TUNNELS:
MACHINE EXCAVATION—
RATE OF PROGRESS—
MACHINE DATA

July 1986
Engineering and Research Center

S. Department of the Interior
au of Reclamation
Information on 20 machine-bored water tunnels constructed by the Bureau of Reclamation is presented graphically and pictorially. Machine data, rates of progress, tunnel profiles, and rock types and strengths are given for each tunnel. The bored diameters of these tunnels varied from 9 to 21 feet. Rocks encountered in boring were: shale, sandstone, conglomerate, quartzite, limestone, siltstone, granite porphyry, granite gneiss, gneissic granodiorite, rhyolite, rhyodacite, and agglomerate. The compressive strengths of these rocks were 300 to 38,000 psi. The boring rates of the machines used varied from 17 to 107 feet for the average calendar day. The maximum progress was 403 feet in 1 three-shift day. This rate was attained in 17.3 hours of machine time while boring an 8-foot 7-inch finished-diameter tunnel through shale having a maximum compressive strength of 6,000 psi. Contract and miscellaneous data are also given for each of the tunnels.

**Key Words and Document Analysis**

- **Descriptors**: *water tunnels (conveyance)*/ tunneling/ *tunneling machines/ *tunnel construction/ *boring machines/ rapid excavation/ rock excavation/ rock properties/ compressive strength/ *project summaries/ progress reports/ *tunnels

- **Identifiers**: COSATI Field/Group 13C

**Distribution Statement**

Available from the National Technical Information Service, Operations Division, 5285 Port Royal Road, Springfield, Virginia 22161. (Microfiche and/or hardcopy available from NTIS).
TUNNELS: MACHINE EXCAVATION—
RATE OF PROGRESS — MACHINE DATA

by
R.S. Sinha

July 1986

Water Conveyance Branch
Division of Dam and Waterway Design
Engineering and Research Center
Denver, Colorado
As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.

The information contained in this report regarding commercial products or firms may not be used for advertising or promotional purposes and is not to be construed as an endorsement of any product or firm by the Bureau of Reclamation.
The "art" of underground tunnel construction has been a relatively slow, laborious, and cyclic process. The introduction of Tunnel Boring Machines (TBM), or "moles" has been an effort to speed up this process. In 1972, the Bureau of Reclamation published REC-ERC-72-9, "Tunnels: Machine Excavation—Rate of Progress—Machine Data," which readily provided pertinent data on the seven, machine-bored tunnels the Bureau had constructed to that time. The tunnels included in the 1972 report are:

- Azotea Tunnel—San Juan-Chama Project, New Mexico
- Blanco Tunnel—San Juan-Chama Project, Colorado
- Oso Tunnel—San Juan-Chama Project, Colorado
- River Mountains Tunnel—Robert B. Griffith (Southern Nevada) Water Project, Nevada
- Starvation Tunnel—Central Utah Project, Utah
- Tunnel No. 1—Navajo Indian Irrigation Project, New Mexico
- Water Hollow Tunnel—Central Utah Project, Utah

In 1974, the Bureau published REC-ERC-74-7, "Tunnels: Machine Excavation—Rate of Progress—Machine Data," which included five additional tunnels. They are:

- Currant Tunnel—Central Utah Project, Utah
- Layout Tunnel—Central Utah Project, Utah
- Nast Tunnel—Fryingpan-Arkansas Project, Colorado
- Tunnel No. 3—Navajo Indian Irrigation Project, New Mexico
- Tunnel No. 3A—Navajo Indian Irrigation Project, New Mexico

Since 1974, the data on eight additional tunnels has been prepared. They include:

- Buckskin Mountains Tunnel—Central Arizona Project, Arizona
- Dolores Tunnel—Dolores Project, Colorado
- Hades and Rhodes Tunnels—Central Utah Project, Utah
- Santa Clara Tunnel—Central Valley Project, California
- Stillwater Tunnel—Central Utah Project, Utah
- Strawberry Tunnel Inlet Rehabilitation—Central Utah Project, Utah
- Tunnel No. 5—Navajo Indian Irrigation Project, New Mexico
- Vat Tunnel—Central Utah Project, Utah

This report includes all 20 tunnels.
<table>
<thead>
<tr>
<th>Tunnel Name, Project, and State</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azotea, San Juan-Chama, New Mexico</td>
<td>1</td>
</tr>
<tr>
<td>Blanco, San Juan-Chama, Colorado</td>
<td>3</td>
</tr>
<tr>
<td>Buckskin Mountains, Central Arizona Project, Arizona</td>
<td>5</td>
</tr>
<tr>
<td>Currant, Central Utah, Utah</td>
<td>7</td>
</tr>
<tr>
<td>Dolores, Dolores, Colorado</td>
<td>9</td>
</tr>
<tr>
<td>Hades and Rhodes, Central Utah, Utah</td>
<td>11</td>
</tr>
<tr>
<td>Layout, Central Utah, Utah</td>
<td>13</td>
</tr>
<tr>
<td>Nast, Fryingpan-Arkansas, Colorado</td>
<td>15</td>
</tr>
<tr>
<td>Oso, San Juan-Chama, Colorado</td>
<td>17</td>
</tr>
<tr>
<td>River Mountains, Robert W. Griffith Water Project (So. Nevada), Nevada</td>
<td>19</td>
</tr>
<tr>
<td>Santa Clara, Central Valley, Utah</td>
<td>21</td>
</tr>
<tr>
<td>Starvation, Central Utah, Utah</td>
<td>23</td>
</tr>
<tr>
<td>Stillwater, Central Utah, Utah</td>
<td>25</td>
</tr>
<tr>
<td>Strawberry Tunnel Inlet Rehabilitation, Central Utah, Utah</td>
<td>27</td>
</tr>
<tr>
<td>Tunnel No. 1, Navajo Indian Irrigation Project, New Mexico</td>
<td>29</td>
</tr>
<tr>
<td>Tunnel No. 3, Navajo Indian Irrigation Project, New Mexico</td>
<td>31</td>
</tr>
<tr>
<td>Tunnel No. 3A, Navajo Indian Irrigation Project, New Mexico</td>
<td>31</td>
</tr>
<tr>
<td>Tunnel No. 5, Navajo Indian Irrigation Project, New Mexico</td>
<td>33</td>
</tr>
<tr>
<td>Vat, Central Utah, Utah</td>
<td>35</td>
</tr>
<tr>
<td>Water Hollow, Central Utah, Utah</td>
<td>37</td>
</tr>
</tbody>
</table>
BLANCO TUNNEL
SAN JUAN CHAMA PROJECT
COLORADO-NEW MEXICO

TUNNEL PROFILE

HYDRAULIC PROPERTIES

- Tunnel Diameter (Tunnel Liner Plate Construction - 18")
- Elevation
- Station

ELEVATION

- Monthly Average Flow
- Monthly Average Temperature
- Monthly Average Pressure
- Monthly Average Air Velocity

MACHINE DATA

- Manufactured by Robbins
- Model IDA-120
- Length: 40 ft
- Weight: 20,000 lbs
- Thrust: 372,000 lbs
- Torque: 17,000 ft-lbs
- Cutters: 22-in. disc
- Thrust in center
- Head rotated by 4-phase 440 volt motors
- Laser beam guidance
- Muck conveyor/training

PROGRESS

- Average: .75 ft per calendar day
- Average: .54 ft per working day
- Maximum: 1.5 ft per day
- Maximum: 1.5 ft per hour

CONTRACTS

- Colorado Constructors
- Specification No. DC-626
- Total bid for 45,576 feet
- $31,987,755 (FOB on linear foot basis)

MISCELLANEOUS DATA

- Track gauge: 24"
- Ventilation line: 24"
- Voltage into tunnel: 440 volts
- Number of men to operate boring machine: 8 per shift
- Max water temperature: 60°F
- Max rock temperature: 93°F

TIME-DATE AND DAYS

TUNNEL MACHINE-PROGRESS CHART

- Outlet Portal: Surface left by machine supported with rock bolts and steel mat
- Fallout: Area resupported
- Trailing dust collection and muck conveyor system
- Left side of machine
- Cutter head
NAST TUNNEL  
FRYINGPAN - ARKANSAS PROJECT  
COLORADO

TUNNEL PROFILE

MAchine DATA
MANUFACTURED BY WIRTH & COMPANY, ERFURT, GERMANY
MODEL: TB II-500 IN
LENGTH: 25 FT. WITH SOFT TRAILING POWER SUPPORT 100 TONS
MAX. TORSION: 15,000 LB-FT 20,000 LB-FT 2500 FT LBS
CUTTER HEAD ORIGINALLY AHEAD OF BRR WITH FLAT FACE, DEMANDED TL-24, BRR-72 BURTON INSERT
CUTTERS: 20 NO FACE OR ARCH SHIELDS, CUTTER HEAD LATER REPLACED WITH FLAT FACED HEAD, 25 CUTTERS WITH FACE OR ARCH SHIELDS
ROTOR, THRUST & GRIPPERS HYDRAULICALLY OPERATED
LASER BEAM GUIDANCE
WASTE DISPOSAL: TRAILING CONVEYOR IN TRAIN

PROGRESS
MAXIMUM FOR 1 DAY: 75 FT.
AVERAGE PER MACHINE: 35 FT.
PER SHIFT: 12.5 FT.
PER CALENDAR DAY: 16.6 FT.

MISCELLANEOUS DATA
TRACK GAGE: 48" 90° VENTILATION LINE: 72" VOLTAGE SUPPLY INTO TUNNEL: 480 VOLTS
TYPICAL UNDERGROUND MACHINE
CREW: 11 MEN
MACHINE LIMITED TO 580 FT RADIUS CURVE
5 SHIFT DAY: 6 DAY WEEK OPERATION

CONTRACT DATA
CONTRACTOR: PETER Kiewit Sons Co.
SPECIFICATIONS No.: 0C-6382
BID (TUNNEL PORTION): 5,682,754


TIME-DATE AND DAYS
TUNNEL MACHINE - PROGRESS CHART
RIVER MOUNTAINS TUNNEL
SOUTHERN NEVADA WATER PROJECT
NEVADA

TUNNEL PROFILE

HYDRAULIC PROPERTIES

<table>
<thead>
<tr>
<th>TUNNEL</th>
<th>G</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>LENGTH</td>
<td>5,000</td>
<td>4,500</td>
<td>4,000</td>
<td>3,500</td>
<td>3,000</td>
</tr>
<tr>
<td>ELEVATION</td>
<td>2,000</td>
<td>1,500</td>
<td>1,000</td>
<td>500</td>
<td>0</td>
</tr>
</tbody>
</table>

Machine: Bored Tunnel 15,933 ft - Dist. Bored 12.0 ft
Tunnel: 19.53 ft, 270 days, March 26, 1968

MACHINE DATA
MANUFACTURED BY JARVA
MODEL (MARK IV, II) 1/2
LENGTH: 57.7 ft, WEIGHT: 15,000 lbs
THROTTLE: 155,000/LBS TORQUE 233,000. FT LBS
3 CUTTERS, 20 STEEL KERF TYPE, 1 TOOTH TYPE
4 TOOTH OR TUNGSTEN CARBIDE INSERT
KRF TYPE 45 DEGREE CUTTERS
ROTATION BY 4-100 HP ELECTRIC MOTORS, LATER MODIFIED TO 6-50 HP
Laser Beam Guidance
WASTE DISPOSAL...TRAVELING CONVEYOR AND TRAIN

PROGRESS

AVERAGE...75.8 ft per calendar day
AVERAGE...100 ft per working day
MAXIMUM...295 ft per day
MAXIMUM...104 ft per 8 hr shift

OVERALL VIEW-OUTLET PORTAL WORK AREA

CONTRACT DATA
UTAH CONSTRUCTION AND MINING - DURING CONTRACT PERIOD CHANGED TO JARVA ENGINEERS AND CONSTRUCTORS, INC.
SPECIFICATION NO. GC-6-595
BID TUNNEL PORTION 13,572.28

MISCELLANEOUS DATA
TRACK GAGE: 95" VENTILATION LINE: 50 VOLTAGE SUPPLY INTO TUNNEL:
4,100 VOLTS
NO. OF MEN TO OPERATE MACHINE: 4 PER SHIFT
AMBIENT TEMPERATURE AT CUTTER HEAD: 95° TO 105° F
ROCK TEMPERATURE: 85° F

TIME-DATE AND DAYS
TUNNEL MACHINE PROGRESS CHART

LASER BEAM GUN MOUNTED ON TUNNEL WALL
VIEW OF JARVA MACHINE DURING ASSEMBLY
BREAK THROUGH
CHANGING CUTTERS-LASER TARGETS IN UPPER QUADRANT
WASTE DISPOSAL-ROTARY CAR DUMP IN OPERATION
ASSEMBLING MACHINE-NOTE CONVEYOR WITH VENTILATION SYSTEM ON TOP

10
STRAWBERRY TUNNEL INLET REHABILITATION
CENTRAL UTAH PROJECT
BONNEVILLE UNIT, UTAH

TUNNEL PROFILE

CONTRACT DATA
CONTRACTOR: AMERICAN-SUMMIT LTD
SPECIFICATION NO. 40-07478
BID NO. 201-180-34
TOTAL COST: $1,682,888.13
TUNNEL COST: $1,650,477.64

MACHINE DATA
MADE BY MITSUI MITSUI MACHINERY CO., LTD
MODEL NO. MHR-5-125-22
LENGTH: 125 FT
WEIGHT: 59 TONS
TORQUE: 125 TR.
HORSEPOWER: 125 HP
SPEED: 15 RPM
STROKE: 125 IN
BORE DIAMETER: 37.5 IN
LUBRICANT: 1500-2000 S.A.E.
WEIGHT: 9 1/2 TON-9 1/2 TON-6 1/2 TON
SUPPORTS: 30/60/80 TON RACK
15/60/80 TON FLOOR
SUPPORTS: 30/60/80 TON RACK
15/60/80 TON FLOOR

TUNNEL MACHINE-PROGRESS CHART

ADVANCEMENT OF NEW STRAWBERRY INLET TUNNEL
TUNNEL MACHKNE PROGRESS CHART

VIEW OF CONCRETE BEING CONVEYED TO
THE PUMP AFTER BEING
DISCHARGED FROM MORAN CARS

CONCRETE MIXER AND DISCHARGER

WYE "A" BRANCHES TO THE RIGHT
OF NEW INLET TUNNEL AND CONNECTS
TO EXISTING STRAWBERRY TUNNEL

TYING REINFORCING STEEL
IN WYE "A" CONNECTION
WATER HOLLOW TUNNEL
CENTRAL UTAH PROJECT
BONNEVILLE UNIT-UTAH

TUNNEL PROFILE

ELEVATION
9500
9000
8500
8000
7500
7000

HYDRAULIC PROPERTIES
TUNNEL PROFILE
Q A Y K E E

UHLIG CYLINDER
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0

Machine Halted
Through St. 17591757

MACHINE DATA
MANUFACTURED BY ROBBINS; THIS MACHINE USED IN
A JOTEA TUNNEL (MODIFIED FOR THIS JOB)
LENGTH: 93 FT
WEIGHT: 190,000 LBS
THRUST: 470,000 LBS
THORNE 30,000 FTLBS
CUTTERS: 4 TRICONE AND 89 DISC
HEAD ROTATED BY 4 100 HP 440 VOLT MOTORS
LASER BEAM GUIDANCE
WASTE DISPOSAL: TRAILING CONVEYOR & TRAIN

PROGRESS
MAXIMUM CAPABILITY
MAXIMUM FOR 1 DAY: 180 FT
FOR 1 SHIFT: 70 FT
AVERAGE PER DAY: 76 FT
PER SHIFT: 32 FT
PER CALENDAR DAY: 48 FT

CONTRACT DATA
CONTRACTOR-BOYLES BROS.
DRILLING CO., RIBBONS AND RIGGS
SPECIFICATION NO. D.C.-85775
TUNNEL SCHEDULE BID $5,256,422

MISCELLANEOUS DATA
TRACK GAGE: 96"
VENTILATION LINE: 2-2" VOLTAGE SUPPLY INTO TUNNEL: 4160 VOLTS
NO. OF MEN TO OPERATE MACHINE: 6 PER SHIFT
AMBIENT TEMPERATURE AT CUTTER HEAD: 62°F
MACHINE OPERATED: 3 SHIFT DAY, 4 DAY WEEK

GAP IN CUT AND COVER SECTION AT PORTAL FOR INSTALLATION OF MACHINE CUTTER HEAD
LOWERED CUTTER HEAD INTO GAP TO INSTALL ON MACHINE BODY WHICH WAS MOVED IN THROUGH THE CUT AND COVER
WATER FLOWING AROUND MACHINE
BORING THROUGH ZONE OF WET INCOMPETENT ROCK
SUBINVERT CONCRETE PLACED TO PROTECT INVERT ROCK

TIME-DATE AND DAYS
TUNNEL MACHINE-PROGRESS CHART

1968 1969 1970
20,000 19,500 19,000 18,500 18,000 17,500 17,000 16,500 16,000 15,500 15,000 14,500 14,000 13,500 13,000 12,500 12,000 11,500 11,000 10,500 10,000 9,500 9,000 8,500 8,000 7,500 7,000 6,500 6,000 5,500 5,000 4,500 4,000 3,500 3,000 2,500 2,000 1,500 1,000 500 0

BEGIN MACHINE OPERATIONS NOV. 9, 1968
NOTICE TO PROCEED MAY 1, 1968
BEGIN MACHINE OPERATIONS NOV. 9, 1968
FAULTED ZONE
OVERALL AVERAGE: 42.8 FT PER CALENDAR DAY
21,043 FT
49 DAYS
500 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400

37