REC-ERC-86-8

TUNNELS: MACHINE EXCAVATION— RATE OF PROGRESS— MACHINE DATA

July 1986

Engineering and Research Center

U. S. Department of the Interior
Bureau of Reclamation

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16. ABSTRACT

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.

17. KEY WORDS AND DOCUMENT ANALYSIS

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

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REC-ERC-86-8

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

UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

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.

PREFACE

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.

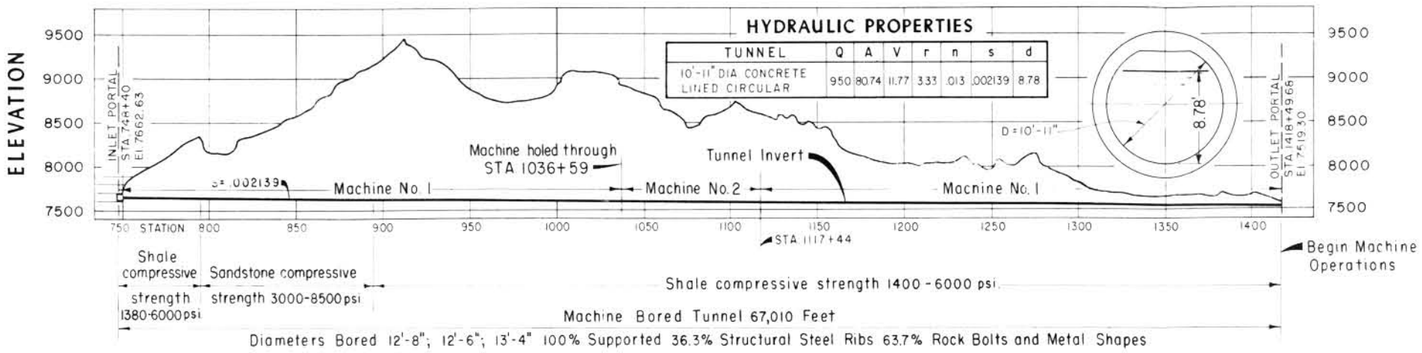
CONTENTS

AZOTEA TUNNEL

SAN JUAN CHAMA PROJECT

COLORADO - NEW MEXICO

TUNNEL PROFILE



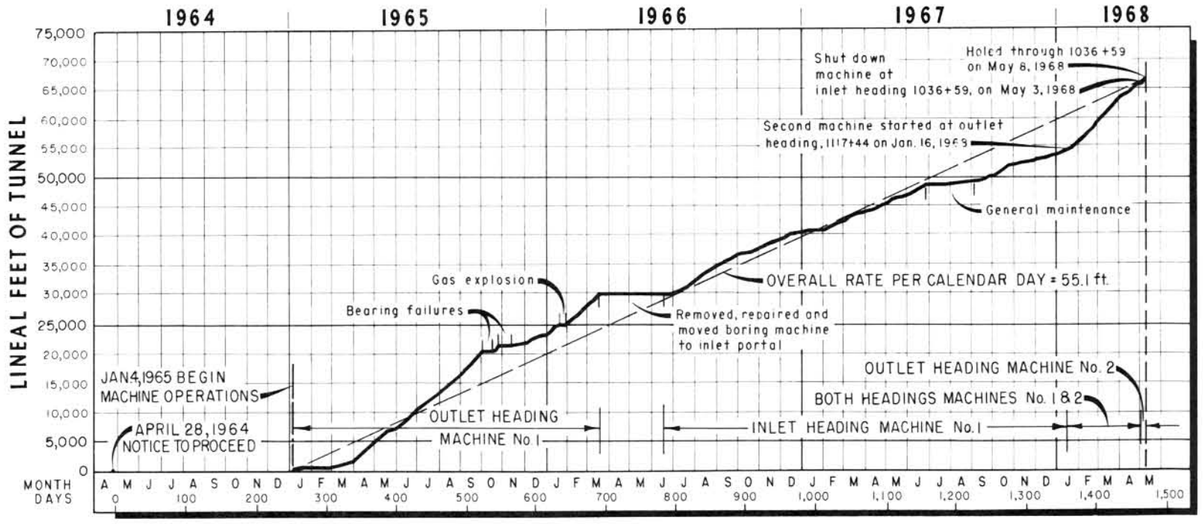
MACHINE DATA (MACHINE No.1)

MANUFACTURED BY ROBBINS — MODEL 104-121A
LENGTH_____35 FT. — WEIGHT-152,200 LBS.
*THRUST___ 477,000 LBS. *TORQUE 300,000 FT. LBS.
CUTTERS___ 25 or 29 DISC, 1-TRICONE IN CENTER
ROTATION BY 4-100 HP, 440 VOLT AC MOTORS
LASER BEAM GUIDANCE
WASTE DISPOSAL_____TRAILING CONVEYOR & TRAIN
MACHINE No.2-SEE OSO TUNNEL MACHINE DATA

*MAXIMUM CAPABILITY

PROGRESS

AVERAGE___55 FT. PER CALENDAR DAY
AVERAGE IN SHALE_____
___153 FT. PER WORKING DAY
AVERAGE IN SANDSTONE_____
___72 FT. PER WORKING DAY



TIME-DATE AND DAYS

TUNNEL MACHINE-PROGRESS CHART

LASER GUN USED FOR GUIDANCE CONTROL

HOLING THROUGH - NOTE CONCENTRIC TRACES OF CUTTER DISCS

CONTRACT DATA

CONTRACTOR-AZOTEA CONTRACTORS JOINT VENTURE; GIBBONS & REED; BOYLES BROS. DRILLING Co; & DUGAN GRAHAM INC.
SPECIFICATION No. DC-6070
BID $13,791,000-INCLUDES APPURTENANT STRUCTURES

MISCELLANEOUS DATA

TRACK GAGE_____30" & 24"
VENTILATION LINE_____24"
VOLTAGE SUPPLY INTO TUNNEL__
_____4,160 VOLTS
No. OF MEN TO OPERATE MACHINE
_____5 PER SHIFT
AMBIENT TEMPERATURES AT CUTTER HEAD_____90°-100° F
ROCK TEMPERATURES__65°-78° F

ASSEMBLING BORING MACHINE

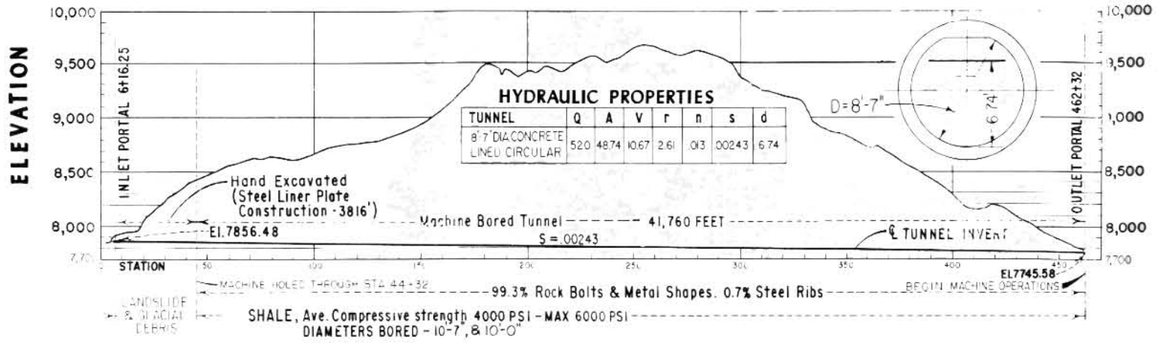
READY FOR LINING

COMPLETED CONCRETE LINED SECTION

BLANCO TUNNEL

SAN JUAN CHAMA PROJECT
COLORADO-NEW MEXICO

TUNNEL PROFILE



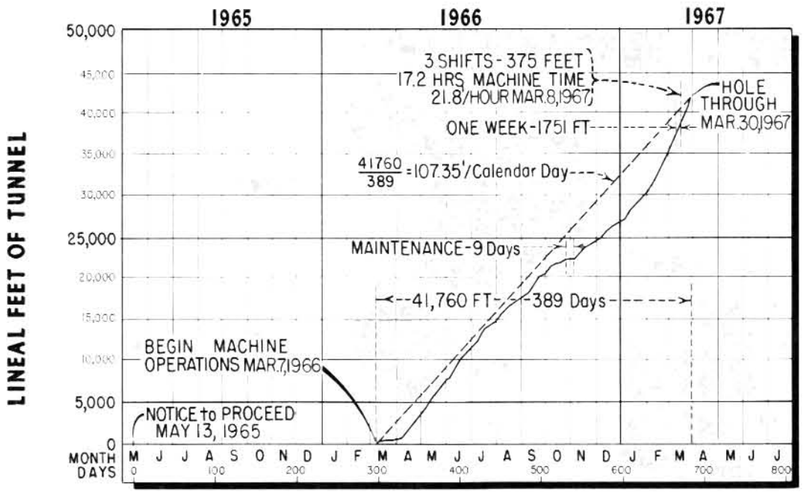
MACHINE DATA

MANUFACTURED BY ROBBINS — MODEL 104 - 120
LENGTH ..... 40 FT — WEIGHT-120,000 LBS
*THRUST ..... 372,000 LBS — *TORQUE 175,000 FT LBS
CUTTERS ... 22-11" DISC, 1 TRICONE IN CENTER
HEAD ROTATED BY 4 - 75 HP, 3 PHASE 440 VOLT MOTORS
LASER BEAM GUIDANCE
WASTE DISPOSAL
TRAILING CONVEYOR & TRAIN

PROGRESS

AVERAGE .... 107 FT PER CALENDAR DAY
AVERAGE .... 154 FT PER WORKING DAY (14.2 FT/HR)
MAXIMUM .... 375 FT IN ONE 3 SHIFT DAY (17.2 HRS MACHINE TIME)
MAXIMUM .... 21.8 FT PER HOUR

* MAXIMUM CAPABILITY



TIME - DATE AND DAYS

TUNNEL MACHINE-PROGRESS CHART

CONTRACT DATA

COLORADO CONSTRUCTORS & A.S. HORNER-DENVER, COLO.

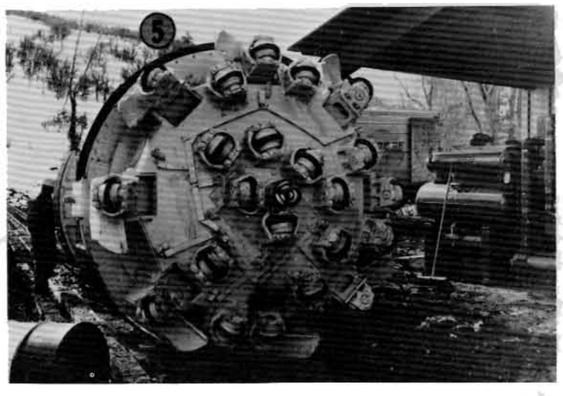
SPECIFICATION NO. DC-6261

TOTAL BID FOR 45,576 FEET OF TUNNEL - $9,188,752.00 (BID ON LINEAR FOOT BASIS)

MISCELLANEOUS DATA

TRACK GAGE ..... 24"
VENTILATION LINE ..... 24"
VOLTAGE INTO TUNNEL ..... 4,160 VOLTS
NUMBER OF MEN TO OPERATE BORING MACHINE ..... 5 PER SHIFT
MAX. AMBIENT TEMPERATURE AT CUTTERHEAD ..... 110°F
MAX. ROCK TEMPERATURE ..... 93°F

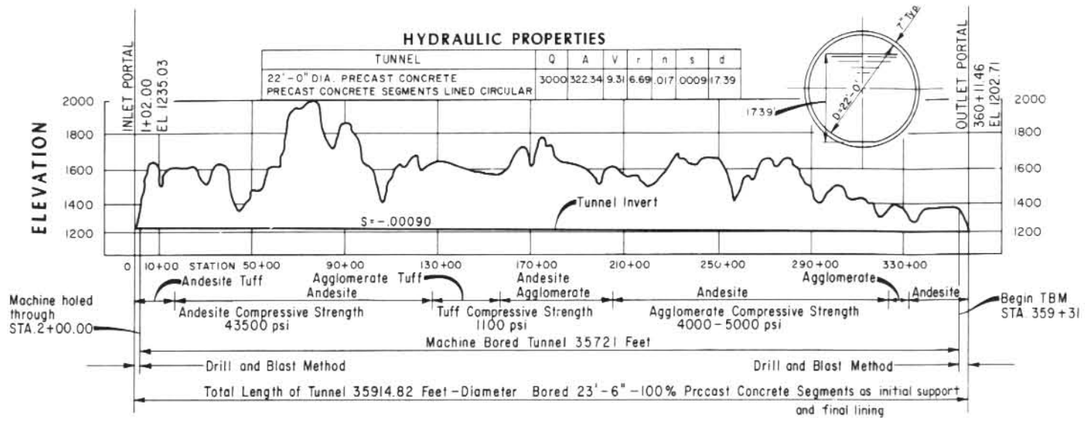
① - OUTLET PORTAL ... Surface left by machine supported with rock bolts & steel mat
② - FALLOUT .. Area resupported
③ - Trailing dust collection & muck conveyor system
④ - Left side of machine
⑤ - Cutter head



BUCKSKIN MOUNTAINS TUNNEL

CENTRAL ARIZONA PROJECT

ARIZONA



TUNNEL PROFILE

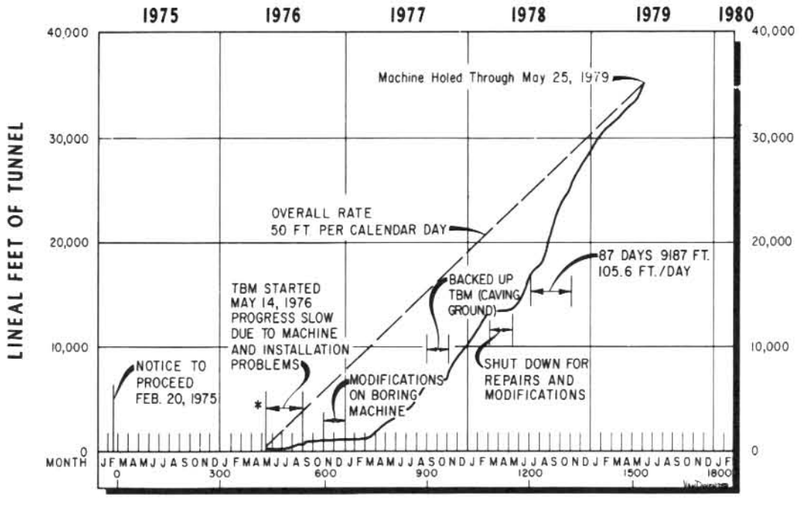
MACHINE DATA

MANUFACTURED BY ROBBINS MODEL 233-172
LENGTH _____44 FT. WEIGHT 350 TONS
*THRUST 2,650,000 LBS. TORQUE 1,550,000 FT. LBS.
CUTTERS 58-15.5 INCH STROKE 5 FT.
DISK CUTTERS, ONE PER AXLE
MACHINE AVERAGE AVAILABILITY 60.3%
HP 6-200/100; 2:1/4.2 RPM
CAPACITY 3000 CUBIC FT. PER SEC.
MINIMUM RADIUS OF HORIZONTAL CURVE 1400 FT.

*MAXIMUM CAPABILITY

PROGRESS

MAXIMUM ADVANCE	SHIFT	62 FT.
	DAY	150 FT.
AVERAGE ADVANCE	SHIFT	16 FT.
	DAY	49 FT.



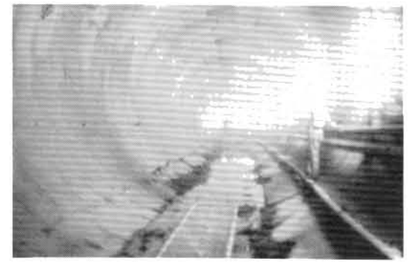
TUNNEL MACHINE-PROGRESS CHART

CONTRACT DATA

CONTRACTOR-J.F. SHEA & Co., INC.
SPECIFICATION No. DC-7096
BID (TUNNEL ONLY) $48,042,278
TOTAL COST TO CONSTRUCT TUNNEL 53,483,355 ($1489/FT.)

MISCELLANEOUS DATA

TRACK GAGE_____36"
VENTILATION LINE_____54"
VOLTAGE SUPPLY INTO TUNNEL FOR TBM _____4160 VOLTS
No. OF SHIFTS PER DAY _____ _____3 SHIFTS
ROCK TEMPERATURE____96°F
LASER BEAM GUIDANCE
WASTE DISPOSAL TRAILING CONVEYOR & TRAIN



COMPLETED TUNNEL, UTILITIES REMOVED LATER

BACKUP EQUIPMENT FOR TBM
MUCK CONVEYOR - TOP MIDDLE
VENTILATION PIPES - UPPER LEFT AND RIGHT

TBM HOLED THROUGH

MUCK CONVEYOR AND SEGMENTS BEING INSTALLED

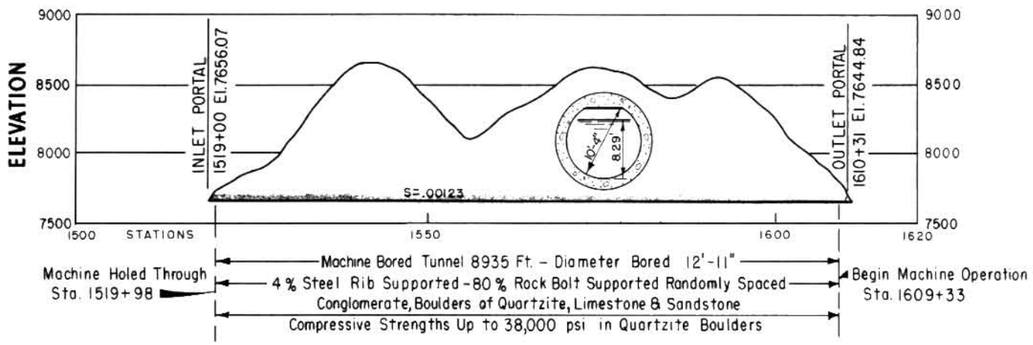
TUNNEL BORING MACHINE
NOTE: GRIPPER PAD AT RIGHT

CURRANT TUNNEL

CENTRAL UTAH PROJECT

BONNEVILLE UNIT - UTAH

TUNNEL PROFILE



HYDRAULIC PROPERTIES

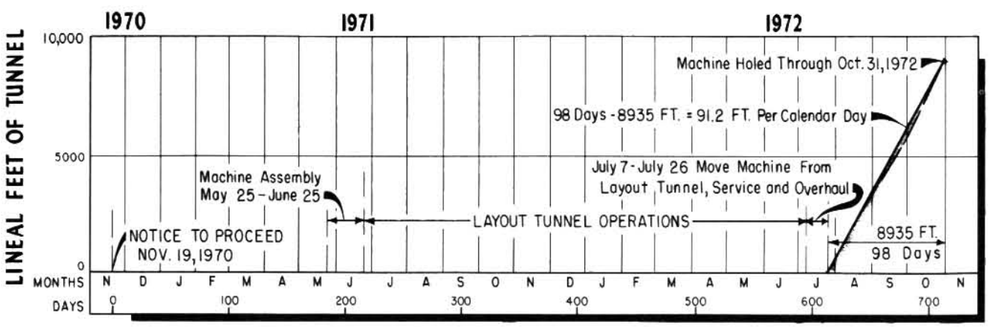
TUNNEL	Q	A	V	r	n	s	d
10'-4 DIA. CONCRETE LINED CIRCULAR	620	72.10	8.60	3.14	013	00123	8.29

MACHINE DATA

MANUFACTURED BY ROBBINS — MODEL 141-127-1
LENGTH ____ 45 FT. — WEIGHT 200,000 LBS.
THRUST ____ 664,000 LBS. — TORQUE 630,240 FT. LBS.
CUTTERS ____ 29 DISC, ONE TRI-DISC AT CENTER
STROKE ____ 3.5 FT.
ROTATION ____ 6-100 HP, 480 VOLT, 3 PHASE ELECTRIC MOTORS
LASER BEAM GUIDANCE SYSTEM
WASTE DISPOSAL ____ TRAILING CONVEYOR & TRAIN
AVERAGE AVAILABILITY ____ 85 %

PROGRESS

MAXIMUM RATE ____
____ SHIFT 110 FT.
____ DAY 232 FT.
AVERAGE PER WORKING DAY ____
____ SHIFT 46 FT.
____ DAY 133.4 FT.
AVERAGE PER CALENDAR DAY ____
____ OVERALL 91.2 FT.



TIME - DATE AND DAYS

TUNNEL MACHINE-PROGRESS CHART

CONTRACT DATA

CONTRACTOR ____ S.A. HEALY Co.
SPECIFICATIONS No. ____ DC-6855
BID FOR 9131 FEET OF FINISHED TUNNEL $3,223,243 ($353 PER FT.)
NOTE: CURRANT & LAYOUT TUNNELS WERE CONSTRUCTED UNDER THE SAME CONTRACT.

MISCELLANEOUS DATA

VENTILATION LINE ____ 36"
VOLTAGE SUPPLY INTO TUNNEL _ 7200V.
ROCK TEMPERATURE ____ 55° ±
AMBIENT TEMPERATURE NEAR CUTTER HEAD ____ 65° ±
WATER FLOWS ____ SEEPS TO 110 G.P.M.
DUST CONTROL ____ WATER SPRAYS AT CUTTER HEAD MOLE THROAT AND MATERIAL TRANSFER POINTS
TRACK GAGE ____ 24"

TURNING UNDER AT INLET PORTAL

OVERHAULING TUNNELING MACHINE AND BACKUP EQUIPMENT AT OUTLET PORTAL

LOADING MUCK CARS AT START OF MACHINE OPERATIONS

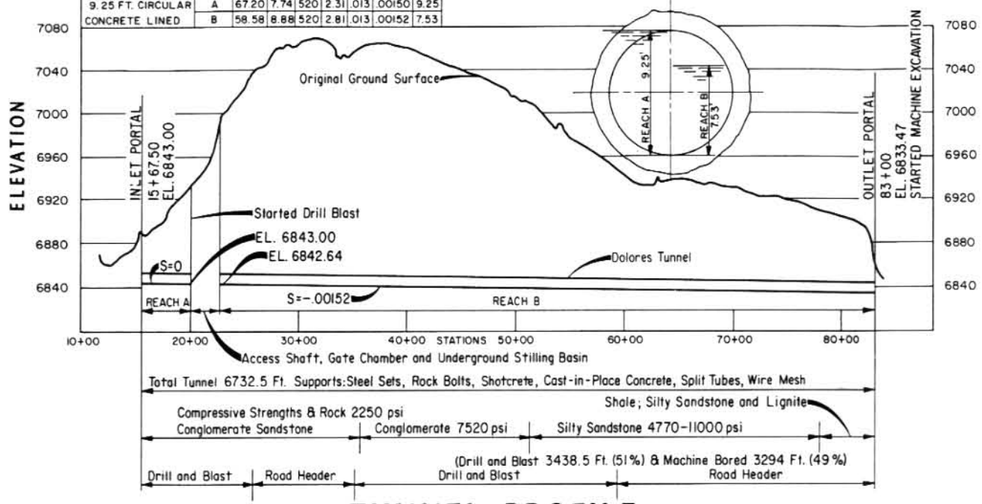
DOLORES TUNNEL

DOLORES PROJECT

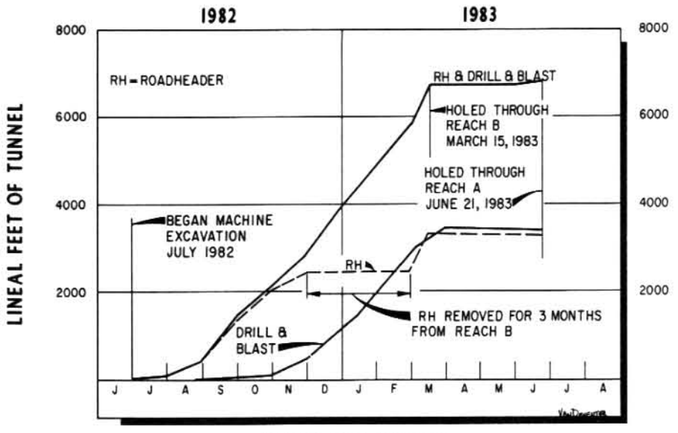
COLORADO

HYDRAULIC PROPERTIES

TUNNEL	REACH	A	V	Q	r	n	s	d
9.25 FT. CIRCULAR CONCRETE LINED	A	67.20	7.74	520	2.31	.013	.00150	9.25
	B	58.58	8.88	520	2.81	.013	.00152	7.53



TUNNEL PROFILE



TUNNEL MACHINE - PROGRESS CHART

MACHINE DATA

MANUFACTURED BY MITSUI MIIKE MACHINERY CO., LTD.
MODEL NO. MRH-S-125-22
LENGTH _____45 FT. WEIGHT_____30 TONS
TORQUE_____HORSEPOWER_____ROTATION
19125 FT. LBS. ____168 HP_____46 RPM
22950 FT. LBS. ___100 HP_____23 RPM
STROKE_____19.69 IN. BORE DIAMETER___11'-0"
CUTTER TYPES___PICKS
MACHINE TYPE: RIPPER
CUTTING DIMENSIONS:
HEIGHT_____9.8 FEET-14.1 FEET
WIDTH_____10.5 FEET-16.4 FEET
DIAMETER OF CUTTERHEAD_____25.6 INCHES
CAPACITY TO CUT UP TO 145000 PSI ROCK
PERFORMANCE-GOOD IN 8000-11000 PSI ROCK
SAME MACHINE USED IN STRAWBERRY REHAB. TUNNEL

PROGRESS

MAXIMUM ADVANCE	DAY 70 FT.
AVERAGE ADVANCE	DAY 35 FT.

CONTRACT DATA

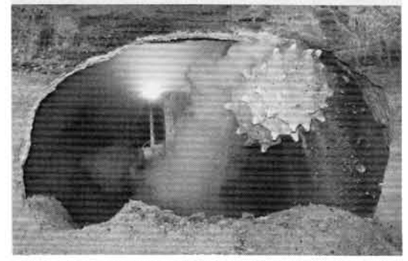
CONTRACTOR-OHBAYASHI-GUMI LTD.
SPECIFICATION No. 4D-C7496
BID (TUNNEL ONLY) $5,229,172
COMPLETION COST (TUNNEL ONLY) $4,860,000

MISCELLANEOUS DATA

TRACK GAGE _____24"
VENTILATION LINE _____18"
VOLTAGE SUPPLY INTO TUNNEL _____480 VOLTS
ROCK TEMPERATURE_____45°F
LASER BEAM GUIDANCE
WASTE DISPOSAL-GATHERING UNIT WITH LOWER AND UPPER CONVEYOR AND ELECTRIC TRAIN

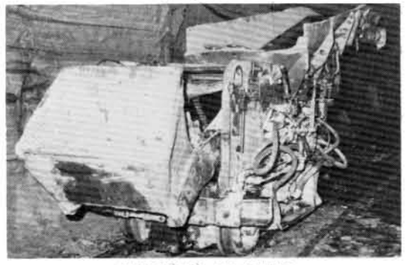
MITSUI MIIKE ROAD HEADER TUNNELING MACHINE

TESTING ROAD HEADER

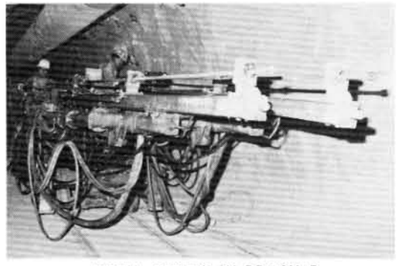


HOLED THROUGH REACH B MARCH 16, 1983

LOADING CONCRETE IN HOPPERS FOR TUNNEL



MUCKING MACHINE



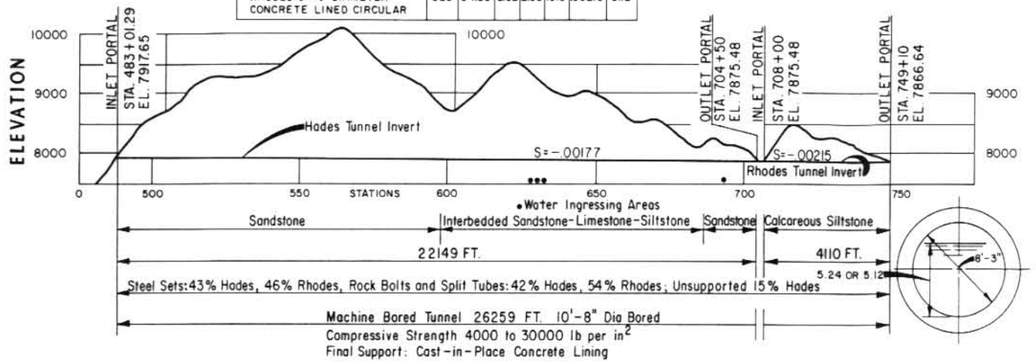
DRILL JUMBO IN REACH B

HADES & RHODES TUNNELS

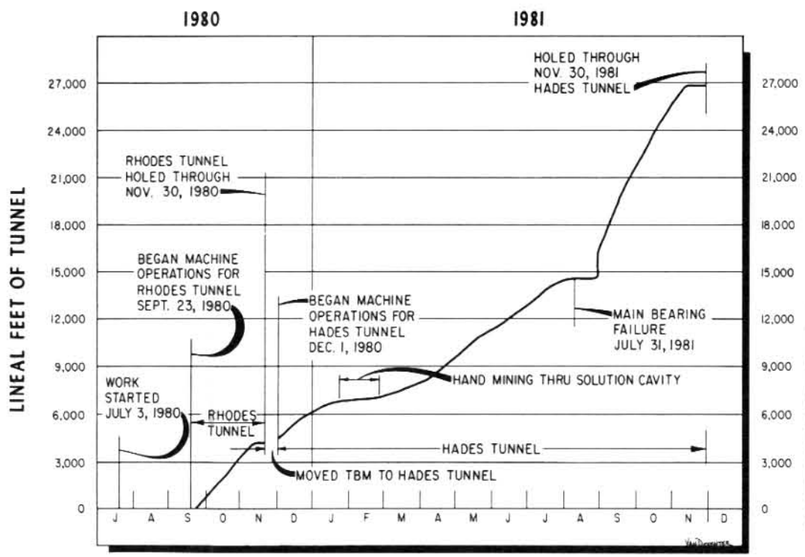
CENTRAL UTAH PROJECT
BONNEVILLE UNIT, UTAH

HYDRAULIC PROPERTIES

TUNNEL	Q	A	V	r	n	s	d
HADES 8'-3" DIAMETER CONCRETE LINED CIRCULAR	305	35.81	8.52	2.35	.013	.00177	5.24
RHODES 8'-3" DIAMETER CONCRETE LINED CIRCULAR	325	34.89	9.32	2.33	.013	.00215	5.12



TUNNEL PROFILE



TUNNEL MACHINE - PROGRESS CHART

MACHINE DATA

MANUFACTURED BY ROBBINS — MODEL NO. 1011-198
LENGTH 37 FT. — WEIGHT 83 TONS
THRUST 840,000 LBS.
TORQUE 375,000 FT. LBS. — STROKE 4 FT.
BORE DIAMETER 10'-8" — ROTATION 7 RPM's
HORSEPOWER 500 HP
CUTTERS 4-12" DIA. TWIN DISK CENTER CUTTERS
23-14" DIA. DISK CUTTERS

PROGRESS

MAXIMUM ADVANCE	SHIFT	111 LIN. FT.
	DAY	327 LIN. FT.
AVERAGE ADVANCE	SHIFT	28.6 LIN. FT.
	DAY	85.8 LIN. FT.

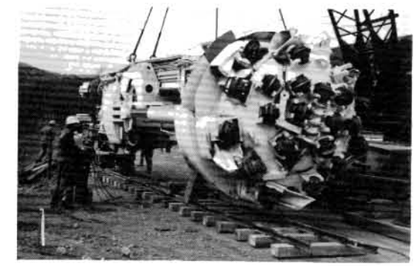
CONTRACT DATA

CONTRACTOR-HARRISON-WESTERN CORPORATION
SPECIFICATION No. DC-7421
BID $34,681,703.
TOTAL COST $34,833,948.03

MISCELLANEOUS DATA

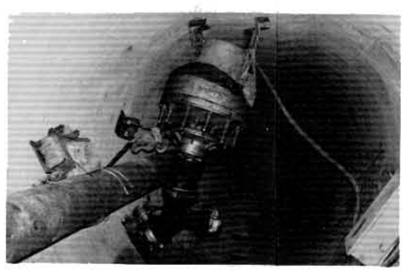
TRACK GAGE 24"
VENTILATION LINE 30" DIA.
VOLTAGE SUPPLY INTO TUNNEL 480 VOLT
3 SHIFTS PER DAY - 13 MEN PER SHIFT - 5 DAYS A WEEK
WATER FLOWS 1200 - 13,000 GAL./MIN. SEASONAL UP TO 6,000 GAL./M
ROCK TEMPERATURE 56°
LASER BEAM GUIDANCE WITH TWO INLINE TARGETS
WASTE DISPOSAL - TRAILING CONVEYOR & MUCK TRAIN

SIDE VIEW OF ROBBINS MOLE MODEL #1011-98



FRONT VIEW OF ROBBINS TBM MODEL #1011-98

MORAN CAR READY TO HAUL CEMENT TO TUNNEL FOR BACKFILL GROUTING



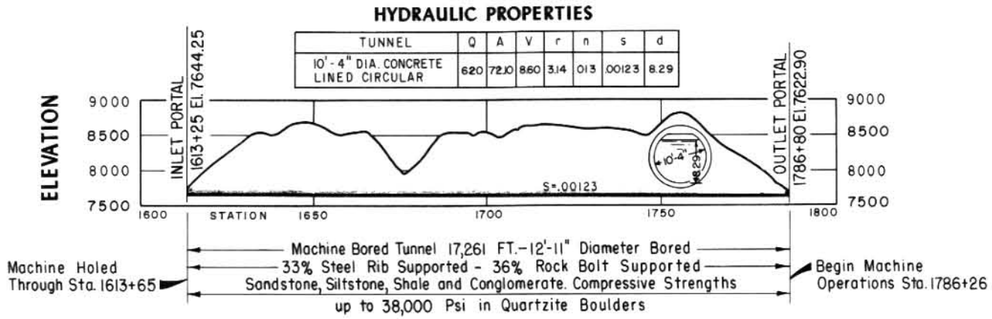
88 HP PUMP INSTALLED TO PUMP WATER FROM SPRING IN THE INVERT TO THE INLET OF HADES TUNNEL

WATER IN TUNNEL

LAYOUT TUNNEL

CENTRAL UTAH PROJECT

BONNEVILLE UNIT-UTAH



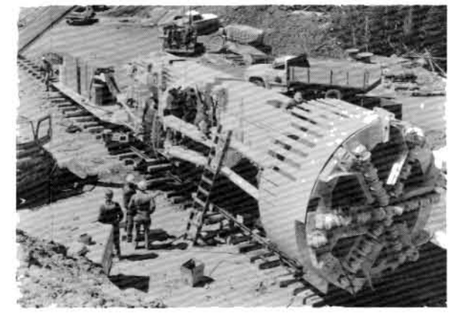
TUNNEL PROFILE

CONTRACT DATA

CONTRACTOR____S. A. HEALY Co.
SPECIFICATIONS No.___ DC-6855
BID FOR 17,355 FEET OF FINISHED TUNNEL $6,126,315 ($353 PER FT.)

MISCELLANEOUS DATA

VENTILATION LINE_____36"
VOLTAGE SUPPLY INTO TUNNEL___ _____7200 VOLTS
ROCK TEMPERATURE____=55°F ±
AMBIENT TEMPERATURE AT CUTTER HEAD_____=65°F±
WATER FLOWS-SEEPS TO 100 G.P.M.
DUST CONTROL-WATER SPRAYS AT CUTTER HEAD, MOLE THROAT AND MATERIAL TRANSFER POINTS
THIS MACHINE USED IN CURRANT TUNNEL NEARBY
TRACK GAGE_____24"



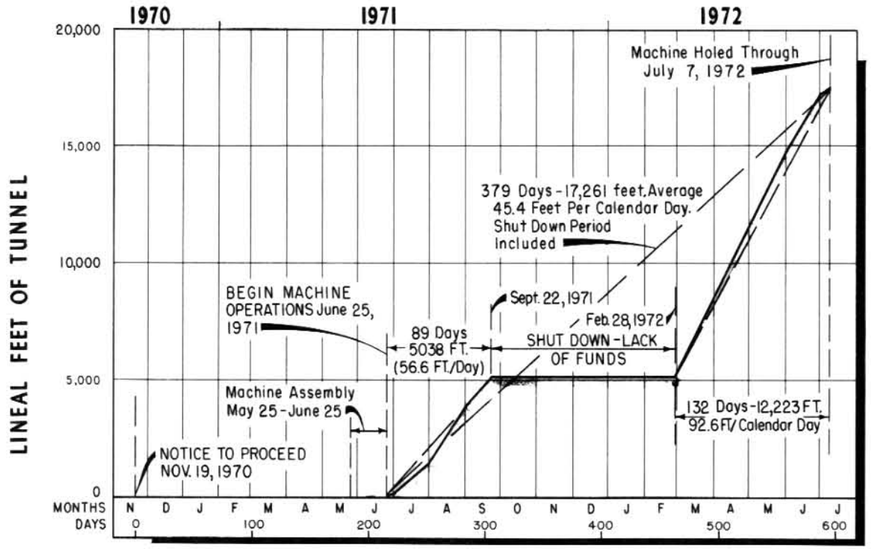
MACHINE ASSEMBLY

MACHINE DATA

MANUFACTURED BY ROBBINS MODEL 141-127-1
LENGTH_____45 FT. WEIGHT 200,000 LBS.
THRUST 664,000 LBS. TORQUE 630,240 FT. LBS.
CUTTERS_____29 DISC, ONE TRI-DISC AT CENTER
ROTATION 6-100 HP, 480 VOLT, 3 PHASE ELECTRIC MOTORS
LASER BEAM GUIDANCE SYSTEM - 3.5 FT. STROKE
BORE DIAMETER 12'-11"
WASTE DISPOSAL_____TRAILING CONVEYOR & TRAIN
AVERAGE AVAILABILITY 85 %

PROGRESS

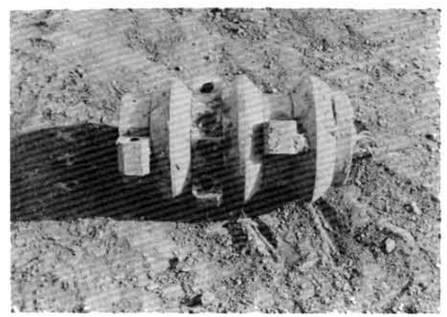
MAXIMUM RATES_____
____SHIFT 92 FT.
____DAY 234 FT.
AVERAGE-PER WORKING DAY___
____SHIFT 40 FT.
____DAY 114 FT.
AVERAGE-PER CALENDAR DAY___
_OVERALL - 45.4 FT.
_PRIOR TO SHUT DOWN-56.6 FT.
_AFTER SHUT DOWN-92.6 FT.



TIME - DATE AND DAYS

TUNNEL MACHINE - PROGRESS CHART

RACK OF REBUILT DISC CUTTERS



WORN TRI-DISC CENTER CUTTER

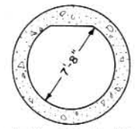
REPLACING MAIN BEARING

CUTTER HEAD AT HOLE THROUGH

NAST TUNNEL

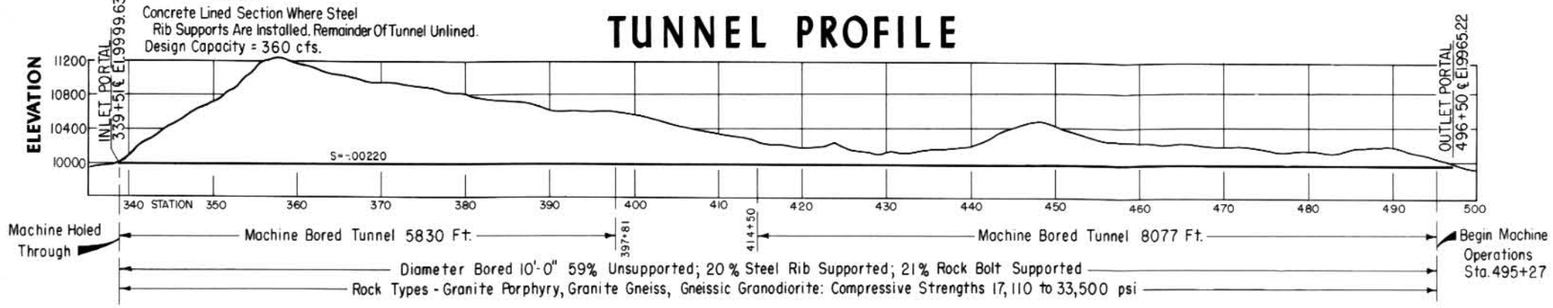
FRYINGPAN - ARKANSAS PROJECT

COLORADO



Concrete Lined Section Where Steel Rib Supports Are Installed. Remainder Of Tunnel Unlined. Design Capacity = 360 cfs.

TUNNEL PROFILE



MACHINE DATA

MANUFACTURED BY WIRTH & COMPANY, ERKELENZ, GERMANY — MODEL TB II-300 H
LENGTH 25 FT. WITH 90 FT. TRAILING POWER SUPPORT UNIT — WEIGHT, INCLUDING TRAILING CONVEYOR 120 TONS
MAX. THRUST 873,000 LBS. — MAX. TORQUE 445,000 FT. LBS.
CUTTER HEAD ORIGINAL HEAD HAD 3' DIA. WITH FLAT FACE, REMAINDER SLOPED BACK 19°-26 BUTTON INSERT CUTTERS NO FACE OR ARCH SHIELDS. CUTTER HEAD LATER REPLACED WITH FLAT FACED HEAD, 29 CUTTERS, WITH FACE & ARCH SHIELDS.
ROTATION, THRUST & GRIPPERS HYDRAULICALLY OPERATED.
LASER BEAM GUIDANCE
WASTE DISPOSAL TRAILING CONVEYOR & TRAIN

PROGRESS

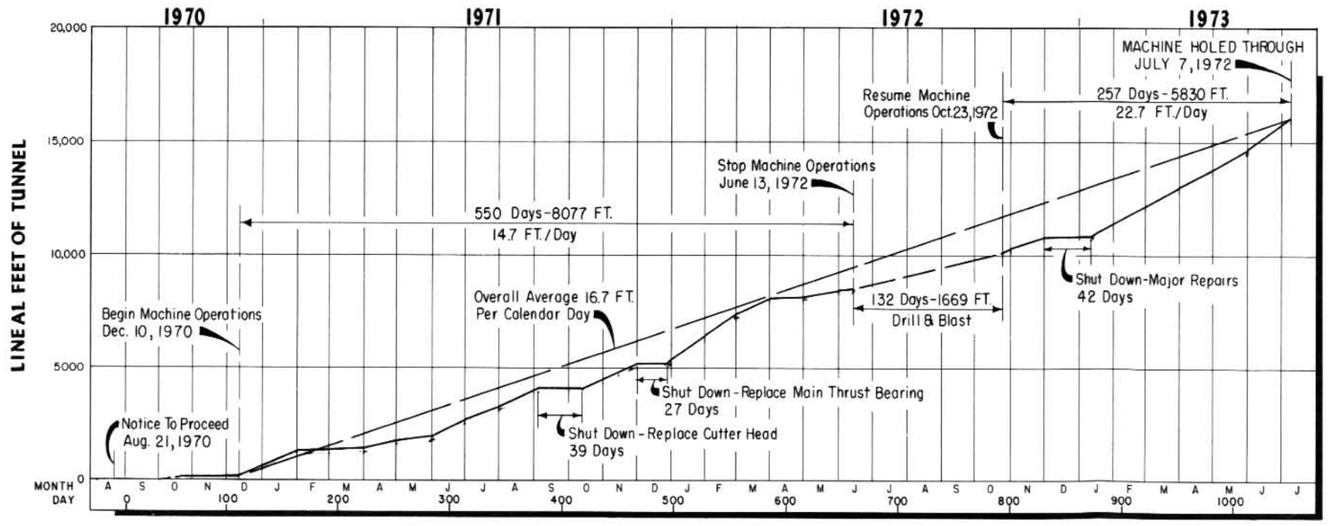
MAXIMUM FOR 1 DAY 73 FT.
1 SHIFT 33 FT.
AVERAGE PER WORKING DAY 17.4 FT.
PER SHIFT 5.8 FT.
PER CALENDAR DAY 16.7 FT.

MISCELLANEOUS DATA

TRACK GAGE 36"
VENTILATION LINE 22"
VOLTAGE SUPPLY INTO TUNNEL 4160 VOLTS
TYPICAL UNDERGROUND MACHINE CREW 11 MEN
MACHINE LIMITED TO 580 FT. RADIUS CURVE
3 SHIFT DAY - 6 DAY WEEK OPERATION

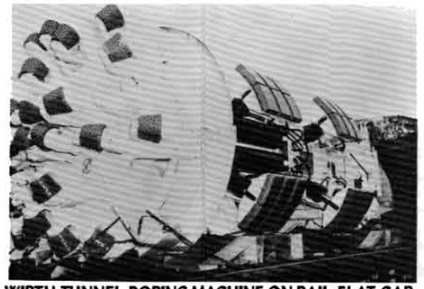
CONTRACT DATA

CONTRACTOR PETER KIEWIT SONS Co.
SPECIFICATIONS No. DC-6829
BID (TUNNEL PORTION) $ 6,828,754



TIME - DATE AND DAYS

TUNNEL MACHINE - PROGRESS CHART

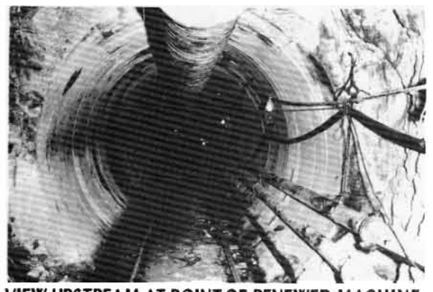


WIRTH TUNNEL BORING MACHINE ON RAIL FLAT CAR

TRANSITION FROM CONVENTIONAL EXCAVATION (DRILL & BLAST) TO MACHINE EXCAVATION AT STA. 495+27 NEAR OUTLET PORTAL

LOOKING UPSTREAM TOWARD HEADING SHOWING 40' BRIDGE SECTION OF MUCK CONVEYOR. THIS PROVIDES SPACE IN WHICH TRACK IS LAYED

VIEW LOOKING DOWN STREAM FROM STA. 490+00 SHOWING EXCAVATED SURFACE AND CURVE

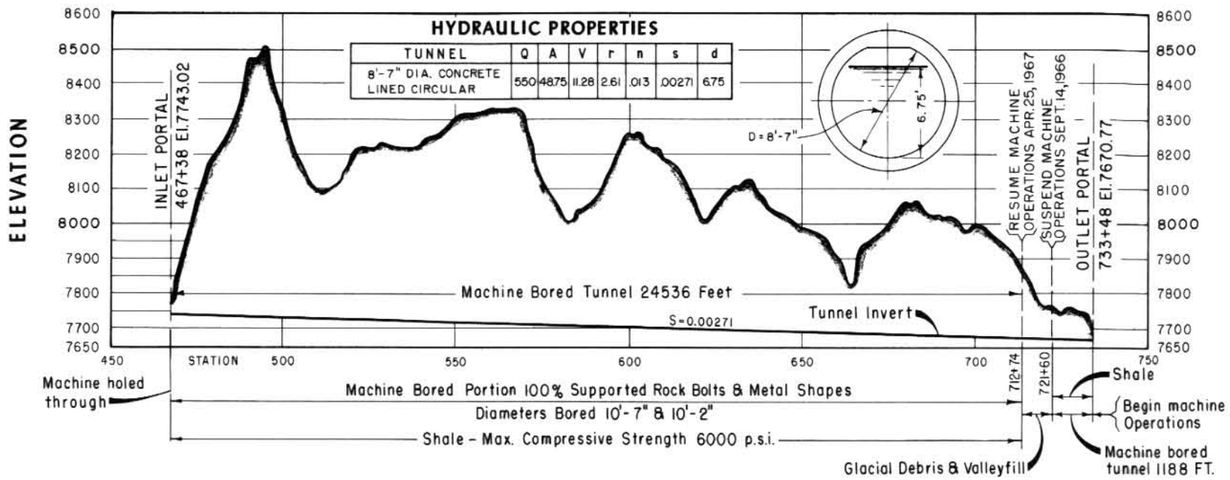


VIEW UPSTREAM AT POINT OF RENEWED MACHINE BORING STA. 397+79

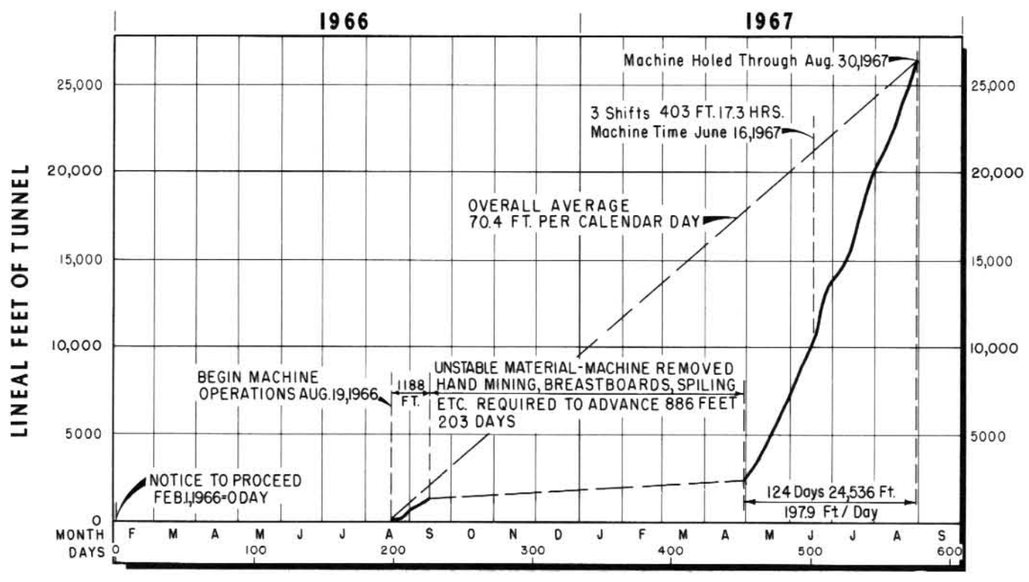
OSO TUNNEL

SAN JUAN CHAMA PROJECT

COLORADO - NEW MEXICO



TUNNEL PROFILE



TIME-DATE AND DAYS

TUNNEL MACHINE - PROGRESS CHART

MACHINE DATA

MANUFACTURED BY ROBBINS MODEL 104-121A
LENGTH 40 FT. WEIGHT 105,000 LBS.
*THRUST 372,000 LBS. *TORQUE 175,000 FT. LBS.
CUTTERS 22 DISC, 1 - TRICONE IN CENTER
ROTATION BY 4-75 HP ELECTRIC MOTORS 440 V.
LASER BEAM GUIDANCE
WASTE DISPOSAL TRAILING CONVEYOR & TRAIN

*MAXIMUM CAPABILITY

PROGRESS

AVERAGE (OVERALL) 70.4 FT. PER CALENDAR DAY
AVERAGE (EXCLUDING TIME IN BAD GROUND) 197.9 FT. PER CALENDAR DAY
MAXIMUM (17.3 HRS. MACHINE TIME) 403 FT. IN ONE 3 SHIFT DAY

CONTRACT DATA

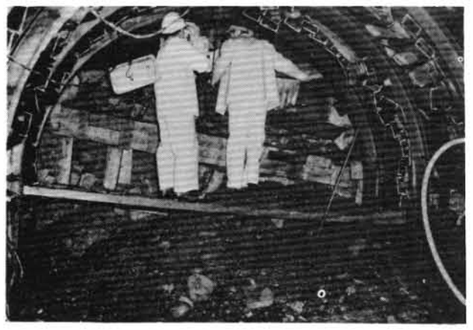
CONTRACTOR-BOYLES BROS. DRILLING Co.
SPECIFICATION No. DC-6380
BID (TUNNEL PORTION) $ 5,301,816

MISCELLANEOUS DATA

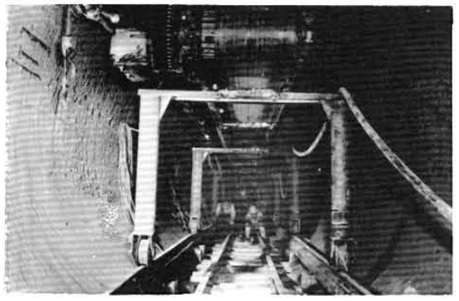
TRACK GAGE 24"
VENTILATION LINE 24"
VOLTAGE SUPPLY INTO TUNNEL 4,160 VOLTS
No. OF MEN TO OPERATE MACHINE 5 PER SHIFT
AMBIENT TEMPERATURES AT CUTTER HEAD 90° F
ROCK TEMPERATURE 74° F
AFTER COMPLETING THE EXCAVATION IN OSO TUNNEL THIS MACHINE WAS REBUILT AND HEAD ENLARGED TO 12'-8" DIA. THEN PUT IN OUTLET END OF AZOTEA TUNNEL

MUCK TRAIN AT DISPOSAL AREA

OUTLET PORTAL



NOTE CHANNEL SPILING AND BREAST BOARDS REQUIRED IN UNSTABLE MATERIAL



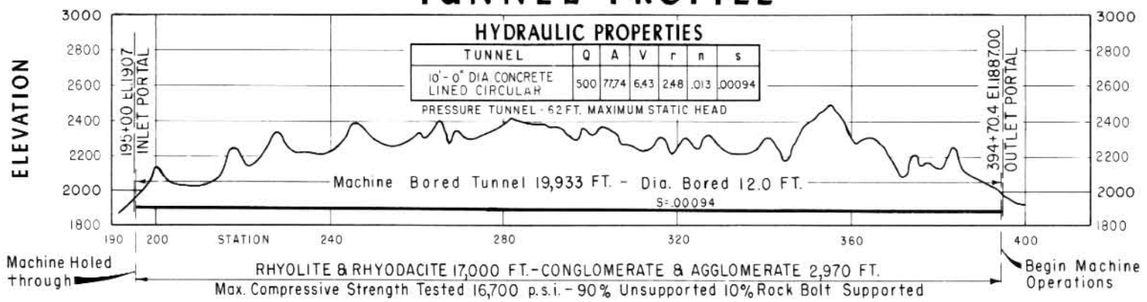
WASTE HANDLING CONVEYOR AND LOADING SYSTEMS

RIVER MOUNTAINS TUNNEL

SOUTHERN NEVADA WATER PROJECT

NEVADA

TUNNEL PROFILE



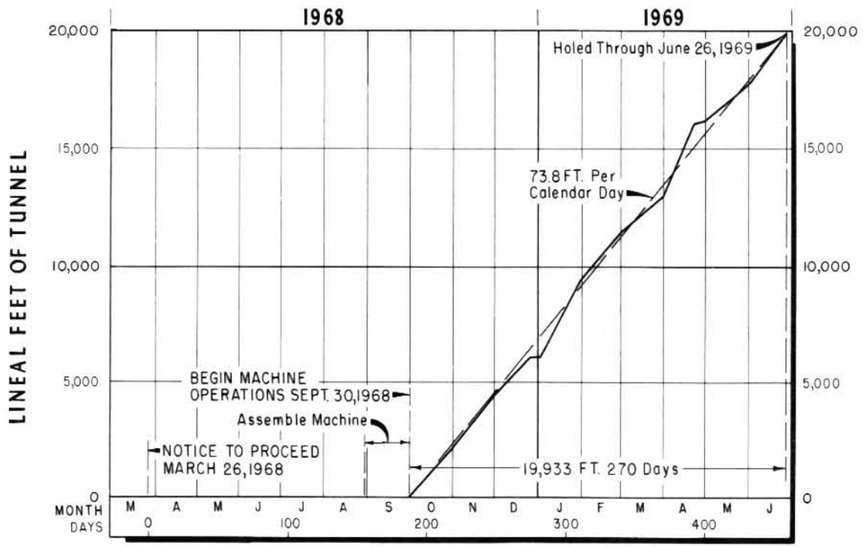
MACHINE DATA

MANUFACTURED BY JARVA MODEL MARK 11-12
LENGTH 37 FT. WEIGHT 130,000 LBS.
*THRUST 886,000 LBS. *TORQUE 235,000 FT. LBS.
31 CUTTERS, 26 STEEL KERF TYPE, 1 TOOTH TYPE
4 TOOTH OR TUNGSTEN CARBIDE INSERT
KERF TYPE AS GAGE CUTTERS
ROTATION BY 4-100 HP ELECTRIC MOTORS, LATER
MODIFIED TO 6-50 HP.
LASER BEAM GUIDANCE
WASTE DISPOSAL - TRAILING CONVEYOR AND TRAIN

PROGRESS

AVERAGE
73.8 FT. PER CALENDAR DAY
AVERAGE
108 FT. PER WORKING DAY
MAXIMUM
293 FT. PER DAY
MAXIMUM
104 FT. PER 8 HR SHIFT

*MAXIMUM CAPABILITY



TIME - DATE AND DAYS

TUNNEL MACHINE - PROGRESS CHART

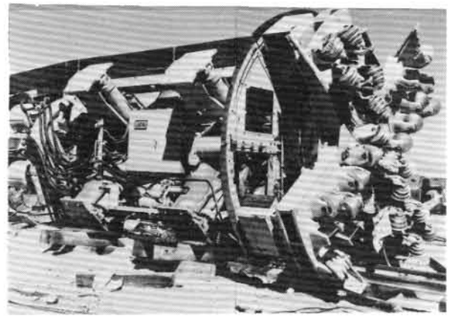
CONTRACT DATA

UTAH CONSTRUCTION AND MINING - DURING CONTRACT PERIOD CHANGED TO FLUOR UTAH ENGINEERS AND CONSTRUCTORS, INC.
SPECIFICATION No. DC-6595
BID (TUNNEL PORTION) $3,572,128

MISCELLANEOUS DATA

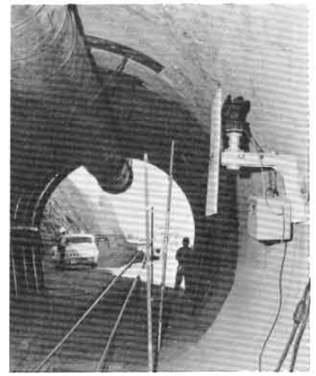
TRACK GAGE 24"
VENTILATION LINE 30"
VOLTAGE SUPPLY INTO TUNNEL
4,160 VOLTS
No. OF MEN TO OPERATE MACHINE
4 PER SHIFT
AMBIENT TEMPERATURES AT CUTTER HEAD 95° TO 105° F
ROCK TEMPERATURE 82° F

OVERALL VIEW - OUTLET PORTAL WORK AREA

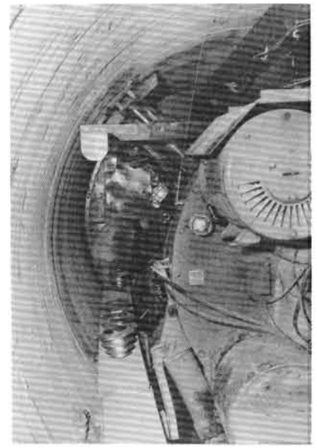


VIEW OF JARVA MACHINE DURING ASSEMBLY

BREAK THROUGH



LASER BEAM GUN MOUNTED ON TUNNEL WALL



CHANGING CUTTERS-LASER TARGETS IN UPPER QUADRANT

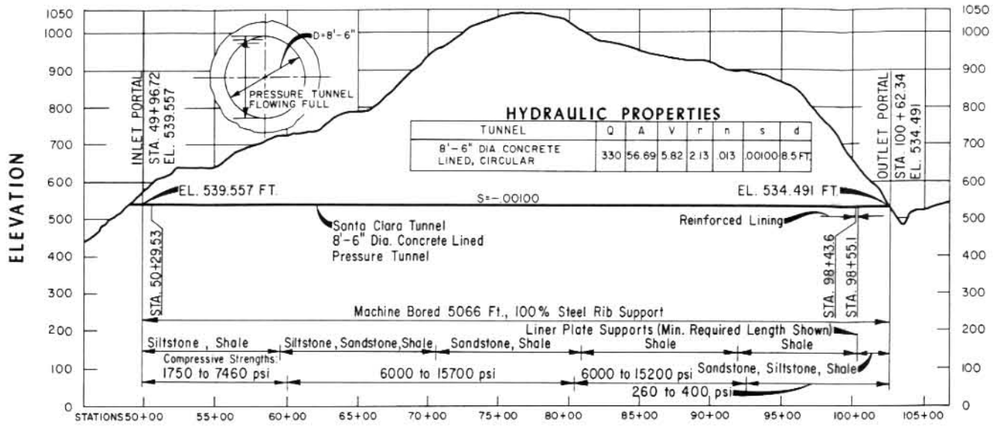
WASTE DISPOSAL - ROTARY CAR DUMP IN OPERATION

ASSEMBLING MACHINE - NOTE CONVEYOR WITH VENTILATION SYSTEM ON TOP

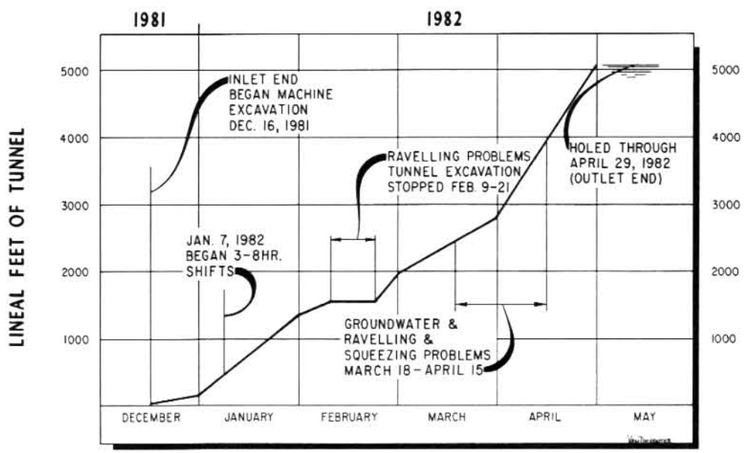
SANTA CLARA TUNNEL

CENTRAL VALLEY PROJECT

SAN FELIPE DIVISION, CALIFORNIA



TUNNEL PROFILE



TUNNEL MACHINE - PROGRESS CHART

MACHINE DATA

MANUFACTURED BY CALDWELL
LENGTH _____ 16 FT. WEIGHT 135,000 LBS.
THRUST (JACKING) 1200 TONS
TORQUE MAX. 500,000 FT. LBS. STROKE 5.5 FT.
BORE DIAMETER 10 FT ROTATION 6 R.P.M
CUTTERS 19-14" DIAMETER SMITH CUTTERS
HORSE POWER 400 HP WITH ROBBINS CUTTER RINGS

PROGRESS

MAXIMUM	SHIFT	81 FT.
	DAY	146 FT.
AVERAGE	CALENDAR DAY	37.5 FT.
	DAY	70 FT.

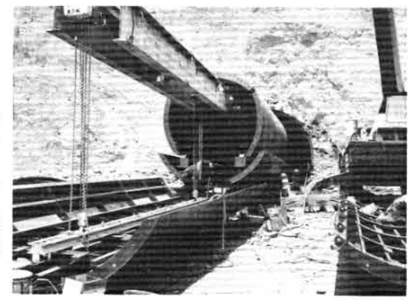
CONTRACT DATA

CONTRACTOR - SHANK-ARTUKOVICH
SPECIFICATION No. 2D-C7462
BID (TUNNEL ONLY) $7,738,897.

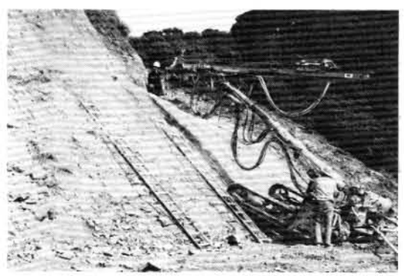
MISCELLANEOUS DATA

TRACK GAGE 36"
VENTILATION LINE 38"
VOLTAGE SUPPLY INTO TUNNEL 480 VOLTS
No. OF SHIFTS PER DAY 3 SHIFTS
WATER FLOW 61 GPM
ROCK TEMPERATURE 61°
LASER BEAM GUIDANCE
WASTE DISPOSAL TRAILING CONVEYOR & TRAIN

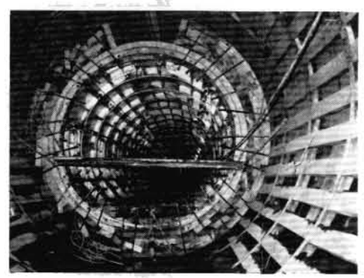
CALDWELL TBM AFTER TUNNELING THROUGH



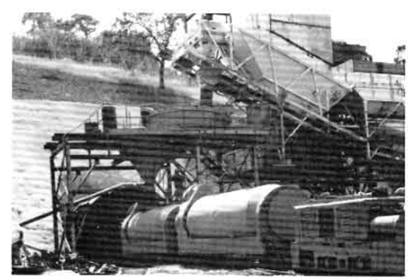
ASSEMBLING STEEL FORMS USED FOR CONCRETE LINING



INSTALLING ROCK REINFORCEMENT BARS AT OUTLET PORTAL PRIOR TO HOLING THROUGH



BULKHEAD IN PLACE BEFORE CONCRETE LINING OF TUNNEL



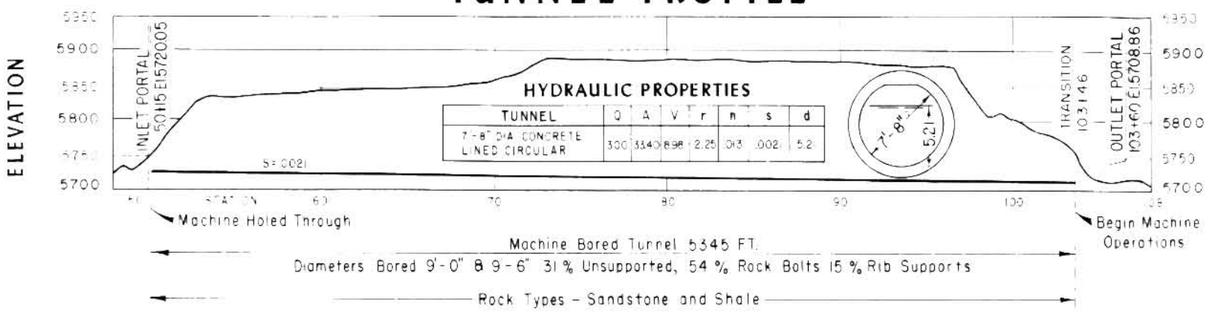
LOADING MORAN CONCRETE RAIL CARS

STARVATION TUNNEL

CENTRAL UTAH PROJECT

BONNEVILLE UNIT - UTAH

TUNNEL PROFILE



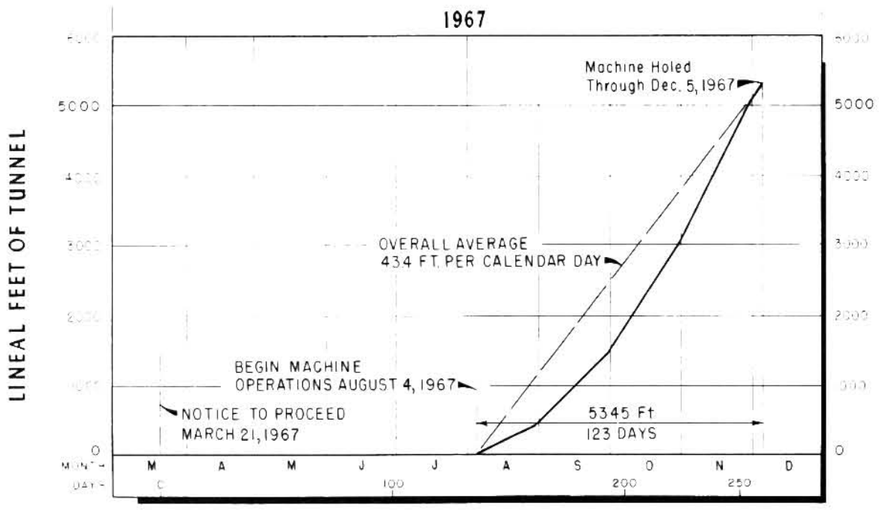
MACHINE DATA

MANUFACTURED BY ROBBINS MODEL 81-113
LENGTH 48 FT. WEIGHT 66,000 LBS.
*THRUST 220,000 LBS.
CUTTERS 1-TRICONE AND 20 DISC
HEAD ROTATED BY 2-100 HP, 440 VOLT MOTORS
LASER BEAM GUIDANCE
WASTE DISPOSAL TRAILING CONVEYOR & TRAIN

*MAXIMUM CAPABILITY

PROGRESS

MAXIMUM FOR 1 DAY 129 FT. (2 SHIFTS)
FOR 1 SHIFT 66 FT.
AVERAGE PER DAY 64.4 FT. (2 SHIFTS)
PER SHIFT 32.2 FT.
PER CALENDAR DAY 43.4 FT.



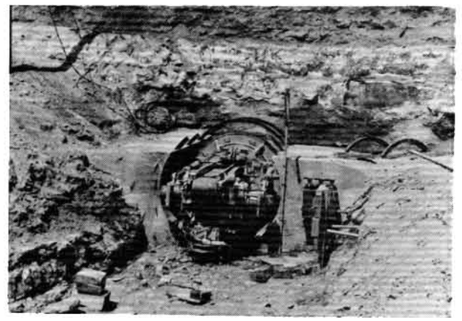
TUNNEL MACHINE - PROGRESS CHART

CONTRACT DATA

CONTRACTOR W W CLYDE & Co.
SPECIFICATION No. DC-6489
BID (TUNNEL PORTION) $ 870,065

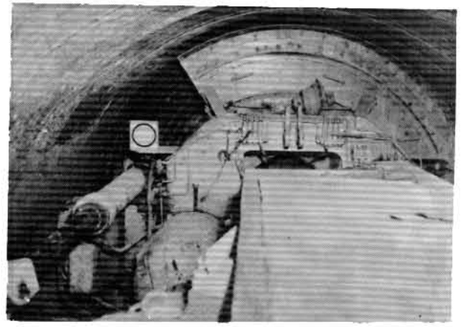
MISCELLANEOUS DATA

TRACK GAGE 24"
VENTILATION LINE 24"
VOLTAGE SUPPLY INTO TUNNEL 4,160 VOLTS
No. OF MEN TO OPERATE MACHINE 4 PER SHIFT
MACHINE OPERATED 2-8 HOUR SHIFTS PER DAY, 3 rd SHIFT FOR MAINTENANCE
AMBIENT TEMPERATURE AT CUTTER HEAD 70° F
ROCK TEMPERATURE 58° F



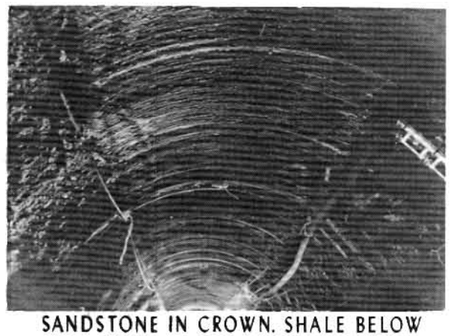
PARTIALLY ASSEMBLED MACHINE AT PORTAL. NOTE SPECIALLY CONSTRUCTED CONCRETE "LAUNCH PAD"

SANDSTONE & SHALE SECTION. THE SHALE DETERIORATES RAPIDLY



MACHINE AT HEADING. NOTE LASER BEAM TARGET

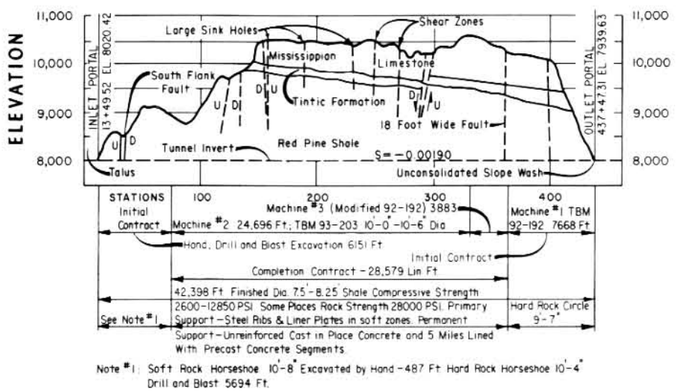
MACHINE HOLED THROUGH AT INLET PORTAL



SANDSTONE IN CROWN. SHALE BELOW BEGINNING TO DETERIORATE

STILLWATER TUNNEL

STRAWBERRY AQUEDUCT
CENTRAL UTAH PROJECT
BONNEVILLE UNIT - UTAH

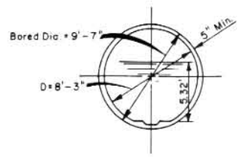


Note #1: Soft Rock Horseshoe 10'-8" Excavated by Hand - 487 Ft. Hard Rock Horseshoe 10'-4" Drill and Blast 5694 Ft.

TUNNEL PROFILE

HYDRAULIC PROPERTIES

TUNNEL	Q	A	v	r	n	s	d	D
CAST IN PLACE CONCRETE	285	33.49	8.51	2.23	.013	.00190	5.32	7.50
PRECAST CONCRETE SEGMENTS	285	43.12	6.61	2.50	0.018	.00190	6.20	8.25



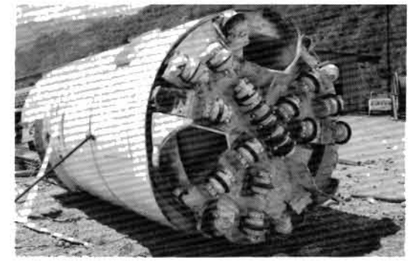
MACHINE DATA

	1	2	3
MANUFACTURED BY	ROBBINS	ROBBINS	ROBBINS
MODEL NUMBER	92-192	92-192(M)	93-203
LENGTH	23 FT.	18 FT.	45 FT.
WEIGHT	123 TONS	97 TONS	99 TONS
TORQUE	225,000 FT LBS	157,500 FT LBS	353,113 FT. LBS
STROKE	40 IN.	12 IN.	48 IN.
BORE DIAMETER	9'-7"	10'-3"	10'-0" & 10'-6"
THRUST MAX.	500 TONS	969 TONS	
WORKING	250 TONS	482 TONS	360 TONS
CUTTERS	24-12" DIA.	23-12" DIA. 4-12" GAGE	2-12" TWIN DISC CENTER 20-14" DISC
ROTATION	300 HP 7 RPM	300 HP 10 RPM	400 HP 8.3 RPM

LASER BEAM GUIDANCE
TBM 92-192 WAS USED FOR THE INITIAL CONTRACT THEN MODIFIED FOR THE COMPLETION CONTRACT

PROGRESS

AVERAGE PER CALENDAR DAY
CONTRACT #1 TBM 92-192 — 29.0 LIN FT.
HAND EXCAVATION — 9.6 LIN FT.
DRILL & BLAST — 27.4 LIN FT.
CONTRACT #2
TBM 92-192 MODIFIED — 30 LIN FT.
TBM 93-203 — 135 LIN FT.
MAXIMUM PER CALENDAR DAY
CONTRACT #1 92-192 115 LIN FT./DAY
CONTRACT #2 93-203 227 FT./DAY
MODIFIED 92-192 = 103 FT./DAY



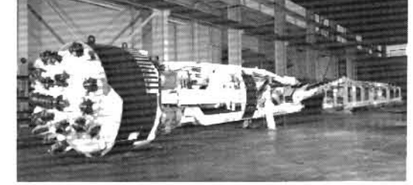
TBM 92-192

CONTRACT DATA

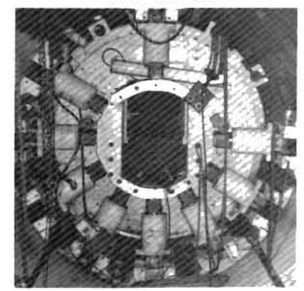
INITIAL CONTRACTOR - HARRISON-WESTERN CORP., JOHN W. COWPER CORP. (JV) SPECIFICATION DC7246
COMPLETION CONTRACTOR - TRAYLOR BROTHERS, INC. & FRUIN - COLNON CONSTRUCTION COMPANY, SPECIFICATION No. 40 C2035
INITIAL CONTRACT COST $19,552,549
BID COMPLETION CONTRACT $41,000,900

MISCELLANEOUS DATA

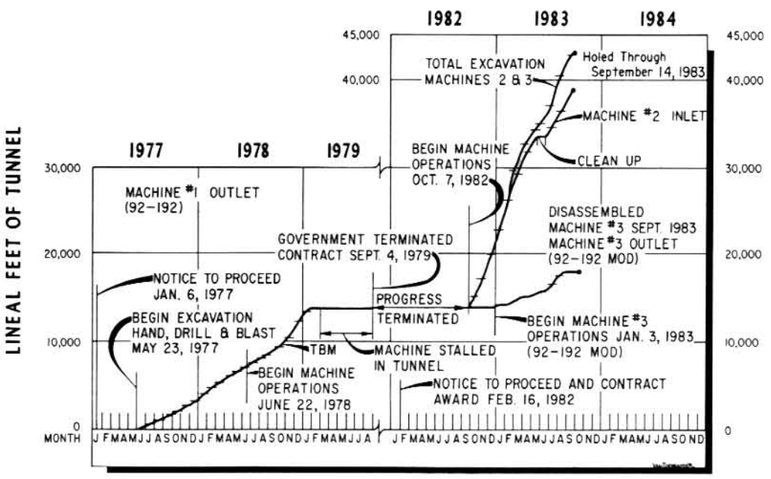
TRACK GAGE 30"/24"
VENTILATION LINE 30" DIA.
VOLTAGE SUPPLY INTO TUNNEL 440 VOLTS
No. OF SHIFTS PER DAY 3 SHIFTS
ROCK TEMPERATURE 57°F
WATER INFLOWS 0-50 GAL. PER MIN.
WASTE DISPOSAL - MUCK CARS EMPTIED BY ROTARY CAR DUMP



TBM 93-203



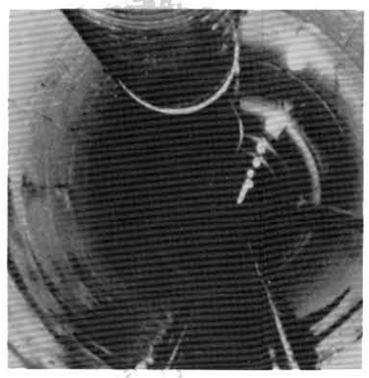
VIEW OF TBM 92-192 (m) WITH NINE OF THE TWELVE GRIPPER BLADES INSTALLED



DATES AND MONTHS

TUNNEL MACHINE-PROGRESS CHART

PLACING PEA GRAVEL BEHIND STEEL PLATE LINERS USING THE SHOTCRETE MACHINE

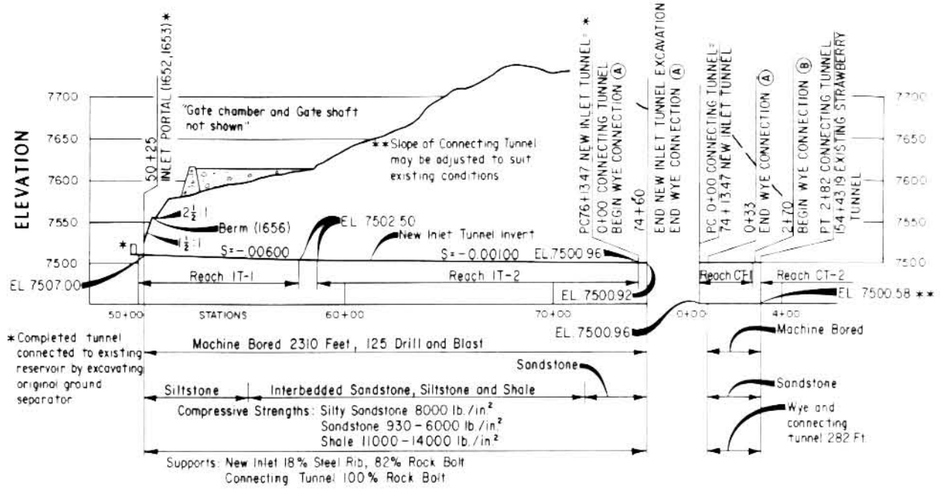


COMPLETED INTERIOR, UTILITIES REMOVED LATER

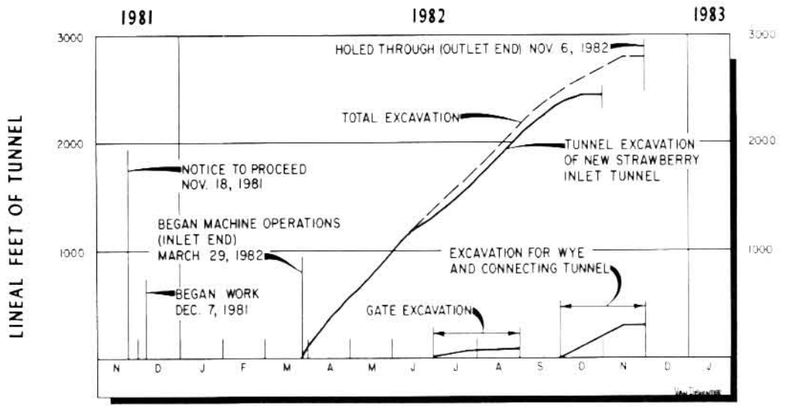
STRAWBERRY TUNNEL INLET REHABILITATION

CENTRAL UTAH PROJECT

BONNEVILLE UNIT, UTAH



TUNNEL PROFILE

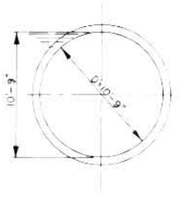


TUNNEL MACHINE-PROGRESS CHART

HYDRAULIC PROPERTIES

TUNNEL SECTION	REACH	Q	A	V	r	n	s	d	DIA.
CIRCULAR	IT-1	550	90.76	6.06	2.69	.013	.00075	10.75	10.75
*CIRCULAR	IT-2	550	GRADUALLY VARIED FLOW			.013	VARIES	VARIES	10.75
CIRCULAR	CT-1	550	GRADUALLY VARIED FLOW			.013	VARIES	VARIES	10.75
MODIFIED HORSESHOE	CT-2	550	GRADUALLY VARIED FLOW			.013	VARIES	VARIES	10.75x7.0w

* Hydraulic jump occurs in this reach



MACHINE DATA

MANUFACTURED BY MITSUI MIIKE MACHINERY CO., LTD.
MODEL NO. MRH-5-125-22
LENGTH _____45 FT. WEIGHT_____30 TONS
TORQUE _____HORSEPOWER _____ROTATION
19125 FT LBS ____168 HP_____46 RPM
22950 FT LBS ___100 HP_____23 RPM
STROKE _____19.69 IN. BORE DIAMETER__12"-7"
CUTTER TYPES____PICKS
MACHINE TYPE: ROAD HEADER (RIPPER)
CUTTING DIMENSIONS
HEIGHT _____9.8 FEET – 14.1 FEET
WIDTH _____10.5 FEET – 16.4 FEET
DIAMETER OF CUTTERHEAD_____256 INCHES
CAPACITY TO CUT UP TO 14500 PSI ROCK
PERFORMANCE – GOOD IN 8000 – 11000 PSI ROCK
USED BEFORE IN DOLORES TUNNEL

ROAD HEADER MRH-5-125-22

CONTRACT DATA

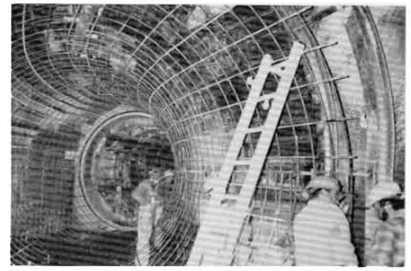
CONTRACTOR – OHBAYASHI-GUMI LTD.
SPECIFICATION No. 4D-C7479
BID $11,204,190.04
TOTAL COST $11,692,888.13
TUNNEL COST $5,045,977.64

PROGRESS

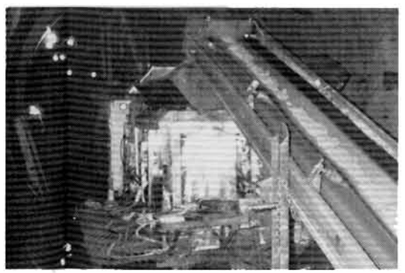
AVERAGE RATE PER DAY/
ROCK BOLTED ZONE _____19.4 FT.
AVERAGE RATE PER DAY/
STEEL RIBBED ZONE _____11.5 FT
AVERAGE RATE PER DAY/
CONNECTING TUNNEL _____12.8 FT.

MISCELLANEOUS DATA

TRACK GAGE _____24"
VENTILATION LINE____12"-24"
VOLTAGE SUPPLY INTO TUNNEL
_____480 VOLTS
ELECTRIC REQUIREMENT_____
_____415 V AT 50 CYCLES
ROCK TEMPERATURE____32°F
WATER FLOWS (MAX.)__100 gpm
LASER BEAM GUIDANCE
WASTE DISPOSAL – GATHERING ARMS, CONVEYOR SYSTEMS, AND ELECTRIC TRAIN SYSTEMS

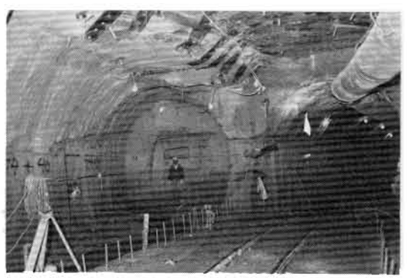


TYING REINFORCING STEEL IN WYE "A" CONNECTION



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

CONCRETE MIXER AND DISCHARGER



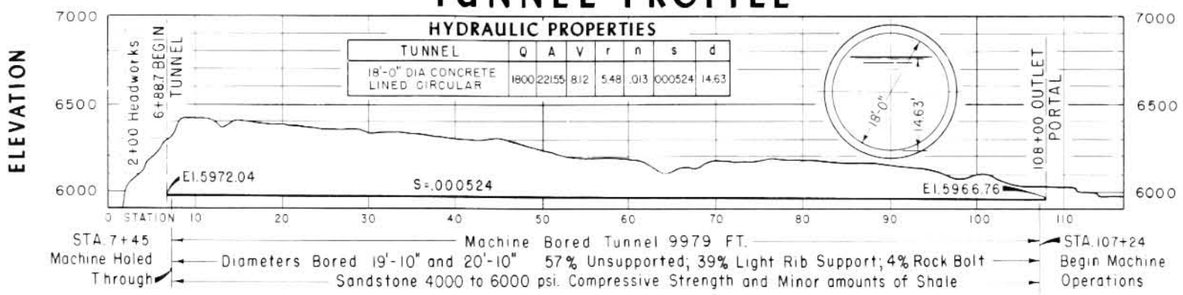
WYE "A" BRANCHES TO THE RIGHT OF NEW INLET TUNNEL AND CONNECTS TO EXISTING STRAWBERRY TUNNEL

TUNNEL NO. 1

NAVAJO INDIAN IRRIGATION PROJECT

NEW MEXICO

TUNNEL PROFILE



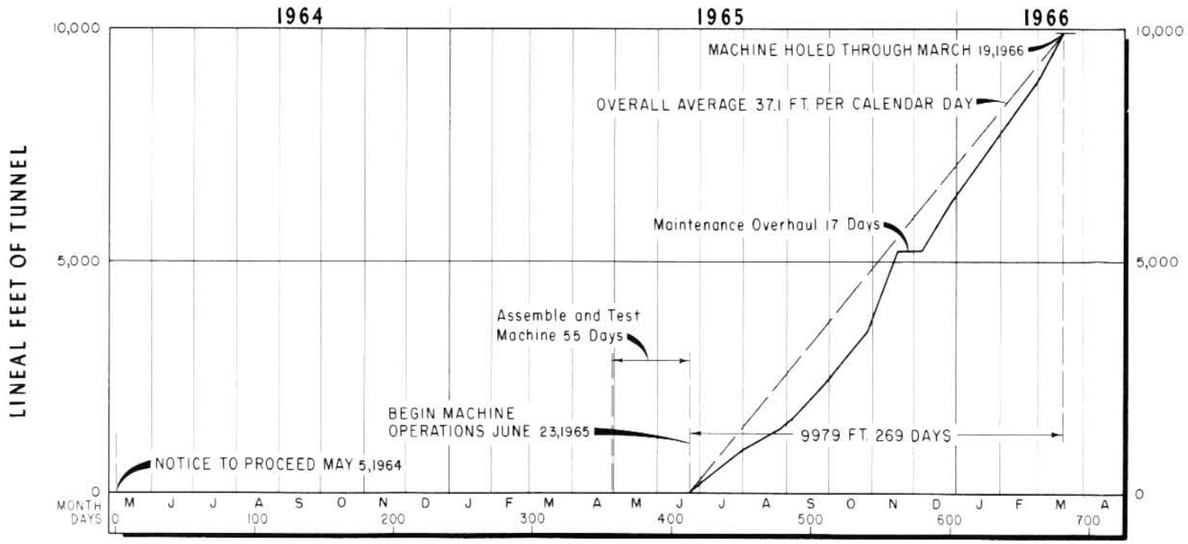
MACHINE DATA

MANUFACTURED BY HUGH B. WILLIAMS MFG. Co.
(A SUBSIDIARY OF HUGHES TOOL Co.) MODEL BETTI I
LENGTH_____64 FT. WEIGHT 560,000 LBS.
*THRUST_____1,400,000 LBS.
CUTTERS-43 ROLLING TEETH & ROLLING DISCS
HEAD ROTATED BY 5-200 HP, 2300 V. ELECTRIC MOTORS
LASER BEAM GUIDANCE
WASTE DISPOSAL____TRAILING CONVEYOR & TRAIN

*MAXIMUM CAPABILITY

PROGRESS

MAX. FOR ONE DAY_____160 FT.
UNSUPPORTED & 97 FT. IN A SUPPORTED SECTION
AVERAGE_____
__37.1 FT. PER CALENDAR DAY
__51.5 FT. PER WORKING DAY



TUNNEL MACHINE-PROGRESS CHART

CONTRACT DATA

CONTRACTOR-FENIX & SCISSON INC.
SPECIFICATION No. DC-6077
BID - $ 324.50 PER LINEAR FOOT
TOTAL COST TO CONSTRUCT TUNNEL $ 3,257,980

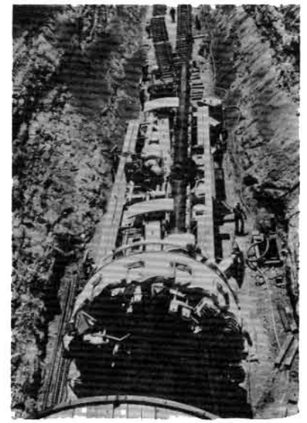
MISCELLANEOUS DATA

TRACK GAGE_____36"
VENTILATION LINE_____42"
POWER SUPPLY INTO TUNNEL_____2300 VOLTS
AMBIENT TEMPERATURE AT CUTTER HEAD_____ABOUT 70°F
ROCK TEMPERATURE - ABOUT 65°F
STRUCTURAL STEEL RIB SUPPORT USED WAS HALF CIRCLE 4" I PINNED AT OR NEAR SPRINGLINE

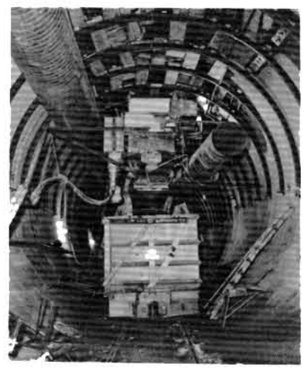
PORTION OF MACHINE ARRIVING AT JOB SITE FROM DALLAS TEXAS

ASSEMBLING MACHINE NEAR TUNNEL PORTAL

RESULT OF PINNING SUPPORTS IN SHALE



FINAL ADJUSTMENT PRIOR TO ENTERING PORTAL

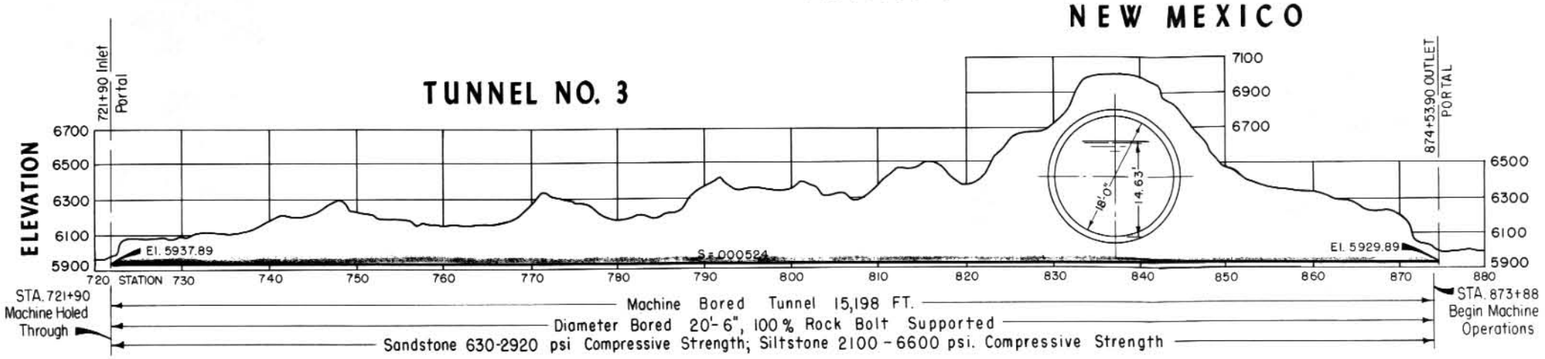


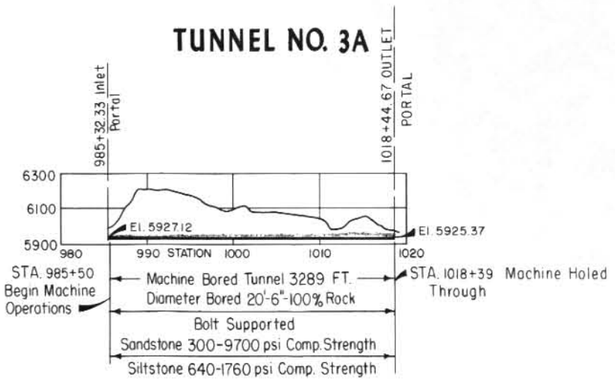
CAR IN LOADING POSITION NOTE HALF CIRCLE SUPPORTS PINNED AT SPRINGLINE IN SANDSTONE

TUNNELS NO. 3 & 3A

NAVAJO INDIAN IRRIGATION PROJECT

NEW MEXICO





TUNNEL PROFILES

MACHINE DATA

MANUFACTURED BY DRESSER INDUSTRIES INC.--MODEL 205
LENGTH - 58'----------WEIGHT 460,000 LBS.
FORWARD THRUST CAPABILITY-------1,600,000 LBS.
AVAILABLE TORQUE-------880,000 FT. LBS. @ 6 RPM
CUTTERS------36 DOUBLE DISC & 32 CONICAL PICKS
STROKE----------4 FEET
4-180 H.P. D.C. MOTORS TO ROTATE HEAD
LASER BEAM GUIDANCE
WASTE DISPOSAL-----TRAILING CONVEYOR & TRAIN
AVERAGE AVAILABILITY----------79 %
SAME EQUIPMENT USED IN BOTH TUNNELS

PROGRESS

	TUNNEL NO. 3	TUNNEL NO. 3A
MAX. RATES		
SHIFT	94 FT.	78 FT.
DAY	260 FT.	180 FT.
AVERAGE RATES		
SHIFT	16.6 FT.	28.9 FT.
DAY	50 FT.	86.6 FT.
AVERAGE PER CALENDERDAY	39 FT.	66 FT.

HYDRAULIC PROPERTIES

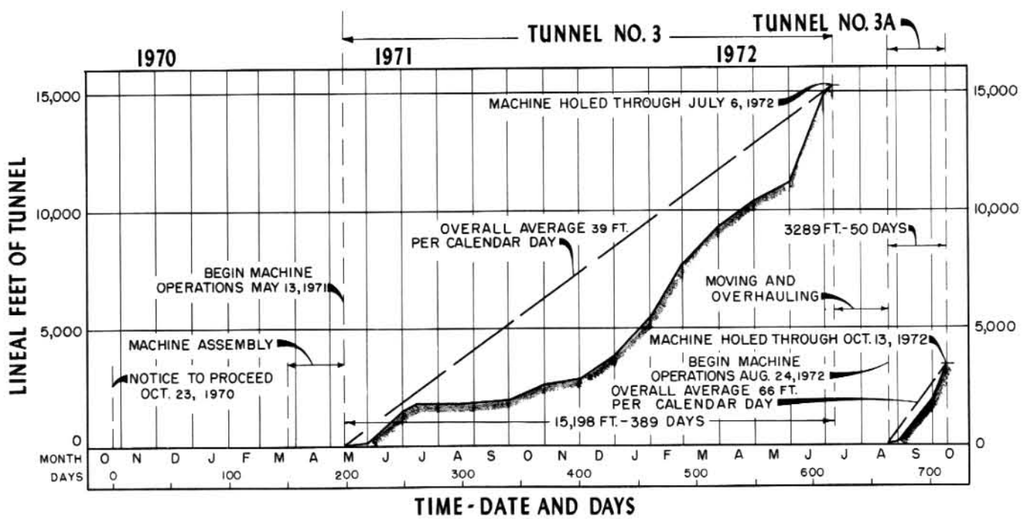
TUNNEL	Q	A	V	r	n	s	d
18'-0" DIA. CONCRETE LINED CIRCULAR	1800	221.55	8.12	5.48	.013	.000524	14.63

CONTRACT DATA

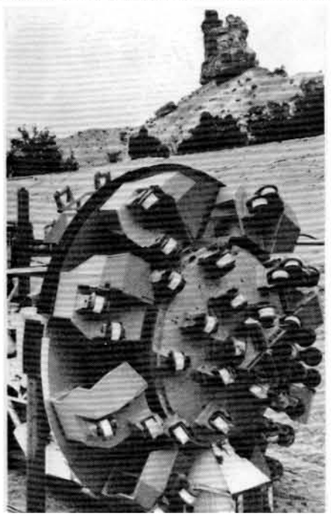
CONTRACTOR-FLUOR UTAH ENGINEERS AND CONSTRUCTORS INC.
SPECIFICATION NO. DC - 6849
BID - $6,783,456 TUNNEL NO. 3
BID - $2,174,097 TUNNEL NO. 3A

MISCELLANEOUS DATA

VENTILATION LINE----------30"
POWER SUPPLY INTO TUNNELS---4160 VOLTS
AMBIENT TEMPERATURE AT CUTTER HEAD ----------70° F TO 100° F
ROCK TEMPERATURE----61° F TO 70° F
PRIMARY SUPPORT--RESIN ANCHORED ROCK BOLTS
AVERAGE PER CALENDAR DAY---39 FT.---66 FT.
MINOR WATER---CAUSED ROCK DETERIORATION
NO. OF MEN TO OPERATE MACHINE---3 PER SHIFT

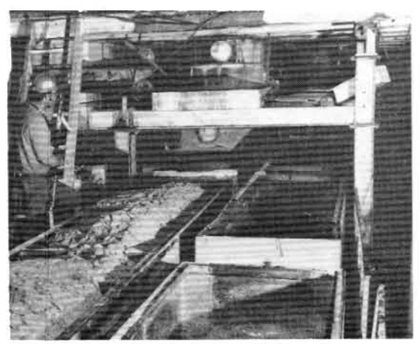


TUNNEL MACHINE-PROGRESS CHART



OUTLET PORTAL TUNNEL NO. 3

TYPICAL CROSSBEDDING & LENSES OF FORMATIONS ENCOUNTERED IN TUNNELS NO. 3 & 3A

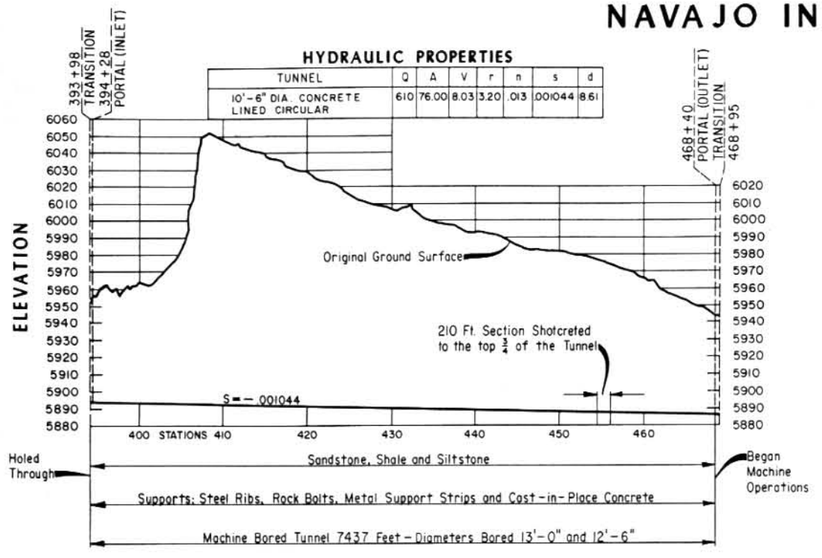


TRAIN LOADING AND CAR TRANSFER STATION

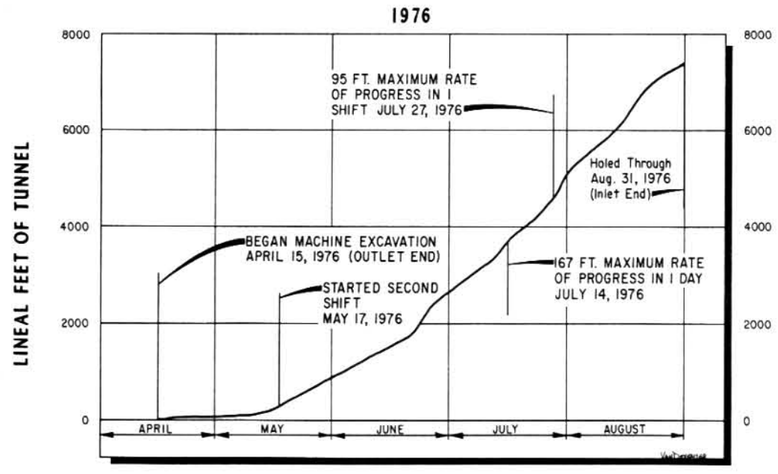
TUNNEL NUMBER 5

NAVAJO INDIAN IRRIGATION PROJECT

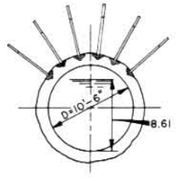
NEW MEXICO



TUNNEL PROFILE



TUNNEL MACHINE - PROGRESS CHART



MACHINE DATA

MANUFACTURED BY TERRA FORM FITTINGS CORP.
MODEL NO.__SERIAL #35 SCOTTWHEEL EXCAVATOR
LENGTH_____21 FT. WEIGHT_____24 TONS
TORQUE MAX. ____485,000 FT.-LB. AT 1.5 RPM's
WORKING___315,000 FT.-LB. AT 3.0 RPM's
STROKE _____36 IN. HORSE POWER___200 H.P.
BORE DIAMETER_13'-0", 12'-6" THRUST___85 TONS
CUTTERS__SIX ROWS OF STRAIGHT CUTTER TEETH
13 TEETH IN EACH ROW
ROTATION _____VARIABLE 0-3 RPM's

PROGRESS

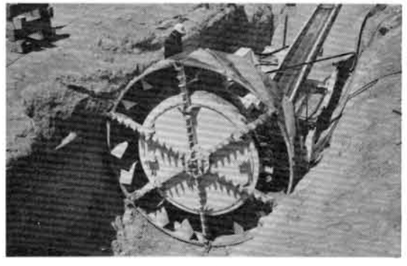
MAXIMUM RATE OF PROGRESS	SHIFT 95	FT.
	DAY 167	FT.
AVERAGE RATE OF PROGRESS	SHIFT 47	FT.
	DAY 84.5	FT.

CONTRACT DATA

CONTRACTOR-BALL, BALL AND BROSAMER, INC. AND GORDON H. BALL, AS AN INDIVIDUAL
SUB-CONTRACTOR-GATES AND FOX COMPANY, INC.
SPECIFICATION No. DC-7146
BID (TUNNEL ONLY) $3,891,820
TOTAL COST (TUNNEL ONLY) $3,697,380

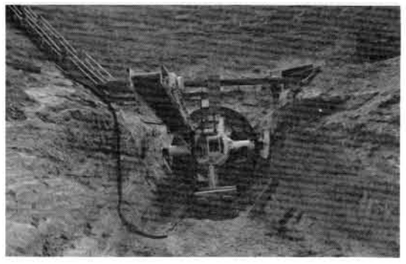
MISCELLANEOUS DATA

TRACK GAGE_____36"
VENTILATION LINE_____30"
VOLTAGE SUPPLY INTO TUNNEL _____480 VOLTS
No. OF SHIFTS PER DAY _____2 SHIFTS
ROCK TEMPERATURE____51°F
WATER FLOWS____NEGLIGIBLE
LASER BEAM GUIDANCE
WASTE DISPOSAL-TRAILING CONVEYOR AND TRAIN

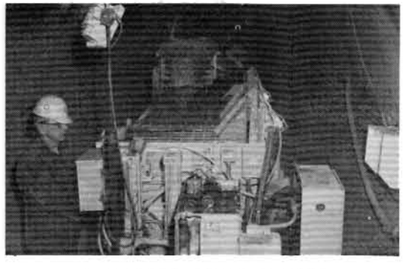


MOLE "SCOTT EXCAVATOR"

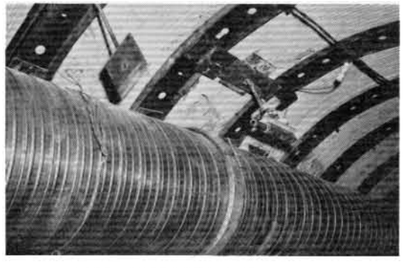
COMPLETED TUNNEL, UTILITIES REMOVED LATER



MOLE TEST RUN



CONCRETE BEING PUMPED

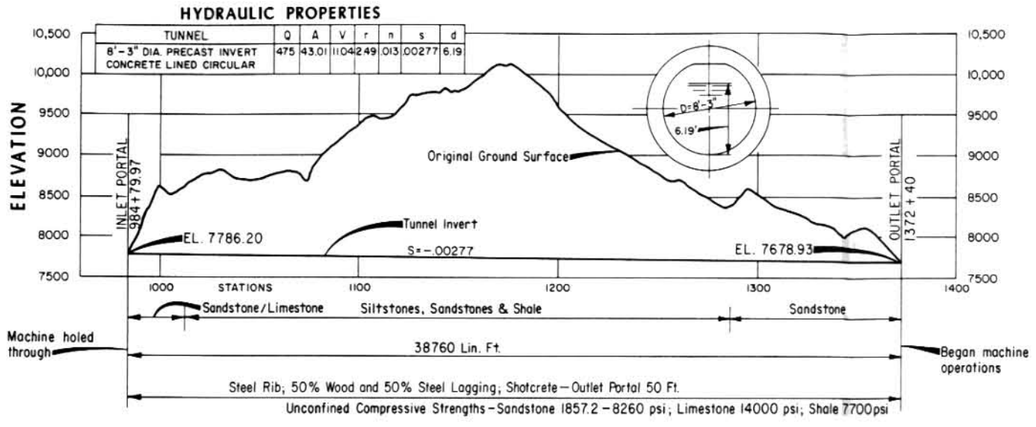


LASER, SUPPORTS AND VENT PIPE

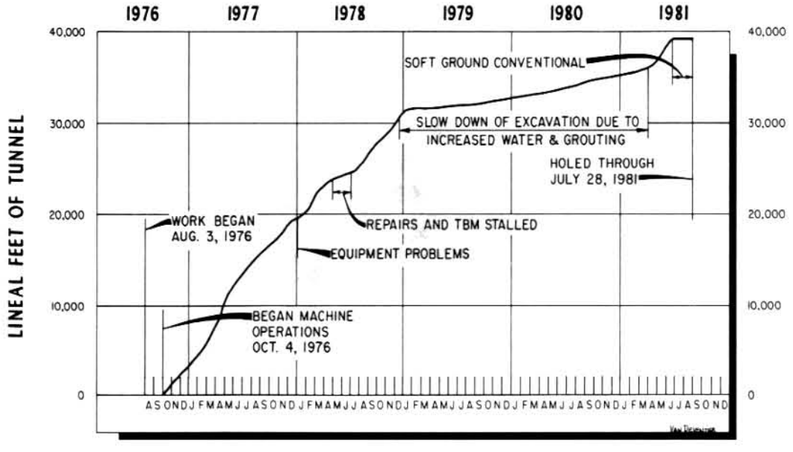
VAT TUNNEL

CENTRAL UTAH PROJECT

BONNEVILLE UNIT, UTAH



TUNNEL PROFILE



TUNNEL MACHINE-PROGRESS CHART

MACHINE DATA

MANUFACTURED BY ROBBINS — MODEL NO. 1010-179
LENGTH 22 FT. — WEIGHT 75 TONS
THRUST 1000 TONS — TORQUE 333,000 FT. LBS.
STROKE 27" — BORE DIAMETER 10'-8"
HORSEPOWER 400 — ROTATION 6.3 RPM's
CUTTERS 26-DISKS 4-12", 22-14"

PROGRESS

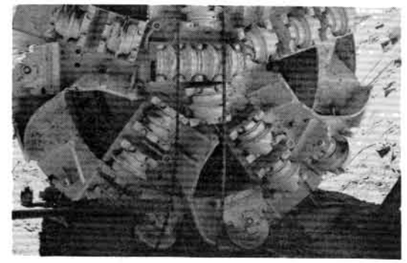
MAXIMUM ADVANCE	DAY 160 FT.
AVERAGE ADVANCE	DAY 50 FT.

CONTRACT DATA

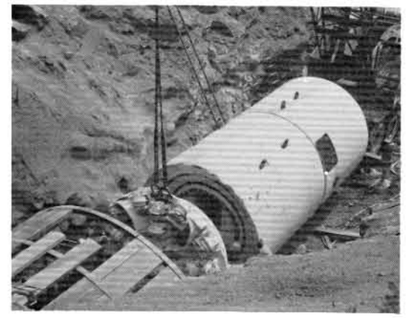
CONTRACTOR-J.F. SHEA & Co., INC.
SPECIFICATION No. DC-7150
BID $26,992,662
TOTAL COST $51,107,787.55

MISCELLANEOUS DATA

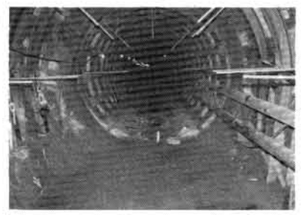
TRACK GAGE 24"
VENTILATION LINE 36"
VOLTAGE SUPPLY 480 VOLTS
No. OF SHIFTS PER DAY 3 SHIFTS
ROCK TEMPERATURE (AVE.) 44°
WATER FLOWS 622-2563 GPM
LASER BEAM GUIDANCE
WASTE DISPOSAL TRAILING CONVEYOR & TRAIN



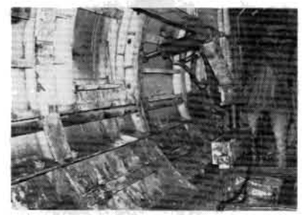
CUTTER HEAD ON TUNNEL BORING MACHINE



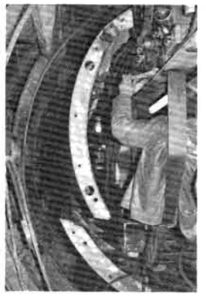
CUTTER HEAD BEING MOVED INTO POSITION FOR ASSEMBLY



MACHINE TUNNELING TRANSITIONING TO CONVENTIONAL TUNNELING



FORMS FOR CONCRETING



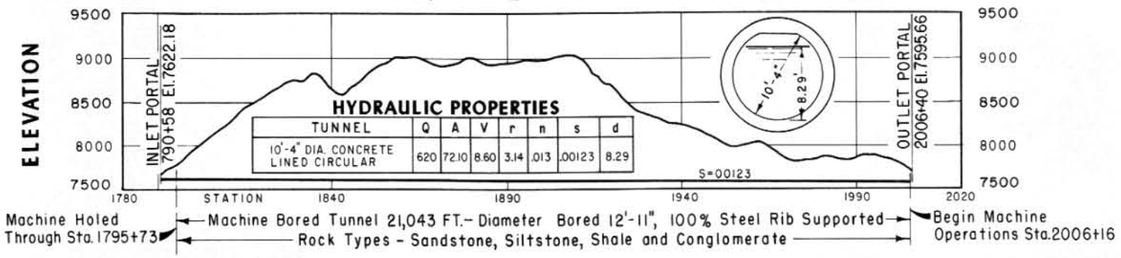
OPERATION OF HYDRAULIC JUMBO WHILE SETTING CONCRETE FORMS (NOTE, EXPANDED RIB TUNNEL SUPPORT)

WATER HOLLOW TUNNEL

CENTRAL UTAH PROJECT

BONNEVILLE UNIT-UTAH

TUNNEL PROFILE



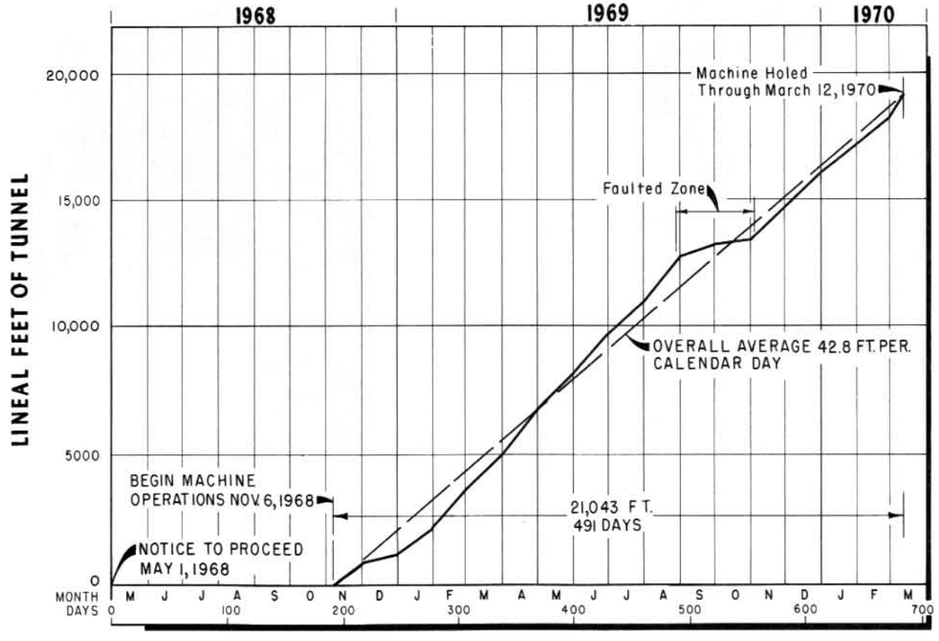
MACHINE DATA

MANUFACTURED BY ROBBINS. THIS MACHINE USED IN AZOTEA TUNNEL (MODIFIED FOR THIS JOB)
LENGTH_____35 FT. WEIGHT 192,000 LBS.
*THRUST 477,000 LBS. *TORQUE 300,000 FT. LBS.
CUTTERS_____1-TRICONE AND 29 DISC
HEAD ROTATED BY 4-100 HP, 440 VOLT MOTORS
LASER BEAM GUIDANCE
WASTE DISPOSAL___TRAILING CONVEYOR & TRAIN

*MAXIMUM CAPABILITY

PROGRESS

MAXIMUM FOR 1 DAY_____180 FT.
FOR 1 SHIFT_____77 FT.
AVERAGE PER DAY_____96 FT.
PER SHIFT_____32 FT.
PER CALENDAR DAY__42.8 FT.



TIME-DATE AND DAYS

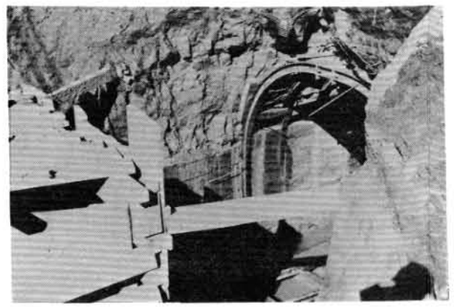
TUNNEL MACHINE-PROGRESS CHART

CONTRACT DATA

CONTRACTOR-BOYLES BROS. DRILLING Co. & GIBBONS AND REED Co.
SPECIFICATION No. DC-6575
TUNNEL SCHEDULE BID $5,236,142

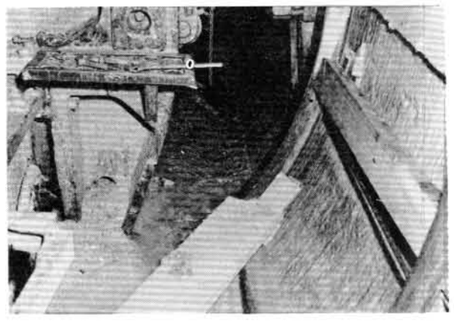
MISCELLANEOUS DATA

TRACK GAGE_____30"
VENTILATION LINE_____24"
VOLTAGE SUPPLY INTO TUNNEL_____4,160 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

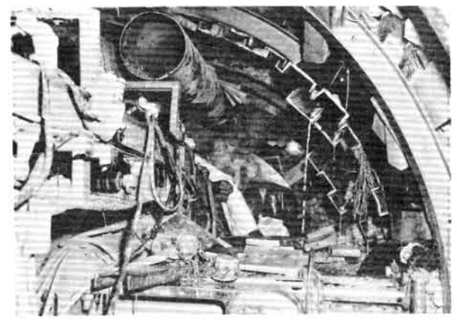


GAP IN CUT AND COVER SECTION AT PORTAL FOR INSTALLATION OF MACHINE CUTTER HEAD

LOWERING 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