
120
110

Texas Cream Limestone
Leander Limestone
Glacier Bluff Dolomite
Pecos Red Sandstone
CT High Pressure Jet Drilling Rate

Drilling Rate

Rotary: 150
Conventional: 300
High Pressure: 1600

Red Sandstone 3-1/8” Bit

Motor Motor
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

RATE – in feet per hour

WEIGHT ON BIT – in 1000s of pounds

Terra-drill

3 Cone Rotary Rock bit
Terra Drill Prototype
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
Automated Offshore 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
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 TEKHNIKAO-VNIIBT
Rock Melt Lining Technology
Project Manager Dr. Alexander Gusman
Rock Melting Power Supply
Russian Rock Melting Generator (VNI I BT)
Russian Rock Melting Generator
Russian Molten Rock Liner
Russian Heating Element
Slit for Measuring Temperature
Ryrometer Temperature Measurement
The End
Advanced Geothermal Turbodrill (AGT)

Bearing Pack

Speed Reducer

Turbine
Planetary Gears

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

Conventional: 76
TUBODRILL: 207
Advanced Geothermal Turbodrill (AGT) Field Test
Turbodrill Performance

- Rotary Speed (RPM):
  - With Gear Box: 85 RPM
  - Without Gear Box: 1100 RPM

- Torque (ft-lbs):
  - With Gear Box: 900 ft-lbs
  - Without Gear Box: 7500 ft-lbs
12 1/4” Carbide Roller Bit
Texas Pink Granite

Drilling Rate (ft/hr)

<table>
<thead>
<tr>
<th>Method</th>
<th>Rate (ft/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotary</td>
<td>42</td>
</tr>
<tr>
<td>LANL Turbodrill</td>
<td>45</td>
</tr>
<tr>
<td>AGT Turbodrill</td>
<td>92</td>
</tr>
</tbody>
</table>