UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
1100 Wilson Boulevard, Suite 910
Arlington, VA 22209

August 17, 1993

MEMORANDUM

To: Lake Barrett

From: William D. Barnard *Bill*

Subject: The tunnel boring machine in N-Tunnel, Nevada Test Site

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I would like to follow up on a discussion I had with Mr. Jerry Saltzman on June 29, 1993, about the Board's trip to the Nevada Test Site to evaluate the status of the 18-ft tunnel boring machine (TBM) currently parked at the end of N-Tunnel. The following describes the background and results of the trip. Due to the sensitivity of some of the issues raised by this trip and the fact that N-Tunnel may soon be sealed, I am transmitting this information to you before a discussion of it appears in the Board's report in the fall on the exploratory studies facility.

Summary

The federally owned TBM currently in N-Tunnel could be moved to the entrance of the tunnel in 5 to 6 weeks at a cost of approximately $1.5 million. Refurbishment, including provisions to mitigate fluid spills, would cost approximately $3.0 million and take 6 to 9 months. In other words, an 18-ft TBM with all the equipment necessary to support its operation could be *ready to begin excavation at Yucca Mountain in 8 to 11 months at a total cost of approximately $4.5 million.*[1] *A new 18-ft TBM with the same equipment would cost somewhere between $7.5 to $10 million*, depending on the complexity of the specifications and would require much more time for delivery.

Based on this analysis, the DOE may want to seriously consider the potential usefulness of the N-Tunnel TBM and support equipment. If the DOE is interested in acquiring this machine and equipment, a decision must be made by September 1993 before the N-Tunnel complex is sealed. Otherwise, a valuable opportunity may be lost.

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[1]*For comparison's sake, acquisition of the 25-ft TBM to be used to excavate the main loop of the exploratory facility will take approximately 24 months (acquisition began in early 1992; delivery is scheduled for early 1994) and cost $13 million, not including some of the necessary support equipment (i.e., tunnel conveyors, ventilation, lighting, high-voltage cables, transformers, and a rail transport system for moving people and materials).*

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Background

In early 1990, the Board initiated a field trip with the Department of Energy (DOE) to N-Tunnel, at Rainier Mesa, Nevada Test Site, to examine the wall rock characteristics of a tunnel that had been excavated by an 18-ft TBM in nonwelded tuff; we also examined the machine used to excavate the tunnel. Since that visit, Board members on several occasions have suggested that the DOE consider acquiring this federally owned TBM for use at nearby Yucca Mountain.

The machine was obtained and refurbished by the Air Force in 1982 for use in its strategic missile basing program. (Due to the relatively high cost of new machines, approximately 70 percent of the tunnels worldwide are excavated with refurbished machines.) The TBM was taken in 1983 to the N-Tunnel complex, where it was used intermittently through 1987. From 1987 through March 1993, the machine was inspected and operated weekly. In March of this year, this weekly activity stopped, as a result of a decision by the Department of Defense to close the N-Tunnel complex. The Defense Nuclear Agency is preparing to conduct one more test in the N-Tunnel complex at the end of September 1993. Subsequent to this test, the complex will be permanently sealed with concrete plugs.

In recent discussions with people at the DOE, we learned that in October 1992 a DOE contractor had evaluated the TBM in N-Tunnel and had determined that the machine was in "reasonably good condition . . .," but the costs to remove the machine could be "exclusively high." (See attachment #1.) Since we had heard that the N-Tunnel complex may be closed in the near future, we were interested in finding out more about the condition and costs of removing and refurbishing the machine. With Board approval, the services of a TBM expert, Mr. Antony Ivan Smith, were obtained to assist Board staff in evaluating the status of the machine.[2] I have enclosed copies of his report for your review. (See attachment #2.) We will be happy to arrange for Mr. Ivan Smith to meet with your technical consultants to clarify any of the issues raised in his report. The Defense Nuclear Agency estimated the cost of removing the TBM from N-Tunnel in a letter report to the Board. (See attachment #3.)

Results

The inspection of the TBM on June 22, 1993, consisted of a physical inspection, operating the machine to see if the hydraulic systems worked, rotating the cutterhead, and examining the cutters. Mr. Ivan Smith and the Defense Nuclear Agency staff concur with the DOE contractor's assessment that the machine is fully operational and could even be used in some environments at Yucca Mountain (e.g., at Busted Butte) *without* refurbishment; however, they do not agree with the cost estimates made by the DOE contractor.

The Defense Nuclear Agency staff estimate that the machine could be moved to the entrance of the N-Tunnel in 5 to 6 weeks at a cost of approximately $1.5 million. (Attachment #3, p. 1) Mr. Ivan Smith indicates that the machine could be refurbished and used for exploratory excavation within Yucca Mountain off the 25-ft main loop, for excavating the Calico Hills loop and/or for excavating the core test area. Refurbishment would consist of installing new electric motors, reconditioning the hydraulics, and providing for fluid spill mitigation as required in the DOE specifications for the 25-ft TBM. This refurbishment could be completed and the

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[2]Mr. Ivan Smith was involved in the first use of the very same machine in 1977 at a project in Chicago and later at a project in Buffalo.

machine delivered to Yucca Mountain in 6 to 9 months at a cost of approximately $3.0 million. (Attachment #2, p. 30) One benefit to acquiring this TBM is that, according to the Defense Nuclear Agency staff, all support equipment would be made available. In other words, an 18-ft TBM with *all* the necessary equipment could be ready to begin excavation at Yucca Mountain in 8 to 11 months at a total cost of approximately $4.5 million.

Mr. Ivan Smith has estimated the cost of a *new* 18-foot TBM — built to commercial specifications — to be approximately $6.5 million. This figure includes the costs for "backup equipment" ($1.5 million) but not for the additional support equipment available with the N-Tunnel machine (i.e., two, 20-ton tunnel locomotives at $250,000; ten, 20-cubic-yard muck cars and a rollover dump at $500,000; and miscellaneous items, approximately $250,000), which would bring the total cost of a *new* machine with the equivalent equipment to approximately $7.5 million. However, using the cost of the recently purchased 25-ft TBM as a basis for calculation, Mr. Ivan Smith estimated that a new 18-ft TBM — built to the DOE's specifications — actually would cost about $9 million. Again, this figure includes backup equipment, but the cost of the additional support equipment available with the N-Tunnel machine would bring the total cost to approximately $10 million. (Attachment #2, p. 31.)

We know that a procurement contract has already been approved to purchase of a 25-ft TBM for excavation of the north and south ramps and the main tunnel at the repository level. However, based on DOE studies, which are consistent with the Board's views, the DOE plans to use a smaller TBM for all excavation outside this 25-ft main loop. Excavating small-diameter tunnels outside the main loop has technical, safety, schedule, and cost advantages, which the Board will discuss in more detail in its report this fall on the exploratory studies facility.

General Comments

In light of the relatively low cost and more timely availability of the N-Tunnel TBM and support equipment, the DOE may want to seriously consider the potential usefulness of this 18-ft machine. In fact, there may be a number of advantages to acquiring the N-Tunnel TBM over buying a new 16- to 18-ft machine, especially if the DOE must continue to operate under budget constraints. (Mr. Gertz indicated to the Board in a presentation on July 13, 1993, that purchase of a small-diameter TBM could be delayed due to constraints on the fiscal year 1994 budget.) According to the Defense Nuclear Agency staff, if the DOE wishes to obtain the machine and support equipment, a decision is required soon, preferably before September 1993.

As I already mentioned, the Board plans to release a special report on the design and excavation of the exploratory facility this fall. We are presently planning to discuss the potential usefulness of the N-Tunnel TBM in that report. I hope that the early availability of this information will be of assistance to you.

Attachments
1. Morrison Knudsen Corporation, Interoffice Correspondence, dated October 15, 1992.
2. Consultant report to NWTRB from Antony Ivan Smith, July 1993.
3. Defense Nuclear Agency letter to NWTRB staff, dated July 14, 1993.

cc:
Board members (w/atts.)

ATTACHMENT 1

Morrison Knudsen Corporation
Interoffice Correspondence

To: Jim Allan　　Date: October 15, 1992

Location: N-WMS - M&O - Morrison Knudsen Corporation, Las Vegas, NV

From: O. Lyle Cripe

Location: Morrison Knudsen Corporation, Equipment Operations

Subject: Robbins Tunnel Boring Machine, Serial Number 115-178 - Demobilization and Removal Review from Slow ALCO, north drift tunnel extension location, October 14, 1992.

Responding to you request of October 6, 1992 for an inspection of the machine and the demobilization difficulties you may incur, I reviewed the machine, and the removal tunnel, October 14, 1992 in the company of Mr. Richard McDonald, MK Corporation, Mr. Hemi Kalia, Los Alamos National Laboratory and Mr. Tom Leonard, Reynolds Electrical and Engineering Co..

The TBM is of 1976 manufacturer, and has been re-powered and upgraded from 900 horsepower to 1200 horsepower, which I am assuming was performed at the time of refurbishment for use on this project site mid-1980.

The Robbins Machine is equipped with an 84" Torrington double tappered roller bearing capable of 1,900,000 lbs of thrust and appears to have functioned very well in the 3000 PSI rock formation where it is presently located.

It must be noted that upon removal of the machine form its present location the <u>Cutterhead should be removed</u> and inspection of the <u>main bearing, cutterhead drive gear, six each drive pinions and transmission drive shafts</u> be performed for wear cracks, pitting and spalding. If all components check out good, the main bearing rolling torque is to be checked and adjusted as needed or the bearing replaced and utilize the original subject bearing as a good back up spare.

Replacement cost of a new "Torrington 84" main bearing is in the $160,000 range and if not stock; delivery for like bearings has been quoted this past year at 30-36 weeks.

I was advised the machine has excavated 8400 ± feet at an average penetration rate of 50 ft per operating shift which appears relative to the 1600 hours noted on the machine service meter.

The basic machine appears to be in reasonably good condition considering being in a shut down condition for the past five years. Inspection of the cutterhead revealed very minimal wear to the 15 1/2" cutters, cutter saddles and bucket lips.

The seal has been seeping gear oil with noticeable ground discoloring evident and fresh oil seeping at the bottom of the main seal retainer area.

The thrust cylinders appear in very good condition, chrome rod plating is in very good condition with minute seepage at the packing glands.

The main control panel piping has considerable oil leakage from connections, control and relief valve assemblies. Very common with these vintage machines.

Muck conveyor belts and hydraulic Staffa drive motors appear to be good; no oil leakage evident past the motor or drive seals, material belts and conveyor support rollers appear good. The trailing deck mounted hydraulic reservoir and electric driven piston pump are of vintage design and are covered with moderate oil and dirt accumulation.

The trailing floor manufactured by, or built on the Moran, design appeared good, but again it is equipped with 1970 vintage hydraulics drive motors and controls.

Six trailing floor units are in the tunnel. The 2 rear units, including the car ramp section, are located outside on the tailings storage area yard.

It was reported the machine has been stored in the powered mode with the 4160v/480volt transformer located on the TBM trailing floor always energized. We rotated the cutterhead, which is done periodically to exercise the machine and fully lubricate the cutterhead main bearing and all six drive pinions and main drive gear. The machine gearing was extremely quiet and appeared tight, not sloppy, loose or heavily worn.

The Gripper assembly appeared good. The thrust ways were good, but the bronze wear plates appeared loose, need adjustment or replacement. The rear support assembly jacking cylinders appear good, but again seeping hydraulic oil from long periods of sitting under pressure.

Removal of the machine appears to be quite a complex problem. My observance of the main tunnel complex during the time I was underground appeared to be very busy with traffic on the main rail line continuously.

If this condition is in existence on both daily operating shifts during a demobilization schedule of the 18 ft machine, removal costs are going to be exclusively high.

Disassembly of the machine, or stripping down to the size for removal by installation of the cutterhead support dollys and the rear walking shoe assembly, is estimated to take a crew of 17 men on each of the two shifts for 20 working days. Figuring the loaded labor rate at $40.00 per hour for the 5400 estimated man hours to demobe the machine and make ready for transport would cost a minimum of $217,600 in labor alone.

Removal and/or moving of numerous heavy concentrations of utilities in the North Tunnel, including shooting and removal of five concrete tunnel plugs, along with moving the machine out of the tunnel is estimated to take crews of 10 men each shift 25 working days or 4000 man hours at labor cost total of $160,000.

The estimated demobe and transport costs do not include support equipment such as tooling, locomotives, cars, drills, manlifts etc. which can be included in a good work-detail schedule plan.

The Demobilization and removal labor cost estimated at $377,600 adjusted to include equipment and tooling can be realistically figured at $450,000 to $500,000. Traffic delays in the working tunnel cannot be realistically estimated. On the street prices of comparable 18 ft Robbins used machines range form $350,000 to $450,000 with three known machines of this size available for sale this date.

A new high performance machine utilizing today's electrics, control, hydraulic motor and hose technology is in the purchase cost range of #5 - 6 million dollars and would be powered to 2500-3500 horsepower.

Updating and complete refurbishment to the subject 185 178 machine, including outdated air cooled motor repair/replacement and transmission upgrading would run in the area of 2 million dollars, considering space in one of the many onsite repair shops is available for machine inspection, repair and updating.

The existing machine appears to be in reasonably good condition for mining 28000 ± feet of tunnel in its lifetime, and I would consider it a good backup machine or good for short tunnel application in like environments that it has been working in.

The projected new work appears very demanding in higher density rock areas with footage quoted in the 30,000 + range. It appears a new machine, designed for the 23000 to 35000 PSI rock penetration mode, complete with new style main bearing, main seal assembly and high capacity 17 1/2" cutters should be very seriously considered.

cc:
Mr. J. N. Lindsay, V.P. Underground Division
Mr. J.P. Monnot, MK Corporate Equipment Operations

G. L. Cripe G. Lyle Cripe
Senior General Superintendent - Equipment

ATTACHMENT 2

An Excavation Strategy for the ESF at Yucca Mountain, NV.

A report prepared for the Nuclear Waste Technical Review Board.

Antony Ivan Smith
2197 Little Bessie Avenue,
Park City, Utah 84060
July 1993

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Abstract

This report, "An Excavation Strategy for the ESF at Yucca Mountain..", has been prepared at the request of the Nuclear Waste Technical Review Board. It represents a preliminary evaluation of condition and suitability of a Robbins 18.6 foot Tunnel Boring Machine for the ESF program. This TBM is currently owned by the Defense Nuclear Agency and is being stored underground in an active state on the Nevada Test Site.

Author

The author, Antony Ivan Smith has had over twenty years of experience in the Tunnel Boring field. As a Consultant to Sandia National Laboratories in tunneling technology and as a member of the "Expert Panel of Cost and Scheduling" he was intensely involved in the methodology as carried out in the current ESF program.

While employed by the Robbins Company he supervised the installation of this Tunnel Boring Machine underground in Mount Prospect, Illinois. Under a special contract he remained with and helped in the direction of the record setting TBM operations until the successful hole-through.

Antony Ivan Smith is a member of many professional associations and has presented papers to the American Nuclear Society on excavation technology and to the NWTRB on repository ventilation concepts. A detailed resume is included with this report.

Introduction

The Tunnel Boring Machine or TBM, is a self propelled, complex and massive piece of equipment built to excavate a full face of rock. Normally most Tunnel Boring Machines are self-contained but they do require ancillary support for utilities such as electric power, ventilation, water and air. The storage of power and communication cable, ventilation ducting, water and air lines also high voltage transformers and switch gear, fans, scrubbers and that are normally attached to a Backup system.

The Backup has another major requirement, the muck removal system. Now the major form is by a series of trains where muck cars are loaded behind the Tunnel Boring Machine via a transfer conveyor from the TBM to the Backup. There are many styles and types of systems but they all perform the same basic function. Normally the backup runs on rails that are placed behind the TBM itself and can be quite lengthy, sometimes being over 600 feet long.

Train based backup and mucking systems have always been quite complex to keep up with the productivity of the TBM. This is most apparent in the longer tunnels. So a new continuous conveyor system has come into practical use. The conveying systems are installed behind the TBM while boring. Booster drives and computer control allow these systems to reach over 20,000 feet per section. Multiple sections can be interfaced together.

Whether a rail or conveyor system is used an integral backup system is required to support the Tunnel Boring Machine. This backup is towed by the TBM while boring and contains all of the required support. It is complicated, with air scrubbers and fans, high voltage transformers and switch gear. It includes storage for rail and utilities and finally the conveying and material handling system.

In the tunnel are man trip cars, flat cars, ventilation cars and locomotives. There are ties, rail and switches, high voltage power cable and utility lines also the tunnel lighting. All these components are a part of a very complex system that makes up the equipment requirements to bore a tunnel. The proper selection of the backup and these core components is critical due to their effect upon the actual utilization of the TBM. The efficiency of this whole system is a major predicator for the capability of the Tunnel Boring Machine.

Executive Summary

This preliminary investigation and report evaluate the use of the government owned, Robbins Tunnel Boring Machine 185-178, 18.6 feet in diameter, for the Exploratory Studies Facility at Yucca Mountain. This TBM has been used most recently underground on the Nevada Test Site at the N Tunnel complex, to bore primary access tunnels for the Defense Nuclear Agency.

Presently this machine and ancillary backup are being stored and maintained in an active condition underground. Additional auxiliary support equipment, TBM spare parts, rail, high voltage cable, transformers, rollover dump, muck cars, locomotives, lights etc., are being stored at the portal site or installed in the tunnel. A practically complete rail mounted, tunneling system is available.

A current market value for equivalent new equipment would be more than $7.0 million. The Defense Nuclear Agency and their subcontractors have made a diligent and superlative effort to store and maintain this TBM and ancillary equipment in a ready condition.

This Tunnel Boring Machine has been passed over by technical experts in earlier reviews, as unsuitable for the ESF project. The proposed deactivation of the site and the sealing of the tunnel has prompted the NWTRB to request an additional review of the adequacy of this TBM for a role in the ESF.

The NWTRB has consistently maintained the position that the schedule has the maximum priority and that the selection of tunneling equipment and methodology should reflect that priority. This TBM has a very high potential level of productivity based upon prior performance. The TBM's practically immediate availability and excellent condition have a significant positive effect upon the schedule also acquisition and refurbishment costs.

Since 1978 this Hard Rock TBM, Robbins 185-178, has successfully completed over 27,000 feet of tunnel. It has achieved a phenomenal performance level both in productivity and diversity during its history.

In 1977 a record of over 70% average utilization of the TBM per day was achieved for a 10,900-foot tunnel project in Mount Prospect, Illinois, a part of the Des Plaines TARP. The rock strength was 20,000-30,000 in competent Dolomitic Limestone. This level of performance has still to be exceeded in large diameter hard rock tunnels; where the world wide project average is about 51% average utilization.

In 1980 it successfully completed a 6,813-foot section of the Buffalo Subway, boring 20,000-35,000 psi limestones in 130 production days. Severe ground conditions were encountered requiring full steel support in some sections of the tunnel, affecting the utilization of the TBM substantially.

After a complete rebuild in 1982, the TBM was moved to the Nevada Test Site. In subsequent tests performed for the Department of Defense, as a part of the ballistic missile egress program, sustained penetration rates in the unwelded tuff of over of forty feet/hour were reached. Again a record breaking performance. This was the world's first application behind a TBM, of a conveyor system used for muck removal.

After completing the project the TBM was then moved practically in one piece to the N Tunnel Complex. At this location it has since bored over 8,000 feet of tunnels for the nuclear weapons testing program. The original rail mounted, backup system was installed behind the TBM.

Currently nearly 70% of the world wide tunneling is being bored by used Tunnel Boring Machines, the properly refurbished TBM can play a very significant role in major projects. The current performance in Lesotho, South Africa of a similar rebuilt 18 foot TBM in head on tunneling against three new Robbins and Atlas Copco TBM's, amplifies the usefulness of used equipment. Recently Robbins 167-266 exceeded by only 49 feet, ten year old Robbins 186-206's monthly productions record of 4,343 feet.

Other Robbins Tunnel Boring Machines with identical main bearings, have completed hundreds of thousands of feet of hard rock tunnel. As examples Robbins 191-161 has now bored a record 95,144 feet after first successfully boring the rock tunnels for the Washington, D.C. Metro. The Robbins 227-183 at the DART Project in Dallas recently achieved a new production record of 1,408 feet per week.

Considering the need for a restrained fiscal philosophy and an improved schedule of tunneling activities, the utilization of this TBM within the ESF program would offer a distinct advantage in both areas. The TBM can be removed from the "N" Tunnel location for a direct cost of about $1.3 million, in about five to six weeks period. A large amount of equipment associated with the TBM would also be retrieved.

This Tunnel Boring Machine Robbins 185-178, is extremely suitable to have an active role in the ESF program. A specific project being the Prototypical Thermal Test Facility at Busted Butte. The thermal testing is a crucial activity and a major milestone on the critical path for the licensing of the repository by the NRC.

Other as critical projects are at the repository level. Over twenty thousand feet of tunnels are required for cross cuts, chambers in the experimental areas and for the additional pilot tunnels that reach out to the repository boundaries. These activities require a TBM that can bore short radius curves and be easily moved around underground.

This TBM has already proved with the current backup system, the ability to bore curves less than 250 foot radius and to be easily moved around underground. A feature that is an important requirement in the selection of a TBM for this aspect of the project. This open-type of TBM i.e., not fully shielded, allows it to be broken down into quite small components and be moved around with the least disturbance to ongoing activities. The type of Tunnel Boring Machine that was recently purchased by the DOE is not conducive to this application. The full shielding and the unusually large bearing, will affect the required mobility. This immobility becomes even more significant if the twenty-five-foot TBM is reduced as a future option, to a smaller diameter.

The pilot tunnel into the Calico Hills formation beneath the repository level is another critical project and a milestone for ultimate licensing of the repository. Based upon its record prior performance in the unwelded tuff, this TBM would be well suited to complete successfully this aspect of the project. It would appear that an off-site entry to Calico Hills might be of considerable merit.

The excellent general condition of the TBM and the low 'sixteen hundred' hours of operation since the last rebuild, clearly shows that the TBM is capable of boring a short series of tunnels in its present configuration. A range for on-site immediate repair might be about $1.0 million in a three-month period. The TBM would be repaired on an as need basis based upon prior inspection and review. This work would be performed at the Busted Butte Site.

After the completion of these tunnels the TBM would be available for further tunneling activities after a refurbishment program. Due to an unusually stringent requirement for fluid and oil mitigation within the repository block, a major component of refurbishment would be the required engineering and modification to meet those specifications.

The comparative history of the performance of used Tunnel Boring Machines has been more than excellent. A reason for this track record might be attributed to the fact that the used Tunnel Boring Machine has been a beneficiary to engineering changes and improvements or that problems have been worked out. It would appear though that another scenario might be the core to this success. There is a close association of individuals during the rebuild that continues on to the actual construction. Typically the rebuild work is performed by the contractor with a very close association to his on-site personnel. It is an amalgamation of skills following a very common direction. This rather unique self interest carries on into the day to day operations and results in excellent performance levels.

The condition of Robbins 185-178 and of the tunnel, clearly shows the skill and dedication of the individuals that were involved with the day to day operations at the N Tunnel Complex. Although bound by theory and technical consultants tunneling is a method of hands on activity and experience. It requires as its major resource the practical experience of manager, engineer, mole operator and miner. An experience that cannot be taught only learned, as well proved by the highly skilled team that is available at NTS.

ESF Background and Historical Summary

The purpose of the ESF or exploratory studies facility was to enter the repository block by shafting and tunneling, to evaluate the potential of Yucca Mountain as a site for the Nuclear Waste Repository. It was an implicit understanding and requirement that any activity associated with the ESF would be for the sole purpose of that evaluation. The design of all components of the ESF was to reflect this fundamental purpose. The size, shape and physical characteristics of the actual excavation were all to follow this basic principle.

It was also implicit in the preliminary design of the ESF that performance related to schedule was a very fundamental priority. An evaluation of certain faults and structures represented a definite no-go or go decision as to the suitability of the site for the repository. An immense cost saving would result if the project was deemed unsuitable in its early stages before the setting up of the long term testing programs.

Many construction concepts for the Exploratory Studies Facility at Yucca Mountain were developed by Sandia National Laboratories in 1991. Expert teams, evaluated and weighed these options for design criteria, programmatic viability, performance characteristics, costs and schedule. This data then was further reviewed by management panels and the final recommendations were then presented to the DOE. These recommendations were specific construction concepts that met the stringent parameters and criteria that had been developed by these teams of experts.

The selected option, excavation by Tunnel Boring Machine, diverged totally from the original construction methods that had been proposed for the ESF, namely a series of conventionally excavated vertical shafts and horizontal drifts. The application of Tunnel Boring Machine methodology would allow for the rapid evaluation of a representative cross section of the proposed repository that included a series of significant structural features and faults. It was though inherent in the philosophy of the proposed TBM methods that the performance or utilization of the TBM, not be impaired by the required testing and control procedures. Agreement had been reached with the designers of these testing programs that the prime objective would be to optimize the performance of the TBM.

It is with this philosophy in mind that an optimum diameter for the pilot tunnel was developed. A major activity and the greatest cost, are the handling and disposal of the bored rock. So a balance has to be reached between actual physical requirement of the ESF and expected performance. Added factors are ground support, transportation, ventilation and service. So a very distinct rise in cost and lowering of performance fits large increases in tunnel diameters. Minimizing size does significantly reduce cost. For these reasons earlier studies recommended diameters in the eighteen-foot range. Currently the twenty-five-foot diameter range has been selected as the optimum for the bored tunnels.

Current Budget requirements have modified the original acquisition program for the purchase of at least four Tunnel Boring Machines.. The present plan is for a single, recently acquired TBM to bore the first pilot tunnel through the repository block. This TBM should be delivered in early 1994. An integral backup system was ordered with the TBM. The material handling and conveying systems have still to be ordered. It is uncertain as to the schedule for the purchase of other required equipment, such as high voltage systems, ventilation etc., which is associated with the TBM and backup.

Recommended Future Utilization

General

This Tunnel Boring Machine, can be used quite viably within the ESF program with a well planned and executed rebuild and modernization program. Before the disassembly of the TBM a very precise testing and evaluation of all of the operational components should be made. This evaluation would improve the lead time for the replacement of any defective components and to allow the development of proper cost and cost schedules.

Advances in tunneling technology in the past ten years have not modified the basic concept of the Tunnel Boring Machine itself. The greatest advances have been in backup development, the introduction of computer technology and in cutter development. The fundamental areas of mechanical design, hydraulics and electrical systems have changed little. Improved performance levels of modern mechanical components' offer increased life but represents a very insignificant figure in any comparison between new and old systems.

There has been no order of magnitude development in performance of the new Tunnel Boring Machines since this TBM was built in 1977. Significant advances have been made in the area of very hard rock tunneling due to cutter development. Considering the rock strengths and fracturing found at the ESF site and the prior performance of this TBM in equivalent rock, a modern day TBM would offer only a moderate improvement in performance. This has been shown in prior reporting from Colorado School of Mines..

Current ESF Specifications

Very detailed specifications were outlined as a part of the RFP for the newly purchased Tunnel Boring Machine. It might appear that some of these specifications might conflict with those of the used Robbins TBM. This comparison is not the subject matter of this report.

It is quite clear that this type of TBM has proven to be very productive and efficient. Extremely severe ground conditions have been encountered and overcome with total success, a situation not expected in the proposed work at Yucca Mountain.

Certain specifications in the RFP are defined to meet a specific standard that would be deemed uncommon to current practice and in particular in this application at Yucca Mountain. Some specifications simply are a preference. The rear mounted cutters and full shielding are unique on a hard rock Tunnel Boring Machine destined to bore in competent rock. The difference between totally enclosed fan-cooled (TEFC) and water-cooled motors has no performance basis at all.

It is difficult to evaluate whether these deviations from common practice would enhance or detract from performance. It would though be detrimental to burden a successful concept with a theoretical projection of requirements, somewhat of an evolutionary blip. Any modifications to this Tunnel Boring Machine should reflect actual rather than supposed necessity. In making any definition or specification of need, current performance of other used Tunnel Boring Machines has to be considered and cannot be ignored.

Thermal Testing Program

The thermal testing program requires an underground in-situ test site to emulate a section of the repository. The program is unique due to the extended period required to develop and do these tests which critical for licensing. In the current program these tests can't start until the pilot tunnel reaches the repository level. A date in time dependent upon many factors including delivery and actual performance of the TBM and associated equipment.

One consideration to accelerate thermal testing was to stop the new TBM underground when it reached the area designated for thermal tests in the main pilot tunnel. A second yet to be purchased TBM would be then be installed to develop the tunnels for the thermal testing. Once these tunnels were underway the first TBM would continue boring the pilot tunnel.

This plan has considerable risk and the potential of a negative effect on both the schedules for the ESF and the licensing by NRC. The accumulated delay would influence the sought after go or no-go decision on the quality of the rock and the condition of the faults in the repository level. This decision has higher a but differing priority to that of the thermal tests.

Busted Butte

It is proposed that this Tunnel Boring Machine might be employed in a new and different role. Boring a tunnel into Busted Butte would offer a location to start the thermal testing early. A timely start of this phase of the program would improve the total schedule and limit any dependence upon the performance and delivery of the recently purchased Tunnel Boring Machine. In this scenario the TBM would be transported to the Busted Butte site from the N Tunnel Complex and be prepared immediately for tunneling. The very limited 'sixteen hundred' hours of operations and the current physical condition of the TBM strongly suggest that all major components are operational.

All critical components, such as the main bearing would be closely inspected and changed if warranted. The rail mounted backup and mucking system would be employed. A period for repair and assembly of the whole system would range from 90-120 days and for a cost of about $1.0 million. The condition of long lead time items, such as the main bearing, might create the differential in time and cost.

Considering the short 3,000 feet length of the first tunnel, sixty to ninety days would be an appropriate estimate to complete the boring. Two additional parallel tunnels would then be bored near to the end of the main tunnel. This triple set of tunnels would offer an underground location to develop the tests and instrumentation for the thermal testing program.

In this location the strength of the Tuff is about 22,000 psi, lower than the strength of the limestones previously bored. The tuff is highly fractured in this location suggesting a much higher potential performance than would normally be projected from the rock strength. This fact has been clearly shown by the performance testing at the Colorado School of Mines and at the TBM bored River Mountain Tunnel. A 19,970-foot tunnel bored in Tuff 17 mile SE of Las Vegas, Nevada. Expected performance in the welded Tuff would be about ten feet/hour.

Repository Block Tunnels

General Requirements

It would be highly recommended that an off site refurbishment be performed before this TBM is used for other proposed tunnels in the repository block. The Tunnel Boring Machine would be upgraded and modernized to optimize performance..

Most probably new cutterhead drive motors and reducers would be installed along with improvements to the hydraulic and electrical systems. A Ring Beam Erector and a set of Rock Drills would be added. to improve performance in poor ground. The 15.5 inch cutter housings would be changed to utilize the higher capacity 17 inch cutters.

Costs of a complete rebuild of the Tunnel Boring Machine would be about $3.0 million and in a six to nine month periods. A figure that includes $.65 million to complete the engineering and installation of a sophisticated fluid mitigation system.

[A potential stipulation might be in the control of cooling fluid and oil leaks. It would be appropriate to specify design ideas to lessen or prevent such leaks but certain practical fundamentals have to be considered. Most leaks are caused by the failure of or the replacement of failed components. Most often a catastrophic failure. The design and need of the system must be dictated by reality not by specification, otherwise it becomes the predicator of performance.]

Calico Hills.

In the assessment of the repository site, the condition and nature of the Calico Hills beneath the repository level is very important. This evaluation has the same go no-go affect as noted for the primary pilot tunnel. A current plan is for a TBM to be installed and to continue from the bottom of the bored ramp at the repository level to the Calico Hills formation. This pilot tunnel would then be bored to note the condition of the rock and significant structural features.

A projected time that for this activity to commence is indeterminable. It is totally dependent upon delivery and performance of the new TBM and the proposed tunnels for thermal testing. The same negative effects, as previously noted, would apply if the Calico Hills TBM is installed concurrently with boring activities at the repository level. This potential interference gives very serious merit to an off block entry to the Calico Hills.

The Calico Hills formation is a very similar rock to the unwelded tuff that Robbins 185-178 bored at the N Tunnel site. About 30,000 feet of tunnel will be required in this phase. This TBM with a modern and efficient conveyor backup system probably can achieve an average over 150 feet per day in the Calico Hills formation. It has been noted that in the unwelded tuff that this TBM was operated at the lowest speed 2.0 r/m. Penetrations exceeded 20 feet per hour.

The Tunnel Boring Machine is highly suitable for this phase of the project. A cost and concept have been outlined in the previous section for a rebuild of the TBM. It would be appropriate to make any additional modifications that would improve the performance characteristics of the TBM. The original backup system would be retained in a stored state for possible future use.

Thermal Testing Tunnels.

The thermal testing concept has been in part addressed in the proposed tunnel at Busted Butte. As originally specified a series of tunnels is required with a diameter near to the proposed size for storage drifts in the repository itself. If these tunnels are bored at the repository level, a TBM will be required that can be easily moved underground and be able to bore tight radius curves.

This Tunnel Boring Machine is well suited for this task. It has previously bored curves up to ninety degrees with a radius of nearly 200 feet. This type of TBM with a small radius main bearing can be easily broken down into quite small components. This is not so with the large diameter bearing and the fully shielded type of Tunnel Boring Machine recently purchased by the DOE.

In most probability a specialized backup system would be required. The present backup system would be an appropriate and well-suited nucleus for this new system. Either a rail mounted or conveyor system could be employed.

Cross Block Tunnels.

These tunnels would be very similar in scope to the thermal testing tunnels. Performance would be the optimum parameter as the idea of these tunnels is to reach out to the limits of the repository. A modified conveyor type mucking system would be employed for improved utilization. As previously outlined this TBM can be moved quite readily in the underground environment and is well suited to this task.

Summary of Proposed Additional Work

This Tunnel Boring Machine Robbins 185-178 and backup system is a viable component in present and future underground operations, the core aspect of the ESF program. It is a TBM that has proved performance levels that meet the requirements of the project. It is also a Tunnel Boring Machine that can offer proven flexibility as it can easily be moved around from site to site on the surface and in particular underground. A very positive attribute.

If the Busted Butte concept is considered, the TBM would be transported to the new site in the largest sections possible and rebuilt as needed at job site. Otherwise, the TBM would be broken down for transportation to a selected repair facility.

It would be a considered normal practice to inspect and repair a Tunnel Boring Machine as needed after each section of tunnel has been completed. This TBM would not need to be brought back to the surface to perform future major rebuilds. It could remain underground until all tunneling work was completed.

TBM Information and History.

Introduction

Currently the Tunnel Boring Machine is at the end of the North Tunnel Extension in the N Tunnel complex. Two backup decks and ramp were removed and stored at the portal site. The TBM is in stable and dry location with power available. Rock bolts and mesh cover the crown up to the rear of the TBM. Rock bolts have been installed above the TBM itself. The ground condition is excellent.

This TBM has bored three different tunnels at the Nevada Test Site, in about 'sixteen hundred' operating hours, for a total distance of about 10,000 feet. Considering the lineal footage, the difficulty of the moves and the potential for damage, this TBM is in excellent mechanical condition. It does not show the normal wear and tear that would have been expected because of this activity.

A review of apparent condition was made and a series of documentary photographs was taken. The review and summary follow.

History

In 1977 this Tunnel Boring Machine was purchased by McHugh Construction of Chicago Illinois, to bore a 10,700-foot section of the Upper Des Plaines TARP. A unique back up and mucking system was supplied by the Moran Company and integrated to an innovative material handling system installed by the Rexnord Company. This TBM with the associated backup and support equipment was able to achieve a level of performance that has yet to be exceeded, an average of over 70% utilization. The tunnel was bored in a Dolomitic Limestone with a compressive strength between 18,000 and 30,000 psi. Extremely competent rock. There were very few as needed rock bolts installed and no rib steel.

This Tunnel Boring Machine also achieved a standard of performance in another aspect of operations. The tunnel alignments required a series of tight curves less than 250 feet in radius. The first curve was located within a few feet of start up, a sixty degree left hand turn. The second curve was located approximately halfway through the 10,000-foot project, a ninety degree right hand turn. Both curves were completed with little or no degradation of performance.

The TBM was then prepared to bore a section of the Buffalo Subway Tunnel in 1980 for S&M Constructors of Solon Ohio, the Joint Venture partner of McHugh Construction, Chicago, Illinois. This 7,000-foot tunnel was successfully completed in Limestone with a compressive strength between 16,000 and 35,000 psi. Some delay was noted due to the poor rock condition in some locations.

In 1983 the TBM was refurbished for the Egress Demonstration Project at the X Tunnel site for the Department of Defense. During these tests penetration rates were achieved that exceeded 30 feet per hour. The maximum reported penetration was 40 feet per hour, a performance level that has not been exceeded to date. A conveying system was developed for muck removal, the progenitor of the highly productive systems that are being introduced today, boring about 700 feet in these tests.

In June 1983 the TBM was transported by truck in practically one piece to the N Tunnel site at the NTS. It was mated to the original backup system that was successfully employed in Chicago. The TBM has bored more about 10,000 feet of access tunnel at the N Tunnel site. After completing the South drift it was backed up over 3,000 feet and placed into a new underground starting chamber. Approximately 4,000 feet of a parallel tunnel, the North drift, was completed before termination of operations in December 1987. The TBM has been in active storage since that date.

Inspection

Backup System.

Decks.

The backup decks appear in excellent condition. Other than a film of dust no severe oxidation or structural damage is apparent. This patina of dust was more noticeable around operating equipment.

The loaded and empty car pullers were lubricated and in an operating condition. The car transfer, flop-gate and lift mechanisms were found in the same operational condition. The physical appearance was excellent with no leaks to be noted: also there was no visible mechanical damage to pins chains and cylinders etc.

The hydraulic pack and operators' control center was covered with some dust and fine grain material. It is in excellent condition. The fans and scrubber are in the same condition. These units were not operated.

Conveyor Bridge.

Structurally the bridge appeared in good mechanical condition. The conveyor belt has been recently operated and shows excellent tracking. There are no inoperative rollers or components.

The section of the bridge that attaches to the TBM has a considerable amount of material spillage, a very normal condition.

Electrical Cabinets

The Electrical Cabinets show a patina of dust quite moderate considering the location beneath the conveyor belt. No mechanical damage was apparent.

The interior of the cabinets would be considered quite clean considering the time spent underground. There was no evidence of damage caused by failed components or of fire. Upon power up all components operated normally.

Tunnel Boring Machine.

Rear Supports.

The rear supports were in contact with the ground and showed no mechanical damage at all. There are no leaks from hoses, seals or wipers. The chrome on the rods is excellent.

Grippers.

The grippers were thrust out to the rock with a maintainable gripper pressure. There was no apparent scarring oxidation or damage to the rods themselves. The general condition was excellent.

The gripper slides were greased and had no appearance of severe oxidation or damage. A moderate gap is apparent in the slides.

The propel cylinder attachment and springs also showed excellent condition.

Some oxidation was apparent on the extended portion of the propel cylinder rods. This condition would have no effect upon operation. Otherwise, the chrome appeared excellent.

Lube Oil System.

There appeared a heavy film of dust around the lube oil tank due to the tacky nature of the oil film. There were no leaks other than residual oil film from filter changes etc. The system appeared to operate as normal.

Cutterhead Support.

This general area of the TBM is quite dirty from fines and material, a normal condition. Apparently the TBM was shut down in an operating mode. There was no appearance of any mechanical damage or repair. An additional support for each of the cutterhead drive motors was noted as a change or modification from the original installation.

Hoses and cables were properly placed and showed no damage or wear. Side support indicators were intact and the cylinders and slides are in an operating condition.

The TBM conveyor was viewed through the lower access port and seemed in excellent condition.

Cutterhead.

The cutterhead was rotated using the inching system. Some cavitation from the hydraulic pumps was noted when initially starting. The Inching drive was engaged and operated normally. There was no unusual noise from the cutterhead drive system. A small leak was noted at the seal area, it may be the normal seal lubricant, not lube oil from the cutterhead cavity. Again all systems appeared in excellent condition. Normally on a Tunnel Boring Machine poor maintenance and catastrophic problems have clear external indication.

The cutterhead buckets were not worn and in excellent condition, typically an area of high wear. There was visible damage in the buckets or cutter housings, no loose or missing bolts were noted. Some cutters were worn but the general condition of the cutters and cutterhead was excellent. It would appear that some cutters had been replaced and some others were due for change.

Operator Area.

This area was found neat and clean. Controls were operative. Gripper pressure was maintained after operation of the pumps. Some minor hydraulic oil leakage is apparent in and around the tubing and fittings, it is also apparent around the pumps and filter area. Mostly this is the residual oil covered with a light dust layer, originating most probably from the assembly of the TBM. The changing of components or filters will also contribute a film of oil that will be collect dust.

Summary

This TBM is in excellent condition and especially considering the 10,000 feet of tunnel bored and the two moves that it has made. Typically a TBM shows damage caused by carelessness, rock fall or accidents. It has been well serviced and cared for.

It would be appropriate before removing the TBM a very detailed inspection is made to review the actual condition of all components. This action would allow for an improved repair and refurbishment schedule, especially considering the long lead times for the purchase or manufacture of some components.

Tunnel Boring Machine 185-178

Technical Specifications.

Robbins	Model 185-178-2
Manufactured	1977
Diameter	18.6 foot
Power	900 Horsepower

Torque	924,300 foot/pounds
Thrust	1.9 Million pounds of thrust
Cutters	39 single disc 15.5 inch cutters.
	2 Twin disc center cutters, 12.0 inch
Cutter Load	45,500 pounds per cutter.
Conveyor	830 cu yd per hour
Modifications	Diameter was increased from original diameter of 18.2 foot
Weight	470.000 lbs
Stroke	5 feet

TBM Extraction and Disassembly

The extraction of the TBM was reviewed with the REEco on site management team. This TBM has been moved underground on a prior occasion when moved from the south to the north drift. A detailed estimate was being prepared by REEco.

Concurrent activities could be performed both at the Tunnel Boring Machine and in the tunnel to prepare for the TBM to be brought out. There is a particular area where instrumentation is located that might not allow passage of the TBM. There are also sets of concrete bulkheads that interfere as well. Transportation dollies for the TBM are available on-site.

Disassembly of TBM

A careful analysis and inspection of the TBM would be performed before the disassembly of any component. This review is essential for further estimating of cost and schedule for future planning.

The conveyor bridge and backup decks would then be broken down for transportation to portal. The first deck with transformer and switch gear would remain in the tunnel.

The Tunnel Boring Machine would be backed up and components would be disassembled and laid in the tunnel floor. The roof supports, buckets, side supports and front support. At this point the TBM would be placed onto the dolly system. If the TBM is not able to clear the obstacles then the gripper shoes, propel cylinders and rear support would be removed as well.

The TBM can effectively be diminished in size to approximately 14 feet in width. The height depends upon the dolly location but is around 15 feet high. It would be strongly suggested that precise measurements be obtained to optimize this phase.

The TBM would be disconnected from the backup and the backup deck with the mounted electrical gear would be removed. Now the TBM would be ready to be pulled back to the portal.

Tunnel Activities

While activities are occurring at the heading on the TBM some remedial work would be required in the tunnel. Depending upon the selected route, a varying amounts of slashing will be required. These areas would require new rock bolts and mesh for ground support. The concrete plugs need to be slashed down as well to adapt to the height of the TBM on the dollies.

Some repair and inspection of the rail will be required and any switches removed due to the interference of the double flanged wheels on the backup decks.

Ventilation ducting would have to be removed on an as need basis and stored. Once the TBM has been disconnected from the high voltage system cable can be removed as well. All unneeded utilities should be brought back to the portal.

Portal Activities.

The rail and rollover dump need to be removed and loaded for transportation. Any utilities such as pipe, cable, rail etc., that has been selected for further use should be loaded out as well.

Once the TBM is brought out to the portal site it would be prepared for loading out. If the TBM is to be used immediately on the test site very little further, disassembly would be required. If the TBM is to be transported to an off-site facility then it would be needed to be broken down into transportable sections.

Once the tunnel is clear of the TBM then the abandoned components need to be loaded from the tunnel and brought out to the portal. These are the components of the TBM that were laid onto the tunnel invert during the initial disassembly.

Crews

It would appear that three distinct activities are to be performed concurrently, at the heading with the TBM, in the tunnel and at the portal.

These crews could use individual resources as necessary. The mechanics and electricians would be required at the TBM to disconnect components. The miners would be drilling out, shooting and mucking the slashed areas and utilized as needed to help in loading components from the TBM and removing utilities. A small crew and crane would be required at the portal to complete disassembly and the loading out of components.

The extraction of the TBM on two shift a day operation, would be envisaged for a period of five weeks, about fifty active shifts. The emphasis on the day shift operation would be at the Tunnel Boring Machine and the portal and the swing shift would be more concerned with the preparation of the tunnel. This procedure would minimize interference between activities.

A 16-18 man shift including supervision would be required.

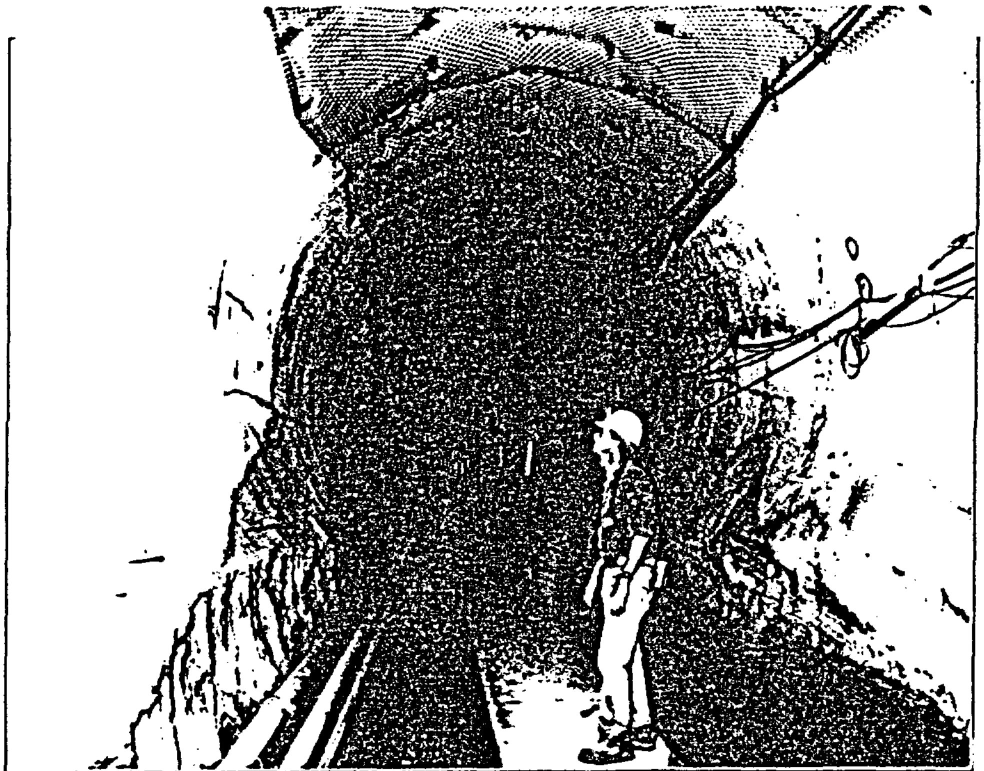
Crew Breakdown

	First Shift	Second Shift
Walker	1	1
Mechanics	4	2
Laborers	2	2
Electricians	2	1
Operators	4	2
Miners	5	10
Totals	18	18

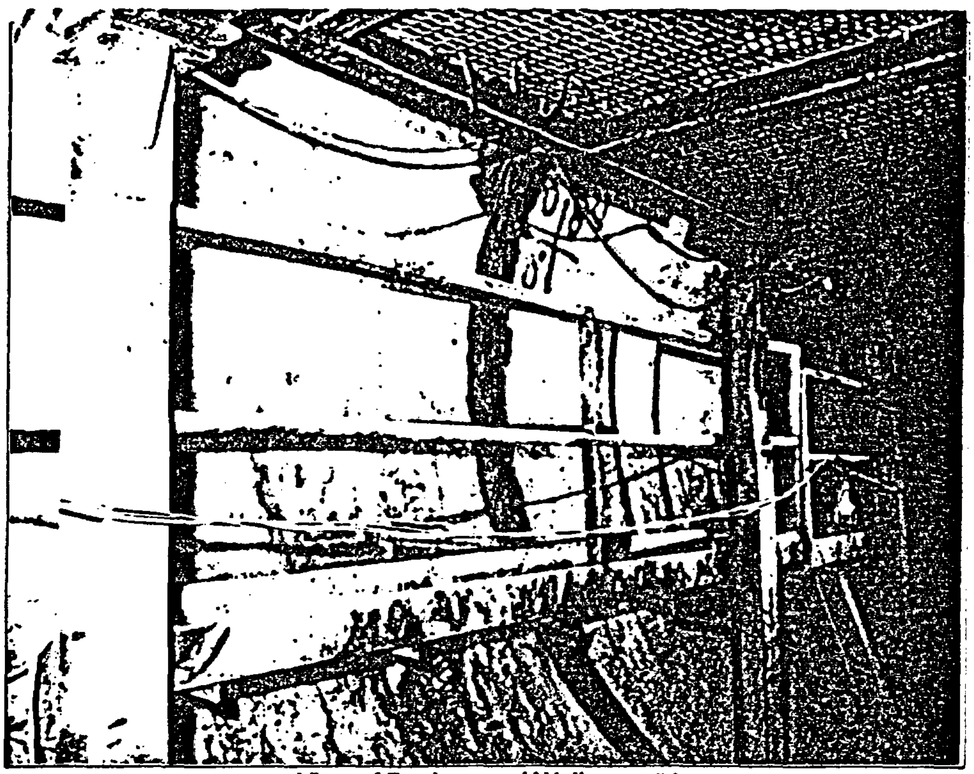
Approximately 900 working man shifts will be required to remove the Tunnel Boring Machine from the N Tunnel Site.

Pictures

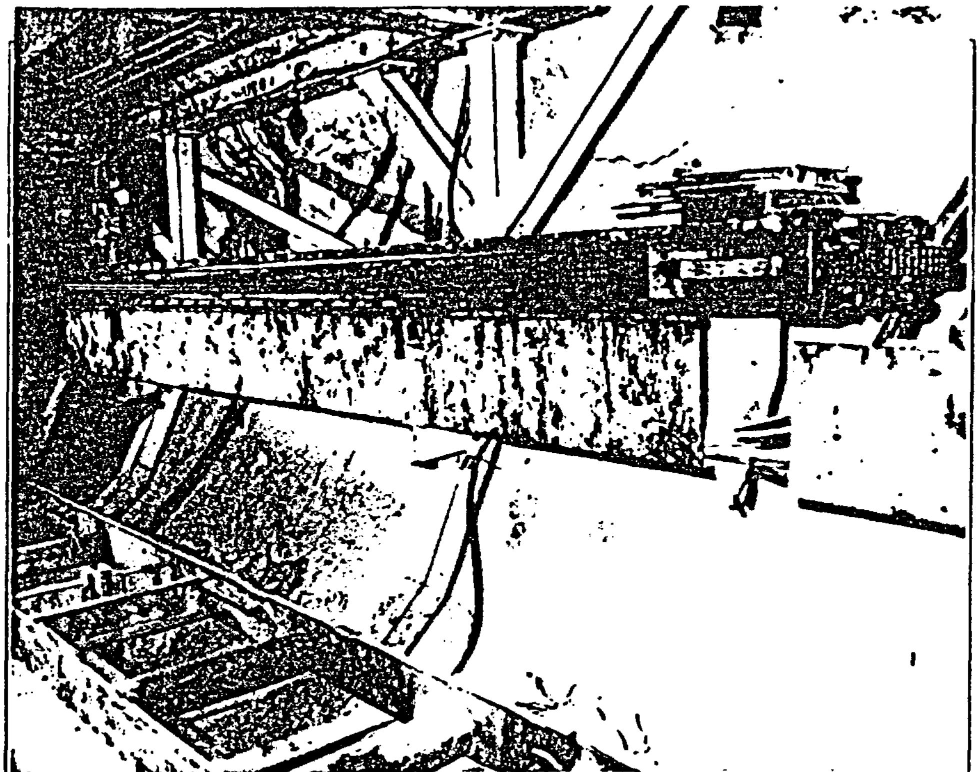
Following is a selection of pictures from a series taken during the inspection of the Tunnel Boring Machine. A summary list of all pictures available is to be found in the Appendix.



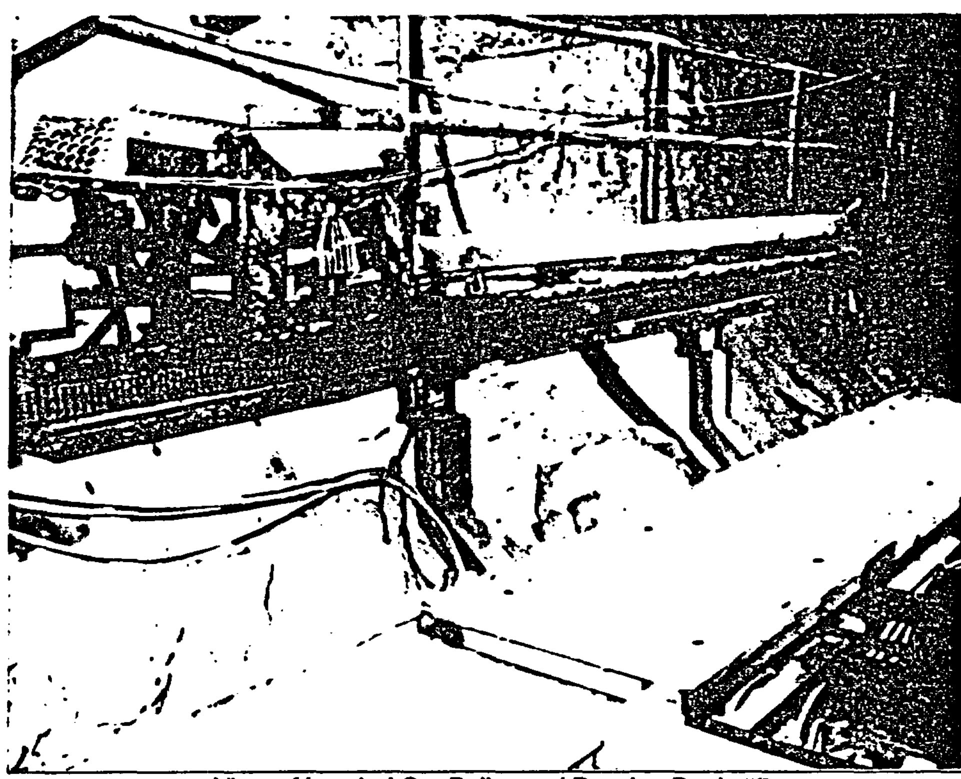
View of 18.6 foot Tunnel at Portal #52



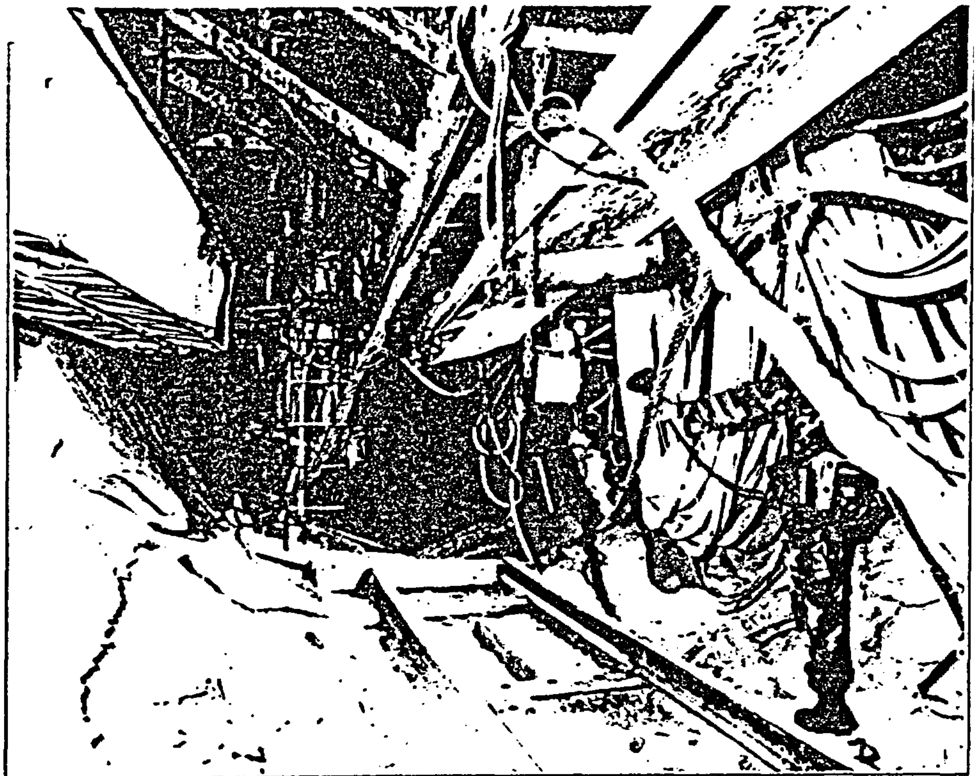
View of Backup and Walkway #1

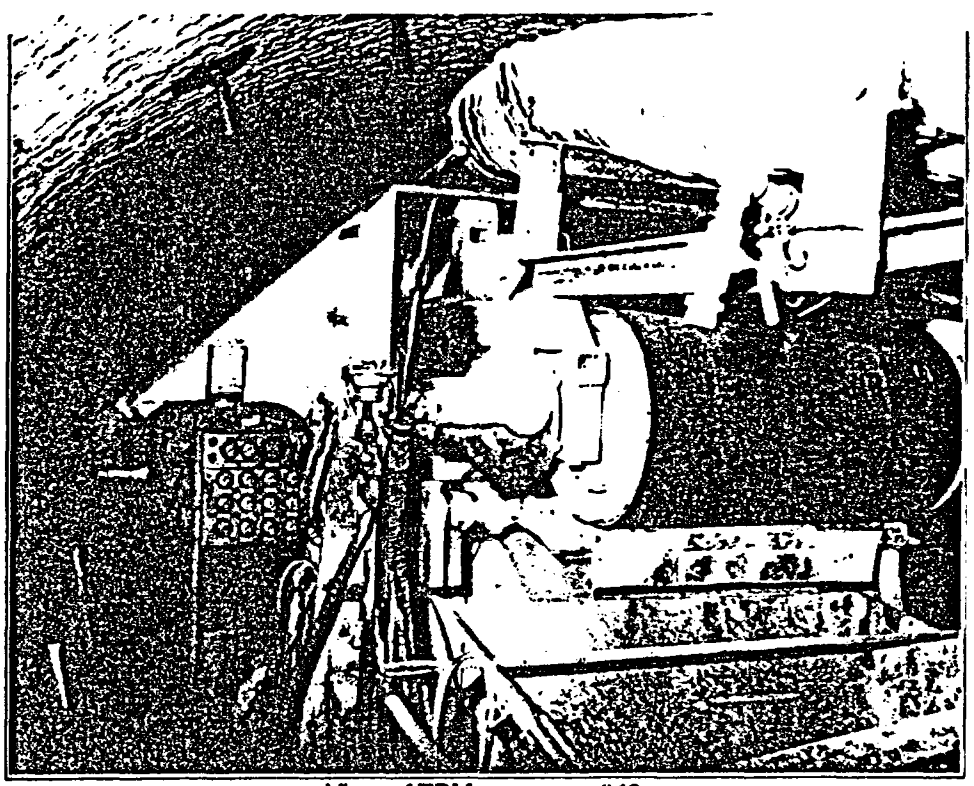


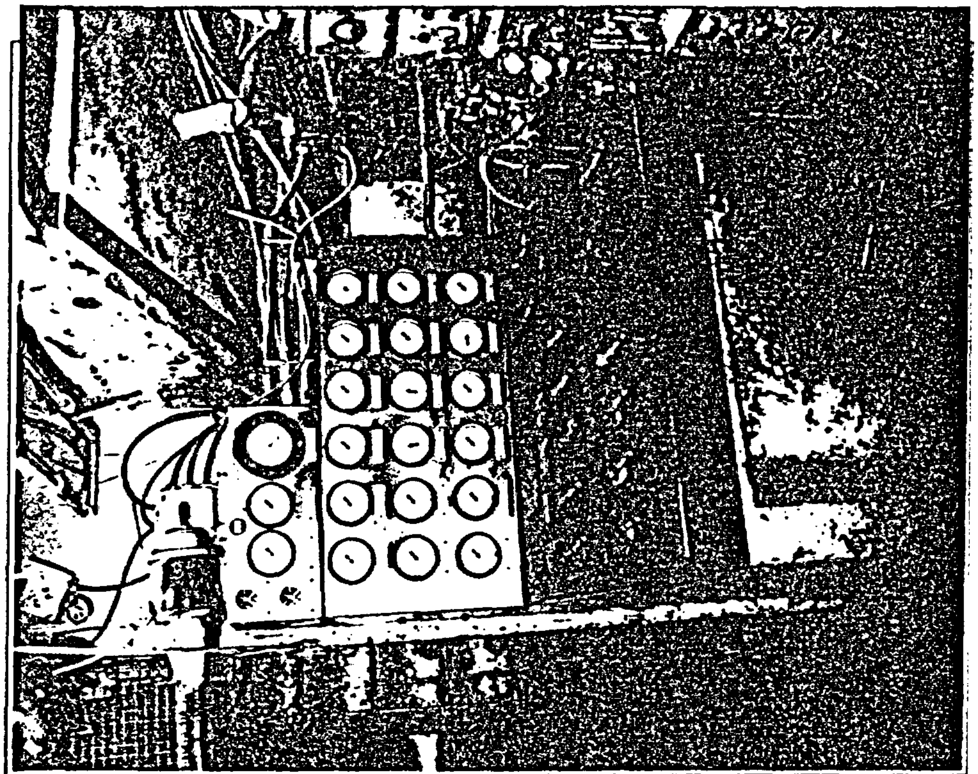
View of Empty Car Puller and Lift Deck



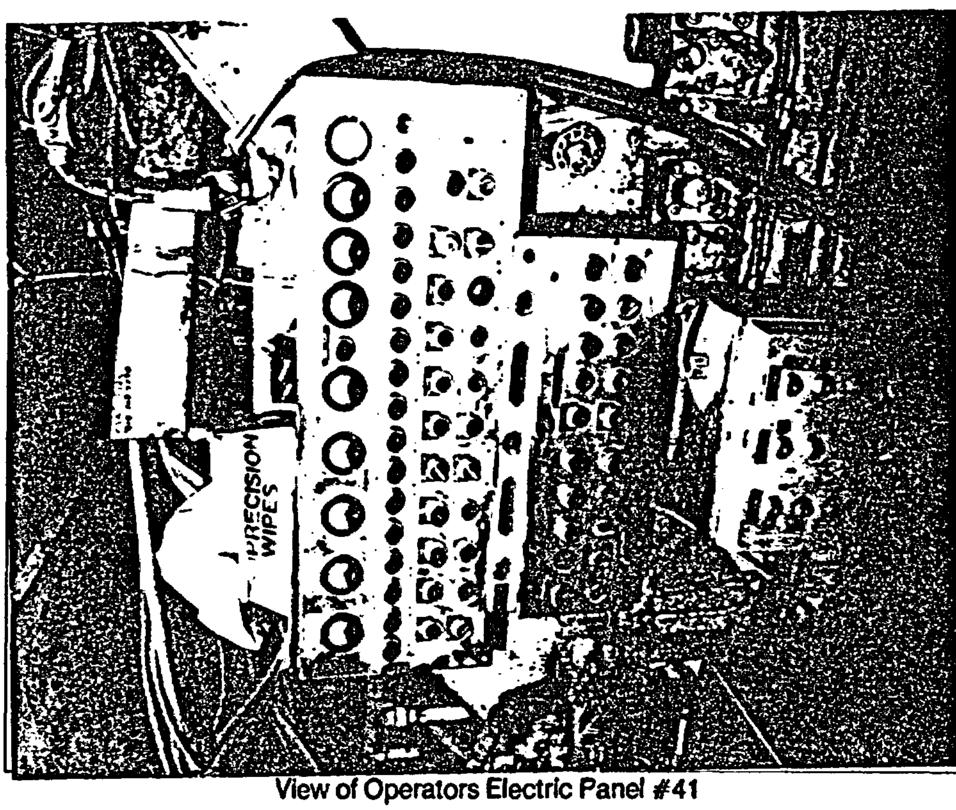
View of Loaded Car Puller and Passing Deck #7


View of underside of Conveyor, note rail #13

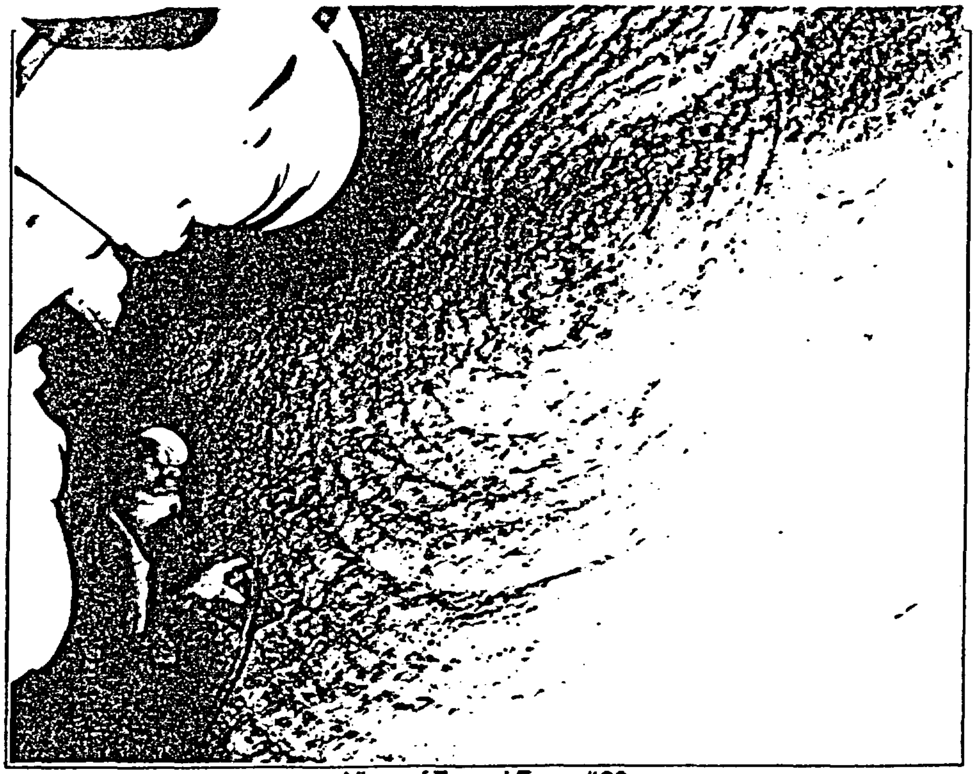

View of TBM conveyor #43



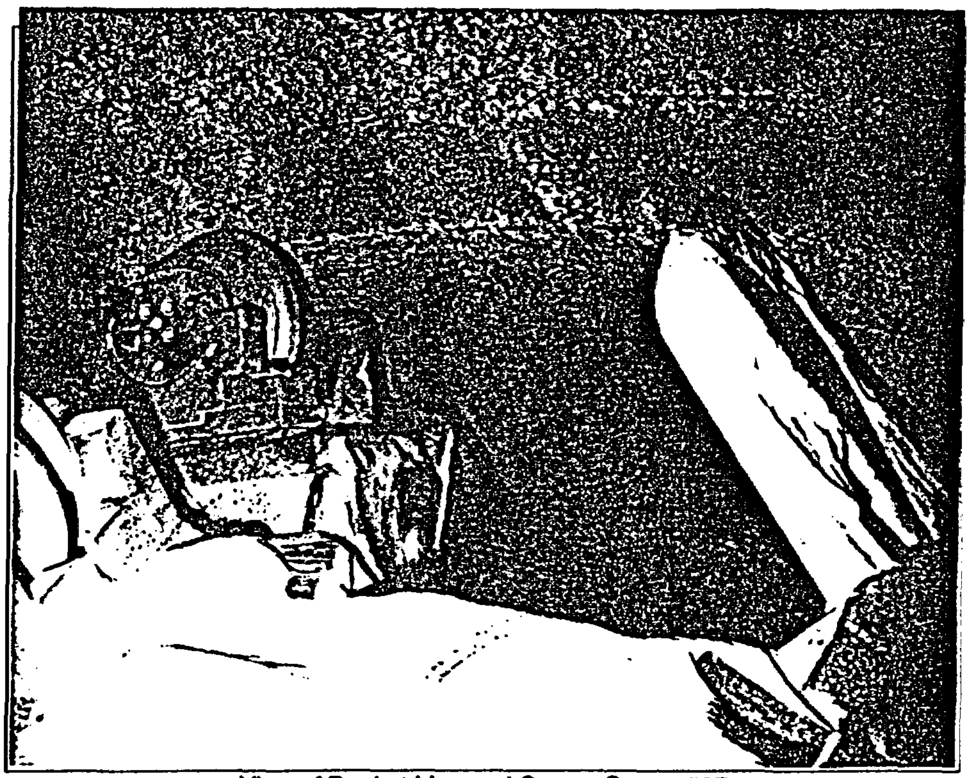
View of Operators Control Console #40



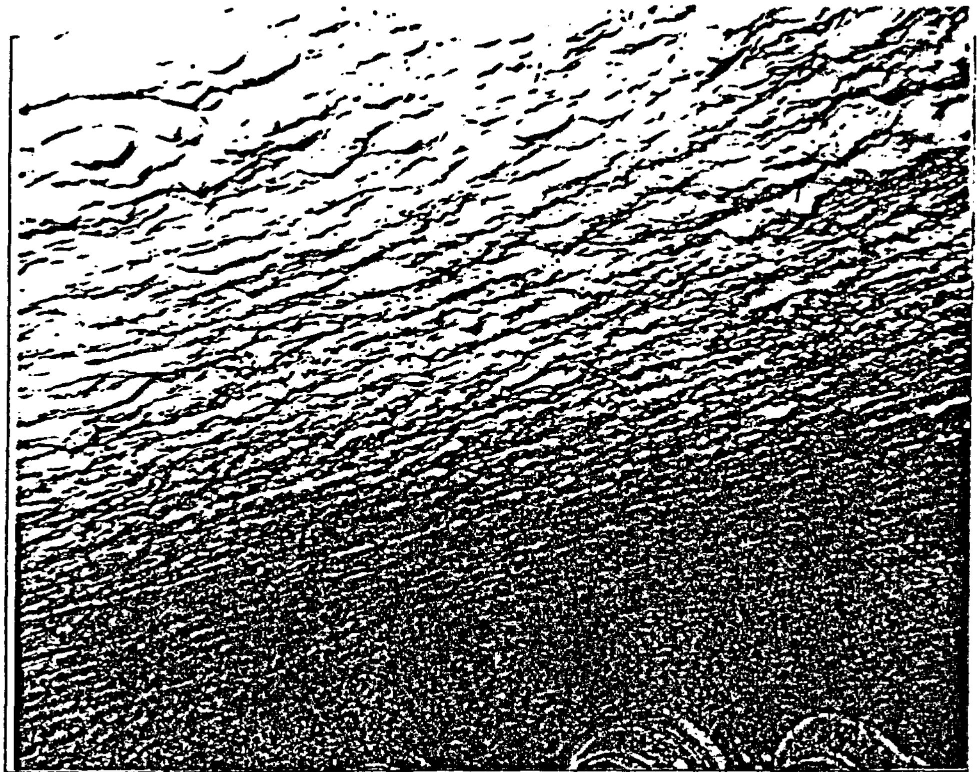
View of Operators Electric Panel #41



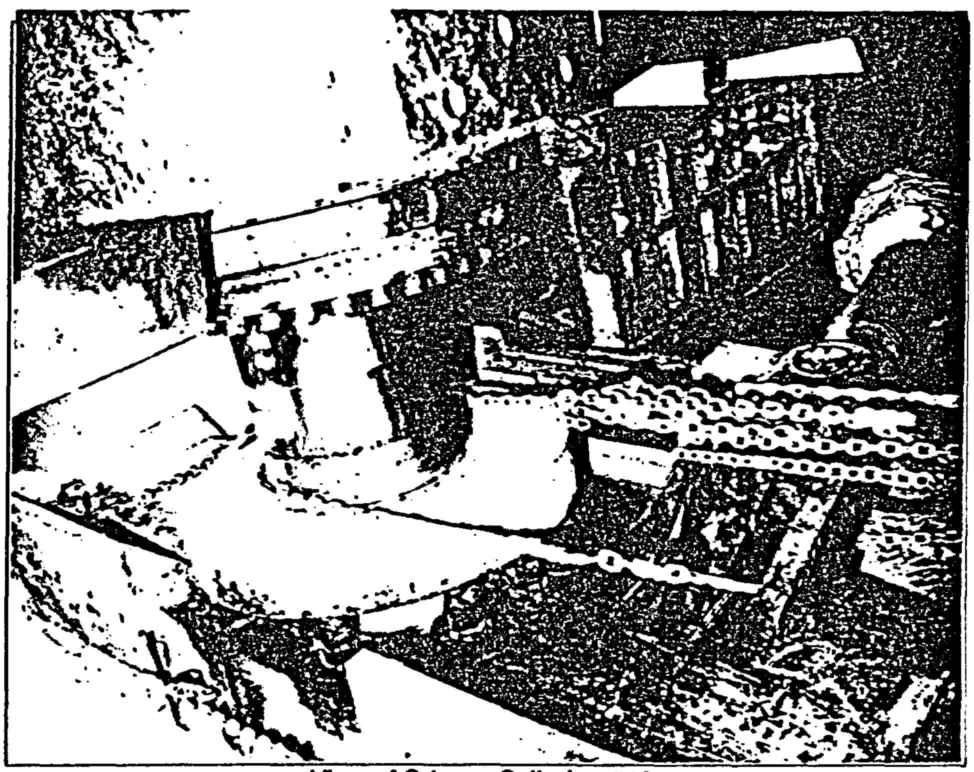
View of Tunnel Face #28



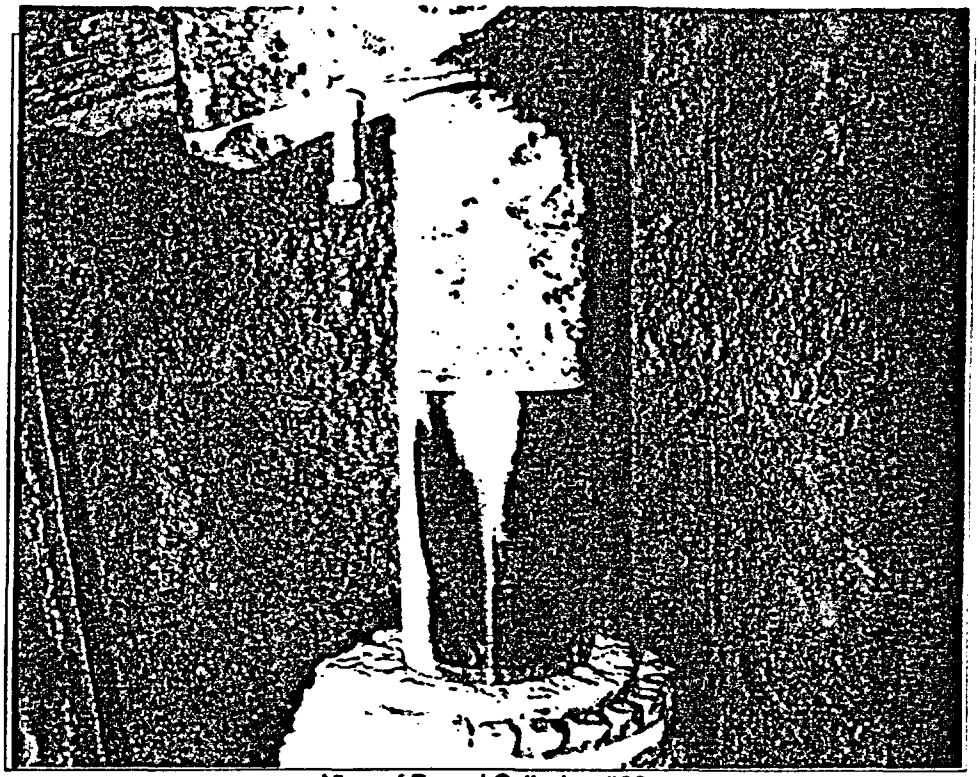
View of Bucket Lips and Guage Cutter #37



View of Tunnel Face #31



View of Gripper Cylinder #16



View of Propel Cylinder #20

View of Roll Over Dump at Portal #54

Appendix

Equipment List.

Quantity	Description
1 ea.	18'7" TBM
10	Backup Decks
10	20 yd Muck Cars
2	Flat Cars
3000 ft.	Rail 90 lb.
15000 ft.	Cable
	Oil Switches
	Fans
	Transformers
	Vent Ducting
	Fish Plates
	Air Line
	Water Line
	Ties
1	Roll Over Dump
1	Batch Plant
2	Agitator Cars
6	Switches
200	Tunnel Lights
2	20 Ton Locomotives

(Note: A precise inventory was not made.)

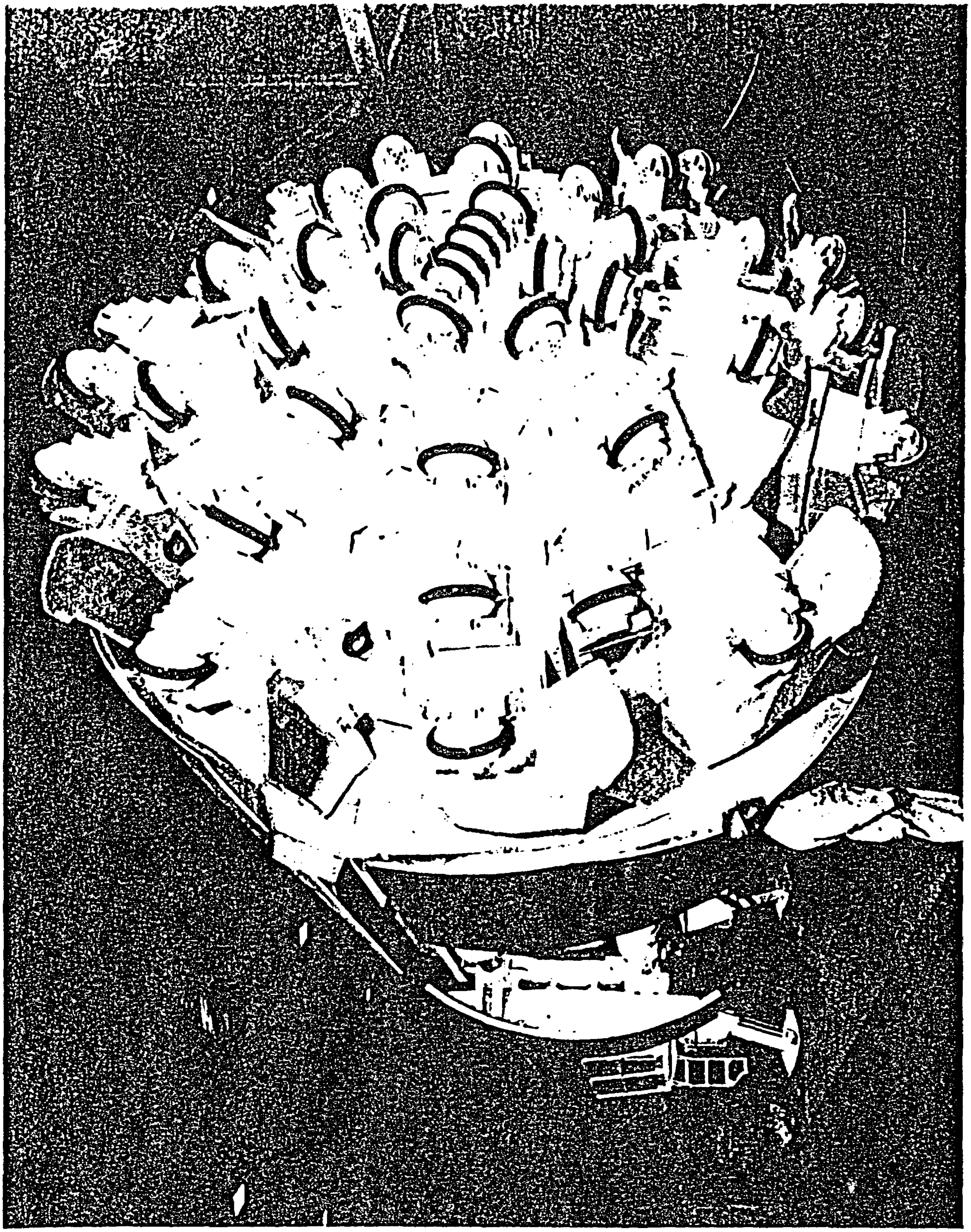
Pictures

Serial No	Description
C-J-704- 1-OUO 22 JUN 93	Backup Decks Rear deck LHS
C-J-704- 2-OUO 22 JUN 93	Backup Decks Rear Deck RHS
C-J-704- 3-OUO 22 JUN 93	Backup Decks Loaded Car Puller RHS
C-J-704- 4-OUO 22 JUN 93	Backup Decks Muck Chute and Flop Gate
C-J-704- 5-OUO 22 JUN 93	Backup Decks Lift mechanism and de-coupler
C-J-704- 6-OUO 22 JUN 93	Backup Decks Loaded Car Puller
C-J-704- 7-OUO 22 JUN 93	Backup Decks Empty Car Puller
C-J-704- 8-OUO 22 JUN 93	Backup Decks Car Transfer mechanism
C-J-704- 9-OUO 22 JUN 93	Electrical Panels Main Breaker
C-J-704-10-OUO 22 JUN 93	Control Cabinet Breakers and relays
C-J-704-11-OUO 22 JUN 93	Control Cabinet Contactors
C-J-704-12-OUO 22 JUN 93	Backup Decks Transfer conveyor facing portal
C-J-704-13-OUO 22 JUN 93	Backup Decks Transfer conveyor facing heading
C-J-704-14-OUO 22 JUN 93	TBM Rear Support
C-J-704-15-OUO 22 JUN 93	TBM Rear Support RHS
C-J-704-16-OUO 22 JUN 93	TBM Gripper Assembly LHS facing heading
C-J-704-17-OUO 22 JUN 93	TBM Gripper Assembly RHS gripper slides
C-J-704-18-OUO 22 JUN 93	TBM Gripper Assembly LHS gripper slides
C-J-704-19-OUO 22 JUN 93	TBM Gripper Assembly RHS facing heading
C-J-704-20-OUO 22 JUN 93	TBM Gripper Assembly RHS propel cylinder
C-J-704-21-OUO 22 JUN 93	TBM Cutterhead Support LHS facing heading
C-J-704-22-OUO 22 JUN 93	TBM Cutterhead Support RHS facing heading
C-J-704-23-OUO 22 JUN 93	Lube Oil Tank RHS view
C-J-704-24-OUO 22 JUN 93	Lube Oil Tank LHS view

C-J-704-25-OUO 22 JUN 93 Side Supports LHS view
C-J-704-26-OUO 22 JUN 93 Cutterhead Support Facing heading
C-J-704-27-OUO 22 JUN 93 Conveyor belt View inside TBM
C-J-704-28-OUO 22 JUN 93 TBM Cutterhead View of Face
C-J-704-29-OUO 22 JUN 93 TBM Cutterhead View of worn 15.5" cutter
C-J-704-30-OUO 22 JUN 93 TBM Cutterhead View of 15.5" cutter
C-J-704-31-OUO 22 JUN 93 TBM Cutterhead Face and center cutter
C-J-704-32-OUO 22 JUN 93 TBM Cutterhead View of 15.5" cutter
C-J-704-33-OUO 22 JUN 93 TBM Cutterhead View of gauge cutter and bucket
C-J-704-34-OUO 22 JUN 93 TBM Cutterhead View of face cutters
C-J-704-35-OUO 22 JUN 93 TBM Cutterhead View of face cutters
C-J-704-36-OUO 22 JUN 93 TBM Cutterhead View of face cutters
C-J-704-37-OUO 22 JUN 93 TBM Cutterhead Bucket lip and gauge cutter
C-J-704-38-OUO 22 JUN 93 TBM Rear Section LHS view facing portal
C-J-704-39-OUO 22 JUN 93 TBM Rear Section RHS view facing portal
C-J-704-40-OUO 22 JUN 93 TBM Rear Section Operators Console
C-J-704-41-OUO 22 JUN 93 TBM Rear Section Operators Panel
C-J-704-42-OUO 22 JUN 93 TBM Rear Section LHS Gripper Assembly
C-J-704-43-OUO 22 JUN 93 TBM Rear Section Discharge Conveyor
C-J-704-44-OUO 22 JUN 93 TBM Rear Section RHS Hydraulic Pack
C-J-704-45-OUO 22 JUN 93 TBM Rear Section RHS Gripper Assembly
C-J-704-46-OUO 22 JUN 93 TBM Rear Section Transfer Conveyor facing portal
C-J-704-47-OUO 22 JUN 93 TBM Conveyor Section Transfer Conveyor facing portal
C-J-704-48-OUO 22 JUN 93 Backup Decks Control Panel
C-J-704-49-OUO 22 JUN 93 Backup Decks Hydraulic Pump
C-J-704-50-OUO 22 JUN 93 Backup Decks Scrubber Fan
C-J-704-51-OUO 22 JUN 93 Backup Decks View facing forward
C-J-704-52-OUO 22 JUN 93 Tunnel View facing heading
C-J-704-53-OUO 22 JUN 93 Portal Site Rollover
C-J-704-54-OUO 22 JUN 93 Portal Site Rollover Dump
C-J-704-55-OUO 22 JUN 93 Portal Site Agitator car
C-J-704-56-OUO 22 JUN 93 Portal Site Agitator car
C-J-704-57-OUO 22 JUN 93 Portal Site Batch plant
C-J-704-58-OUO 22 JUN 93 Portal Site Backup car
C-J-704-59-OUO 22 JUN 93 Portal Site Backup car
C-J-704-60-OUO 22 JUN 93 Portal Site 20 yd Muck cars

Picture

On the following page is a picture of Robbins TBM 185-178, taken at the Robbins plant.



Antony Ivan Smith

[redacted]

Consulting Engineer specializing in Tunnel Boring and Raise Boring equipment design; Tunnel support systems and mining related projects; costing and estimating and risk analysis. Twenty five years of hands on field experience, including Project management and supervision. Developed, designed and implemented unique systems for underground excavation. Supervised rebuild of ten Tunnel Boring Machines. Awarded DOD (USAF) and State of Utah SBIP grants for Advanced Disc Cutter development. Intensly involved with computer applications since 1962 in both system control and applications.

Personal

[redacted]

Education

Victoria College London England. GCE A Level. 1957. McGill University, Montreal, Canada. Chemistry. 1957-59. State University of New York. Geology. 1960. University of Arizona. Postgraduate Geophysics. 1969. University of Utah. Graduate Business School. 1989. Currently proceeding to an advanced degree.

Languages/Security Clearance

Semi-Fluent, Spanish and French.
Top Secret, Department of Defense 1965-1969.

Professional Associations

American Underground Space Association (AUA). Underground Technology Research Council (UTRC). American Society of Civil Engineers. (ASCE). Chairman of the UTRC Committee on Mechanical Excavation. 1990. State of Utah Super Conductor Super Collider Technical Review Committee. 1986. Project Manager Trans Wasatch Super Tunnel Board of Trustees. 1988.

Employment History ....

1993 Consulting Contracts

- **Nuclear Waste Technical Review Board, Washington DC.**

  A report on "An Excavation Strategy for the ESF at Yucca Mountain, Nevada".

1992-1993

- **Perini , ICA, O&G. Morton Grove, Illinois.**

  Senior Tunnel Engineer. Chicago TARP tunnel.

1981-1993 Consulting Contracts

- **Teca, Inc. Park City, Utah. Founder, President and CEO. Consultant.**

Consorcio Rio Blanco, (Ghella SA, Caracas, Venezuala) Santo Domingo, Republica Dominicana. (1991-1992). Rio Blanco Tunnel, Bonoa, RD

Terratec. Hobart, Tasmania, Australia. [1991] Hazelbrook Interceptor, Faulconbridge, New South Wales, Australia.

Sandia National Laboratories, Albuquerque, New Mexico. (1990-1991) Member of The Expert Panel Cost and Scheduling, ESF, Yucca Mountain, Nevada.

Dillingham Construction, Pleasanton, California. (1990) Milwaukee Tunnel. Baltimore Rapid Transit Tunnel.

Tutor Saliba, Los Angeles, California. (1990) Los Angeles Metro Tunnel.

California Union Insurance Company, San Francisco, California. (1990-1991) Milwaukee Tunnel Accident.

Harrison Western Corporation. Denver, Colorado. (1984-1991) LaSalle Station, Buffalo, NY. Jones Island Interceptor, Milwaukee, WI. Milwaukee Deep Tunnel, Milwaukee, WI. Dorval Interceptor, Montreal, PQ, Canada. Sandbar Tunnel, Pinecrest, CA. Calaveras Tunnel, Murphy's CA. Syar Tunnel, Spanish Fork, UT. Goodwin Tunnel, Knights Ferry, CA.

City of Provo, Provo, Utah. (1990) Olmstead Tunnel. Provo, Utah.

Dynatec International, Toronto, Canada. (1988) Falconbridge Tunnel. Sudbury, Ontario, Canada.

American Augers, Wooster, OH. (1988-1900) Halifax Tunnel. Halifax, United Kingdome. St. Louis Interceptor Tunnel. St Louis, MO.

Atlas Copco Jarva, Solon, OH. (1981-1984) Designed hydraulic and electrical systems for an automated new Raise Borer. Developed and manufactured advanced back up system for the Caraquero Project in Peru. Supervised manufacture of Atlas Copco Haaglund Cars. Developed first application of high horsepower variable frequency drive and total torque control for Raise and Tunnel Boring Machines.

1981-1984 Other consulting projects:

Manhattan Water Tunnel. The C5A Gemcor Wing Riveter in Nashville, Tennessee. The Mediterranean to Sea of Galilee Tunnel. Pan Continental Oil Company Uranium Project, Australia. Check bids for tunneling projects in Austin, Texas and Cleveland, Ohio.

1961-1981

- **Traylor Brothers. Evansville, IN. 1979-1981**

  Project Superintendent. Scajaquada Tunnel Buffalo, New York.

- **The Robbins Company, 1973-1979 Kent, WA.**

  Field Superintendent. Responsible for over 25 TBM projects worldwide.

- **Granite Construction/ Peter Kiewit, 1971-1973 Austin, Texas.**

  Tunneling/Concreting Superintendent/Foreman. Austin Cross Town Interceptor.

- **Geoscience Incorporated, 1965-1970. Cambridge, Mass. [A division of Ampex]**

  Western Regional Manager. Geophysical Exploration Services. Tucson, Arizona.

- **Union Carbide Nuclear Company, 1961-1965. Tuxedo Park, NY.**

  Research Assistant. Minerals Exploration Group.

Publications

1965 NASA. "Upper atmospheric determinations at White Sands N.M." 1965 South Australian."Geological report for Pernatty Lagoon-Mt. Gudsen Mining District." 1965 Rio Tinto S.A. "A geological report on the Mt. Gudsen Mining District." 1967-8 SEG Annual Meetings. Geophysical Case histories. 1987 Editorial. American Underground Space Association Newsletter. "The Implications of a Planned Future for a Core Segment of the US Underground Industry." 1990 World Tunneling Magazine. "The Syar Tunnel". Feature article: April issue. 1991 High Level Nuclear Waste Conference. June, Las Vegas Nevada. "Technical Challenge of Mechanical Excavation for Nuclear Waste Repositories." 1991 International Symposium on Mine Mechanization and Automation. "An Automated Raise Borer: Prototype for the Future of Underground Excavation.". "Automated Material handling Systems for Hypo-gravity Lunar/Planetary Environments." 1991 World Tunneling. Feature article: October issue. "The Fort Lawton Parallel Tunnel." 1991 Nuclear Waste Technical Review Board. Evaluation of Ranges of Thermal Loading for High-level Waste Disposal in Geologic Repositories: October: Las Vegas, Nevada. "An overview of preclosure ventilation options." An invited presentation to the NWTRB.

Currently two articles are awaiting publication "A Mathematical Solution to Curves in Tunnels" and an article on leasing concepts.

References.

Dennis Poulton, Tutor Saliba, Los Angeles, CA.
Sidney Green President and CEO, Terra Tek, Salt Lake City, UT.
Sverker Hartwig, The Robbins Company, Kent, WA.
Bernard P. Krzys., Wooster, OH.
Dr. Russel Miller. Professor. Colorado School of Mines, Golden, CO.
Sheldon Talbot, Chief Engineer, (CUP) Central Utah Conservancy District, Provo, Utah.

THE SYAR TUNNEL

The Central Utah Project (CUP) can be regarded as one of the most significant proving grounds in the world for the continued development of the tunnel boring machine. Over the past 25 years, in excess of 29 miles of TBM-bored tunnels have been completed. The 32,000 ft Syar Tunnel is the last major tunnel planned for the CUP. The performance levels of TBM excavation that have reached over 400 ft/d amplify the role that the CUP has played in the art of tunnelling.

Utah is a State with so many contrasts: the shimmering sunsets over the Great Salt Lake; the luxuriant blues of Lake Powell stark in its contrast to the reds of the slickrock; nature's exquisite carvings in Zion and Bryce canyons; the towering peaks of the Wasatch mountains and its pristine snows; and the Uinta mountains with the awesome splendour of vertical walled glaciated valleys gouged by an ancient sinuously moving ice sheet.

The Uinta mountains, a place of incredible beauty, challenges any imagination, with 26 peaks reaching above 13,000 ft. It is America's only east-to-west mountain range, nestled between the Colorado Rockies and Wasatch Range. Its southward flanking streams are the source of supply for the CUP, a project that is totally in phase with the nature that so dramatically surrounds it.

EARLIER PROJECTS

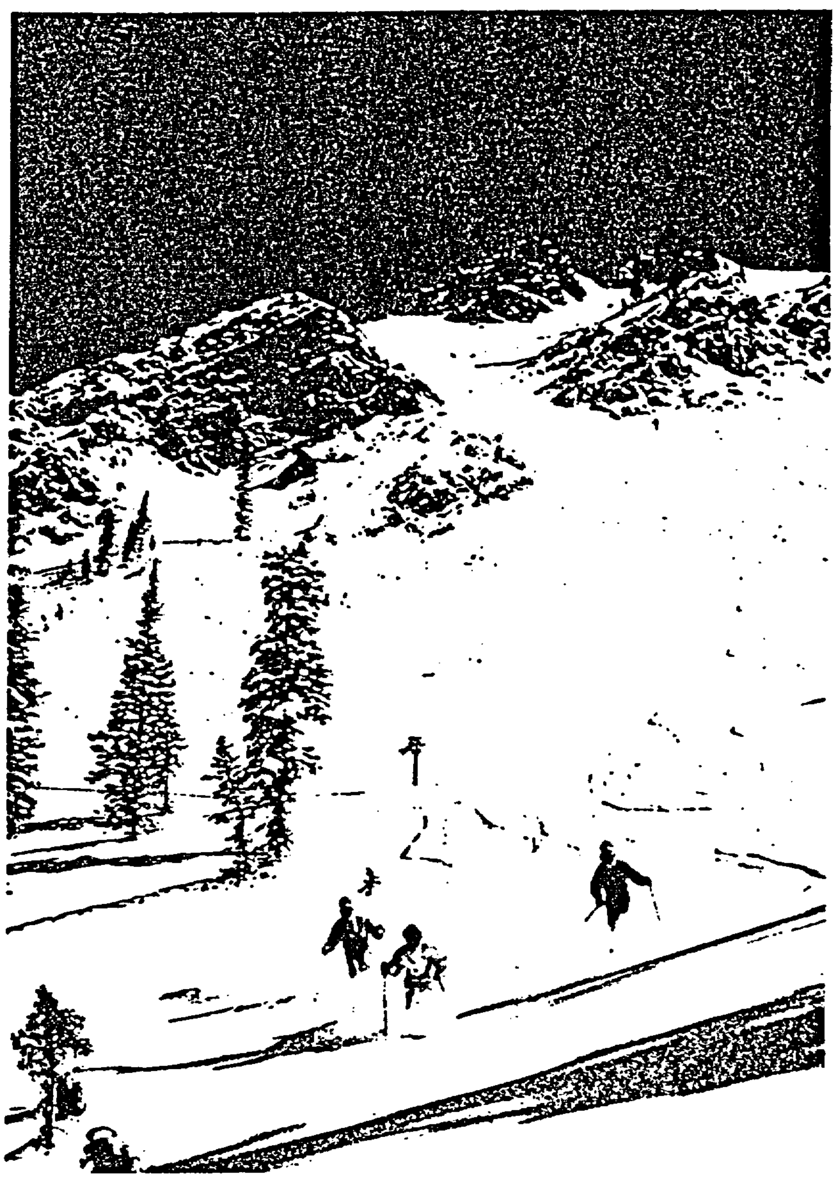
The early Mormon settlers in Utah immediately developed highly refined and organized irrigation systems so as to farm the land in the high mountain desert. It is a land that was totally dependent upon the utilization of the winter snows as a source of water to grow the fruits for their very existence. As the settlements grew to towns and towns to cities the demands for water flowing so effortlessly into the Great Salt Lake Basin exceeded the natural storage in the snow-packed mountains.

At the turn of the century a series of projects to reach out and utilize the water sources available to the east in the Colorado River Basin were completed by the Bureau of Reclamation at Strawberry Reservoir. The first westerly flowing water passed into the Salt Lake Basin through the Strawberry Tunnel in 1902; it was the birth of the Central Utah Project. In the late forties a project was proposed to bring water from the Green River, some 120 miles to the east of Salt Lake, through a series of tunnels, canals and pipelines via the Strawberry Reservoir into the Salt Lake Basin. This was a complex project that was to supply irrigation water not only in the areas of the Salt Lake Basin, but also to the vast expanse of the Ute Indian Reservation to the east of the Strawberry Reservoir. The goal was never reached and the series of tunnels, pipelines and dams stopped one third of the way at The Stillwater Dam on Rock Creek. The Stillwater, Vat, Hades, Rhodes, Current Creek, Layout, Water Hollow and Starvation Tunnels represent the major contribution by the CUP to the TBM method during its infancy.

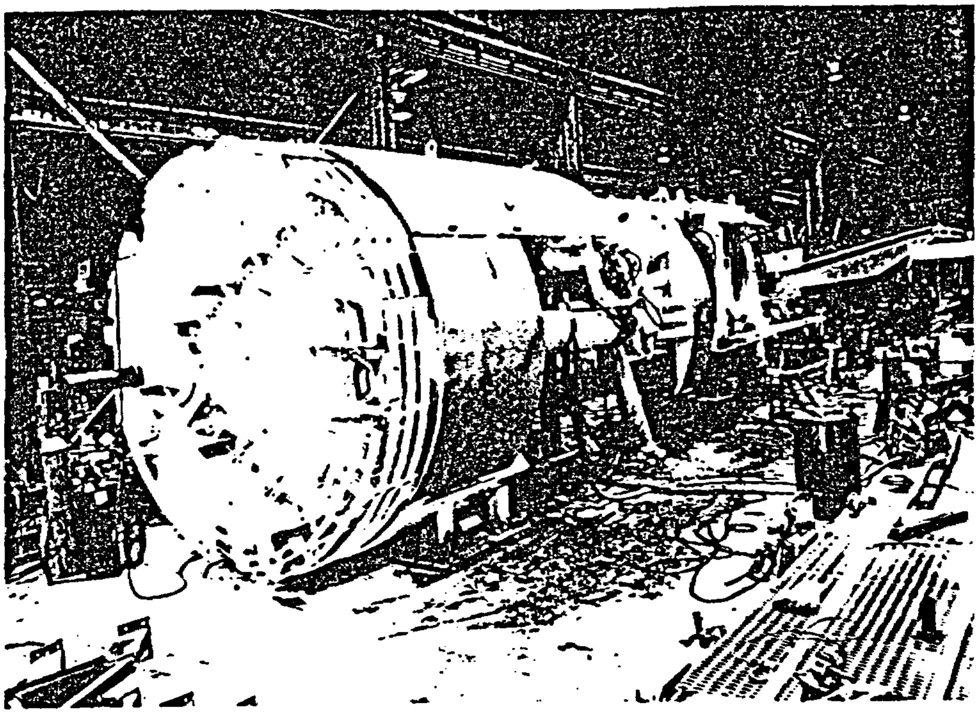
SYAR TUNNEL

The Syar Tunnel reaches from Strawberry Reservoir to Rays Valley to the west to portal at an elevation of 7,375 ft. It is a pressure tunnel with an elevation drop of over 110 ft in its 32,000 ft length. It lies somewhat parallel to the earlier Strawberry

The Wasatch mountains in Utah.



Robbins 129-182 TBM being rebuilt at Boretec.



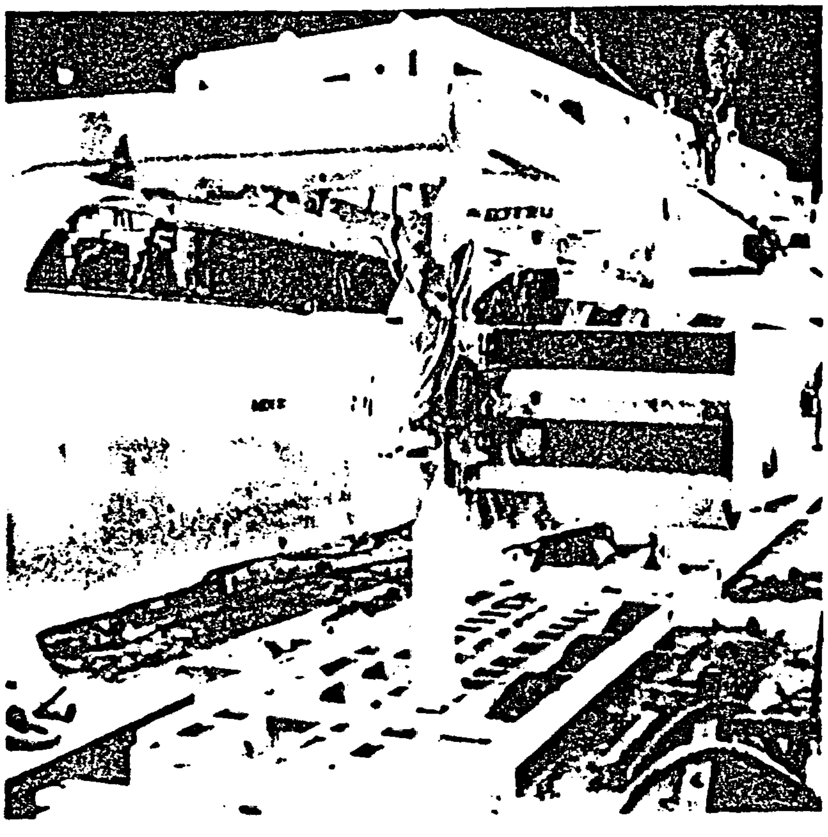
Tunnel and considerable efforts were made by the Bureau of Reclamation to optimize the planning of the new tunnel to avoid the high water flows and adverse geological conditions that were encountered in the original Strawberry Tunnel. The tertiary sedimentary rocks in the alignment consist of shales, limestones, siltstones and claystones.

The Syar project was put up for negotiated bid in 1988 and the project was awarded to Morrison Knudsen Corporation of Boise, Idaho, for $US43·7 million. Morrison Knudsen, whose founders were from Utah, have proven to be one of North America's frontline tunnel contractors.

The company has developed strong internal management teams that bid and manage projects such as the Syar Tunnel.

The utilization of skilled management resources is obviously another reflection on the high performance levels that have been achieved by Morrison Knudsen at Syar.

Interface between TBM System and Continuous Conveyor.

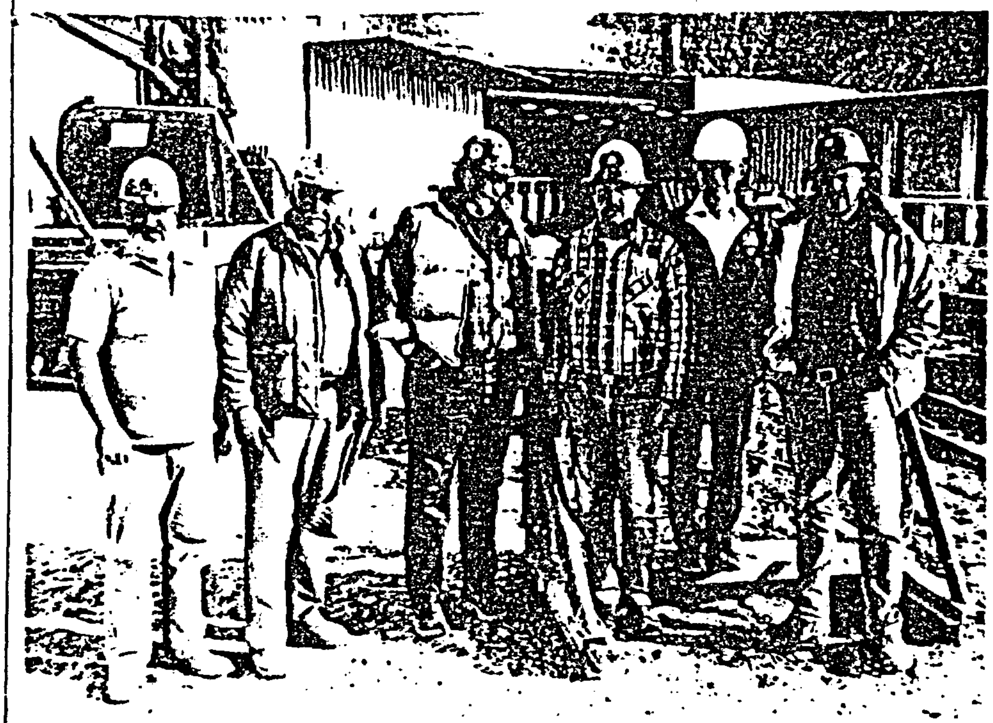


USBR PROJECT MANAGEMENT

The Bureau of Reclamation is a very experienced manager and designer and has, as a result of its work on the CUP, developed a strong and skilled workforce. This experience is well demonstrated in the implementation and acceptance of advanced tunnelling concepts such as those employed at Syar.

Curtiss Pledger is the managing field engineer for the Bureau and he is well supported by a staff of inspectors and engineers both at the site and at the USBR office in Provo, Utah.

Bill Beebe, a long-time Morrison Knudsen employee and a well-respected manager in the mining and construction industry, leads the team as project manager. He is backed up by Phil Busmann as assistant project manager, Dana Rogers as project engineer and other supportive office staff at the field site. Lee Lowry is the general superintendent for the project and the superintendents and crew under his direction represent as skilled a workforce as can be found in North America. Many of these individuals have worked together for the past ten years on numerous tunnelling projects in Utah and California.



Morrison Knudsen field managers Jack Angel, safety supervisor; Lee Lowry, general superintendent; Phil Bussman, assistant project manager; R. Butterfield, business manager; and Dana Rogers, project engineer.

Photo: MK

TUNNEL OPERATIONS

The TBM that was selected by Morrison Knudsen for the project was the Robbins 129-182 that had seen prior service in Austria, Spain and Germany. This TBM was refurbished by Boretec of Solon, Ohio, to accommodate the special tunnelling needs of the project. Cutterhead speed was raised from 5·4 rev/min to 11·54 rev/min. New liquid-cooled motors were installed, raising the horsepower to 746 kW. Torque limiting clutches and soft start contactors were also installed; a complete overhaul and upgrade was performed on other components of the TBM at the Boretec shop.

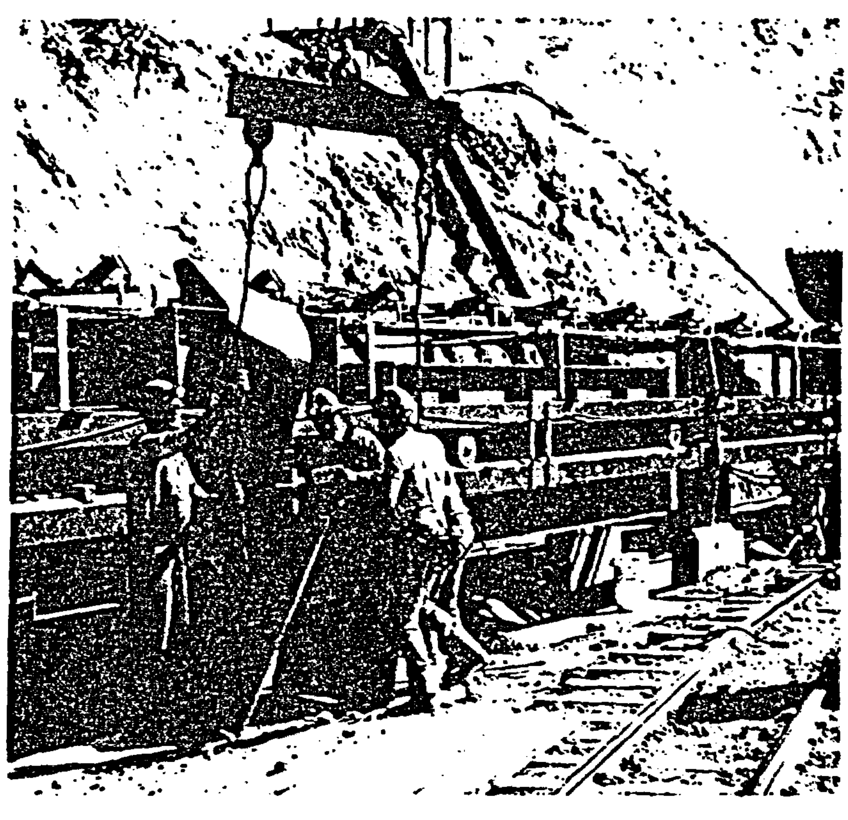
Due to the potential water incursions and problem ground conditions there was a great deal of interaction in the final TBM and system design between Morrison Knudsen, Boretec and the Bureau of Reclamation. There were contingency requirements for ground support, shotcreting, water incursion, as well as those for ventilation, invert segment installation, probe drilling and emergency TBM extraction. The back-up system, including the interface to the continuous conveyor, was designed and manufactured by Boretec. The whole system had to be accommodated in a very diminished and compact working area.

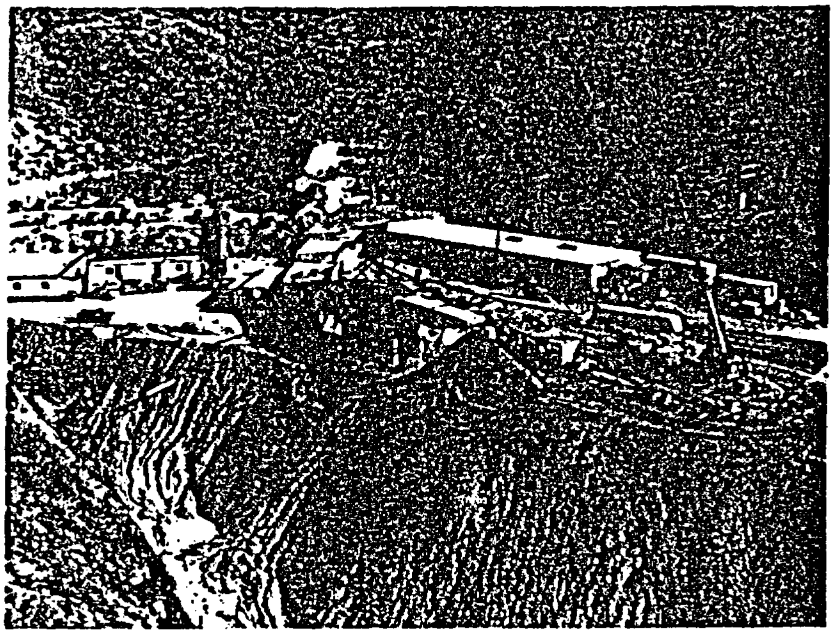
CONTINUOUS CONVEYOR

Morrison Knudsen took a bold step in implementing a Long-Airdox continuous conveyor as the primary means of muck removal for the 11 ft 10 in-dia. bore. The tunnel is designed for the installation of concrete invert segments, for circular steel setts and a 24 in-gauge railroad track. All of this considerably limits the available space for the installation of the conveyor.

The components of the system, 24 in belt frames and rollers, 112 kW main drive, 112 kW booster stations, tensioner/belt magazine and tail-pulley assembly were manufactured by Long-Airdox of West Virginia. Long-Airdox primarily services the coal industry and this application is a perfect example of the utilization of a technology that has been successfully employed within another industry. In the implementation of new technology it takes a considerable effort for all parties involved to achieve a successful utilization of the concept. This is

Loading Long-Airdox belt magazine and tensioner.





Syar Tunnel site.
Photo: USBR

WORLD TUNNELLING
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by Antony Ivan Smith

The author is chairman of Teca, Inc., University Research Park 400 Wakara Way, Salt Lake City, Utah 84108-1211, and specializes in tunnels and equipment.

a small tunnel of considerable length and the conveyor system has performed beyond expectation due to this interaction.

The conveyor system utilizes metal troughing rollers and runs at 600 ft/min. Technically, it required 709 kW of electrical power, but since the system performed so flawlessly one of the booster stations was not installed, lowering the installed power to only 560 kW.

BACK-UP SYSTEMS

As the TBM is advancing the 24 in-wide belt is fed and tensioned from the magazine that has a capacity of 1,000 ft of belting. The Long-Airdox tail-pulley assembly was integrated to the back-up designed by Boretec which had to effectively support and react to the quite high belt tension. This assembly has a window that allows for the installation of the belt frames and roller brackets. These frames are in turn levelled and set on to brackets attached to the steel setts along the tunnel wall. The Long-Airdox conveying system allows for a continuous operation that has proved to be maintenance-free. Safety features such as cable switches and lockouts have been installed for personnel protection.

A Marco stacker is employed at the end of the conveyor assembly to efficiently place, in the limited workplace, the tunnel muck prior to its being transported to a permanent placement area.

The field site is located some 15 m north of US Highway 6, in Spanish Fork Canyon. Due to the elevation of the tunnel of 7,375 ft and the potential for severe winter weather, special protective accommodations have been made. The air returning into the tunnel is heated; the portal switch area, maintenance shops, Marco stacker and belt tensioner are all enclosed and interconnected together to offer an efficient and productive workplace. A marshalling area is located outside where segments, lagging, steel setts and conveyor components are assembled on to the trains. Material is stored offsite in a large inflatable building.

At Syar the 15 t Brookfield locomotives have been relegated to the role of servicing the heading with specially designed cars loaded with segments, steel supports and supplies. This auxiliary role has allowed for distinctly improved ventilation and added a higher level of safety within the tunnel.

The project started boring on July 8, 1989, and now at the end of February 1990 is nearly completed. The tunnel operations are primarily 24 h/d, 5 days/week, with service and maintenance as needed. The overall performance has been phenomenal to say the least; best day 417 ft, best week 1,717 ft, best month 5,866 ft and best 5 days at 344 ft/d. What is more impressive is the consistency of the performance since the tunnel has had to pass through fault zones and areas of water infiltration that have slowed the production.

Currently the project is almost two years ahead of the contractual completion date of April 1993.

FUTURE OPERATIONS

After the completion of the boring phase, the tunnel will be prepared for the installation of the 20 in reinforced concrete lining. A continuous pour operation will be implemented utilizing 450 ft of monolithic forms. Concrete will be transported by agitator cars from a batch plant located at the portal area and pumped into the forms.

The portal area of the tunnel will require the installation of over 400 ft of specially-designed reinforced steel pipe. This pipe will be back-filled with concrete to the portal; a further 150 ft section of pipe outside the tunnel will be the connection for future work.

The Syar Tunnel will bring CUP irrigation water through Spanish Fork Canyon when the 6th Tunnel and Monks Hollow Dam are completed. The ever-increasing demands for culinary water in the Salt Lake Basin might force changes in the ultimate design implementation of the Syar Tunnel. These matters are being discussed in Congress today.

The introduction of what might be called a passive mucking system into the smaller diameter tunnels offers some very distinct advantages, in cost, performance and safety. All of these aspects have been so aptly demonstrated at Syar. The traditional muck train, with its cyclical demands for increasing performance over an ever-decreasing efficiency with tunnel length, has injured and killed too many people. Placing the train into an auxiliary role removes a distinct danger and improves a critical aspect of performance in our industry, namely safety.

In summation it would only be fair to close with a statement made by the field engineer USBR, Curtiss Pledger, "It is a jewel of a contract". Congratulations to everyone involved.

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Addendum 1.

Introduction.

This addendum is the response to a verbal request on August 4, 1993 by the NWTRB to further qualify certain cost scenarios relative to the utilization of the Robbins 185-178 as a part of the ESF program.

The focus of that request was to outline more specifically the cost of purchasing used Tunnel Boring Machines. A letter report submitted by Morrison Knudson[1] noted the availability of three similar eighteen-foot Tunnel Boring Machines for approximately $.35-.45M.

Acquisition Cost Determination

The size variations of Tunnel Boring Machines from six to thirty-five-foot in diameter and the differing performance capabilities of each, creates practically an interminable number of options. An arbitrary grouping or class type can be set but typically actual purchase prices seem most dependent upon condition and suitability.

The present value of used Tunnel Boring Machines is quite difficult to specify. If a particular TBM meets the basic performance requirement of a project a fair market value can be established. Typically a comparison would be made to the cost of a new TBM and then in turn the present value of selected used Tunnel Boring Machines.

The present value of a TBM is driven and established by numerous variables. These variables can be defined in order of suitability as a selection criterion. In this respect they might be defined as in the following order.

Current condition. *General rebuild requirements.*
Drive System. *Cutterhead speed and torque.*
Thrust Capacity. *Penetration rate.*
Diameter. *Engineering and manufacturing cost for required modifications.*
Cutter type. *Suitability of cutters for rock type.*
Backup. *Availability of suitable Backup.*
Roof Support. *Shielding and protection.*
Ground support. *Availability of mounted drills or ring beam erector.*
Manufacturer. *A particular type of TBM or manufacturer.*
Location. *Shipping and transportation.*
Mucking system. *Integration to a muck haulage system.*
Other available equipment. *Major spares, main bearing etc., represent a significant cost.*

The added comments in italics, are informational as they further amplify the particular concern or area.

Once the suitability has been established an initial cost comparison would be developed based upon the relative condition of the Tunnel Boring Machine. The cost of engineering and manufacturing of a modification now becomes a major driver in this process. The suitability can be adjudged by this critical comparison. The selection of a new or used TBM is a complex process.

Evaluation

The following table is a demonstration of a suggested cost and a percentage figure is noted for each option of the proposed projects for this TBM. Normally a similar but more detailed estimate would be developed and employed. The table clearly though, demonstrates this selection phase.

1 Letter Report October 15, 1992. Morrison Knudson Corporation.

Item	Cost $M	Busted Butte	Calico Hills & Repository Levels
Cutters 17"	.20	0	100
Drills	.11	0	100
Ring Erector	.10	0	100
Hydraulics	.30	20	100
Fluid Control	.65	0	100
Gear Drives.	.21	20	100
Backup Repair	.10	100	0
Main Bearing	.20	0	100
Bull Gear	.06	0	100
General	.30	100	100
Electric	.20	20	100
Motors	.12	40	100
Mechanical	.18	60	100
Transportation	.08	30	100
Contingency	.25	100	100
TOTALS		$.97M [1]	$2.96M [2]

Transaction Examples

During the past few years there have been numerous transactions where used Tunnel Boring machines have been purchased by contractors. Either these purchases have been from contractor to contractor or through a specialized rebuilder acting as an middleman.

The following examples represent a sample of transactions for used Tunnel Boring Machine.[3] In each instance, the actual performance capability of the TBM has been a critical component. Robbins 129-182 listed below, achieved world class performance levels at the Syar Tunnel Utah in 1990 for the contractor, Morrison Knudson of Boise Idaho. A 32,000-foot tunnel was completed in less than a year.

All of the Tunnel Boring Machines listed were rebuilt before their boring their respective projects. These costs range from $.3 million to over $4.0 million.

Perini Corporation.
Robbins 1011-198/78/92/93. AP $1.3M. Plus backup. Excellent.
Morrison Knudson
Robbins 1210-187/77/97/89 AP $0.76M. No backup. Unknown.
Robbins 129-182/77/65/89 AP $0.53-0.76M. Plus spares, no backup. Good.
Boretec
Robbins 212-174/79/37/93 AP $0.46M. No backup. Poor.
Harrison Western
Robbins 186-206/79/98/93 AP $1.00M. No backup. Good
Robbins 186-207/79/55/89 AP $1.00M. No backup. Good
Robbins 119-222/83/55/92 AP $1.25M. Plus backup, mucking system. Good.
Atlas Copco Mark 12/80/50/90 AP $1.3M. No backup. Good
Note AP is last known asking price. TBM Id. (Feet Inches-Serial #/Mfg yr/footage/Last Tunnel.)

The average asking price of the eight exampled Tunnel Boring Machines is over $900,000 in an as is where is condition. Five of these were shipped from Europe adding a minimum of 20% to their cost. Only two machines Robbins 119-222 and Robbins 1011-198 were supplied with a complete backup system. A single TBM, Robbins 119-222 was supplied with utility cars, muck cars and rollover dump.

1 See report page 3, Executive Summary, paragraph 7.
2 See report page 3, Executive Summary, paragraph 8.
3 Based on personal communications. ais/08.93.

The list of acquisition of Tunnel Boring Machines also shows a common denominator in the transaction price. The Atlas Copco Mark 12, Robbins 1011-198 and 119-222 both were refurbished with minor modification for less than $1.0M. Robbins 186-206/207 required some engineering changes and modification. The Robbins 1210-187 and 129-182 were upgraded with significant modification and change. The twenty-one-foot Tunnel Boring Machine, Robbins purchased from Morrison Knudson, required in excess of $3.0M to refurbish and upgrade due in part to condition. The three most significant factors in determining the present value of a Tunnel Boring Machine are condition, available additional equipment and required modification or changes.

Current asking prices.

The following figures show recent asking prices for the following representative equipment.[1]

Robbins 186-207 $1.3M, Harrison Western Corporation. *No backup*

Robbins 129-182 $1.6M, Morrison Knudson Corporation. *With backup.*

Robbins 213-190 $2.5M, Traylor Brothers. *No Backup.*

Any valuation of the Tunnel Boring Machine, backup and associated equipment has to represent the sum of all available components. The driving factor in any final evaluation now becomes the estimate of rebuild, a direct function of the condition of all the constituents that make up the system.

Conclusion

Robbins 185-178 currently can be classified as an extremely viable TBM based upon condition. It has a present value with backup muck cars, spares, locomotives, rollover dump and associated equipment of about $1.6M. The quoted value of the used equivalent TBM of $.35-.45M would be considered below the value of current market transactions. These rather low figures obviously represent and relate to the condition of the TBM, they would also appear to reflect a minimum quantity of available spares, auxiliary equipment and backup. The market value of an equivalent new 18-foot TBM is at least $5.0M, backup $1.5M, two locomotives $.25M, cars and rollover dump $.5M and miscellaneous items $.25M.[2]

If the price of the recently purchased twenty-five foot diameter Tunnel Boring Machine for the ESF is extrapolated to an eighteen foot diameter TBM, a cost of $9.0M might be reached. This number includes some backup *but not a mucking system.* This higher price reflects the added cost of the rather exclusory specifications outlined for a new TBM.

A significant factor is time and schedule of construction activities for the ESF program. In order for the program managers to purchase a second Tunnel Boring Machine, new or used, certain stipulations and procedures will have to be followed. The development, publication and review of an RFP would have a considerable cost and would occupy a period of some months. The transfer of this TBM can be effected immediately, without the need for specification, qualification or evaluation of any proposals A critical saving in time and procedure that has a definite but unknown value.

This TBM can be still utilized efficiently and effectively in the current ESF program. It is a situation identical to the massive $600 Hydro-electric project in Lesotho, South Africa. There, the experienced consortium of contractors included a used rebuilt TBM to improve schedule and performance. Robbins 186-206, performed a significant role in having now completed over 30,000 feet of tunnel. This 1978 vintage TBM has achieved the highest level of productivity in comparison to the two new modern 1990's high performance Robbins and the Atlas Copco Tunnel Boring Machines.

1 Based on personal communications. ais/08/93.

2 See report page 2, Executive Summary, paragraph 3.

DEFENSE NUCLEAR AGENCY
FIELD COMMAND, NEVADA OPERATIONS OFFICE
PO BOX 98539
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Nevada Operations July 14, 1993

RECEIVED
JUL 22 1993
NUCLEAR WASTE T.R.B.

Mr. Russ McFarland
Nuclear Waste Technical Review Board
1100 Wilson Blvd., Suite 910
Arlington, VA 22209

Dear Russ:

Enclosed is a copy of the background data of the REECo estimate to remove the TBM from N-Tunnel. It was prepared by Mr. Sam Williams, Sr Engineer for REECo. As you can see the two options presented were nearly identical at approximately $1M (see page 2, Administrative Summary).

I have taken the REECo numbers and added additional test site costs to the estimate as follows:

REECo Removal Estimate	$1,000,000
A&E Support Costs @ 10%	100,000
Health Protection Tech. Supt.	50,000
	$1,150,000
Contingency @ 15%	172,500
	$1,322,500

In addition there will be a weapons program tax of approximately 10% added to the total number required by NV to remove the machine for YMP. The total would be in the range of $1.45M. It has been suggested, if this effort should come to be, that Mr. Ivon Smith be on-site for 2 to 3 days at the point in time that the machine is being dismantled.

If you have any questions please call Larry Ashbaugh at (702)295-7067.

Sincerely,

Laurence J Ashbaugh

Joseph W. LaComb, SES-3
Chief, Nevada Operations

Enclosure

Copies Furnished:
W. Tadlock (REECo) w/o encl
S. Williams (REECo) w/o encl
Tony Ivon Smith w/o encl

REECO ESTIMATE TO REMOVE THE N TUNNEL TBM
Prepared 7-6-93 by: S. M. Williams

ASSUMPTIONS

1. Because of constraints on the approval process to retrieval the TBM, it is assumed removal from the tunnel would not begin until after Chemical Kiloton (CKT) recovery efforts.

2. The TBM removal effort would be conducted independent of CKT activities. It is assumed CKT ground shock will not detrimentally affect the north N Extension drift Slow Alcove or the south N Extension drift.

3. The estimate considers two alternatives: (1) The TBM would be removed through the north N Extension drift Slow Alcove and out the Extension drift. (2) The TBM would be removed through the north drift to the N.22 LOS, out the south N Extension drift to the Extension drift.

4. The N Tunnel mothball effort would be delayed as needed to support the TBM removal effort.

5. FOD/DOD personnel, with the necessary support, would remove the TBM to the u12N Tunnel portal.

6. Without having the opportunity to pass a template throughout the affected u12N Tunnel drifts, the estimates assume removal of vent line and cable trays as the only substantial primary utilities.

7. The TBM and all associated trailing equipment will be left on rail trucks on an unused rail spur in the N Tunnel yard. Removal from the rail system, necessitating a surface operator and crane, has not been estimated.

8. This estimate includes only the removal of the TBM from the tunnel to the N Tunnel yard. The refurbishment of the TBM has not been estimated. The removal of the TBM support equipment and the refurbishment of that equipment has not been estimated. Support equipment consists of the rotary dump mechanism, the fleet of ten muck cars, two 20-ton locomotives (slated for excess) and miscellaneous rail supplies.

9. The REECo overhead rates will remain constant, per the schedule below, throughout the completion of the TBM removal effort:

   G/A rate constant at 23-percent.
   Labor Load rate constant at 135-percent.
   Equipment rate constant at 65-percent.

10. The REECo labor cost will remain constant throughout the TBM removal effort at an estimated value of $87.5/manhour which is equivalent to $3,500/manweek.

11. The average craftsmen crew size should not exceed the breakdown below, and the TBM removal activities would be conducted on a single shift per day basis.

Carpenters	0.25
Laborers	2.0
Wiremen	2.5
Linemen	1.0
UG Operator	5.0
Mechanic	4.0
Miner	16.0
Total	30.75

Part A of each of the two alternatives is assumed to be conducted with a manpower level of 14.25 men per shift. Part B of each of the two alternatives is assumed to be conducted with a manpower level of 16.5 men per shift.

12. This estimate is valid this day and quantitatively represents the scope of work as discussed during the general TBM removal meeting held June 22, 1993 at FOD/DOD.

ESTIMATE

Each of the two potential removal routes have been estimated separately as Alternatives 1 and 2. The costs of preparing the TBM for the two routes does not vary, however, the preparation of the route varies considerably. Alternative 1 is removal through the north Extension drift Slow Alcove. Alternative 2 is removal through the south Extension drift.

Each removal method has been partitioned into two main sections to more accurately reflect the division of work necessary to efficiently remove the TBM. The work involved in the two sections consists of TBM preparations and TBM removal, and has been considered to occur concurrently.

ADMINISTRATIVE SUMMARY

The estimated cost to remove the u12N Tunnel TBM per Alternative 1 is approximately $952,000 and would require approximately 47 shifts of effort; equivalent to approximately 9.5 weeks.

The estimated cost to remove the u12N Tunnel TBM per Alternative 2 is approximately $971,000 and would require the same approximate 47 shifts of effort; equivalent to approximately 9.5 weeks.

ALTERNATIVE 1

A] PREPARATION OF THE TUNNEL COMPLEX FOR THE TBM REMOVAL

1. Upgrade the rail system from the vent raise No. 2 crosscut to the N.22 LOS drift: The rail is currently supported only by steel ties. Lay wood ties the entire length of rail.

   1,400' of re-rail ÷ 150 ft/sh = 9.3 shifts

   Total Labor = 133 manshifts.

2. Remove the 48-inch vent line, north Extension drift, from CS 75+55 to the N.22 LOS intersection, 1,310 feet: This includes one fan. The height of the vent line is approximately 11' 6" top of rail to bottom of line.

   1,310' of vent to remove ÷ 200 ft/sh = 6.6 shifts

   Total Labor = 93 manshifts.

3. Remove the north N Extension drift convection wall: Connect to the convection wall with a locomotive and pull the wall down. Utilize cutting torches and spading hammers and manually remove the necessary remanent wall components.

   Rough removal of wall = 1 shift
   Final clean up of area = 0.5 shift

   Total Labor = 21 manshifts.

4. Remove alcove walls and supplies from Radsafe Alcove, north N Extension drift:

   Remove walls = 1 shift, concurrent with other activities.
   Remove supplies = 1 shift, concurrent with other activities.

   Total Labor = 29 manshifts.

5. Excavate an opening through the north N Extension drift Alcove Protection Plug No. 2: Drill/blast a 14' wide by 16' high opening through the plug. Split and remove penetrations as needed.

   Drill/blast opening = 2 shifts
   Muck and clean up area = 1 shift

   Total labor = 43 manshifts.

6. Prepare the north N Extension drift Slow Alcove for passage of the trailing equipment and the TBM: This includes removal of all cable trays, the Redshack walls and equipment, and the experimenter rack scissor lift. The height from top of concrete to bottom of cable tray support bracket is approximately 10' 8".

   Remove redshack walls/equip = 1 shift, concurrent with other activities.
   Scrap cable trays = 3 shifts, concurrent with other activities.
   Remove scissor lift (salvage) = 1 shift, concurrent with other activities.

   Total Labor = 71 manshifts.

7. Enlarge the opening through the north N Extension drift Alcove Protection Plug No. 1: Enlarge the opening to 14' wide by 16' high by drill/blast techniques.

   Drill/blast opening = 2 shifts
   Muck and clean up area = 1 shift

   Total labor = 43 manshifts.

8. Establish rail from the N.22 LOS drift to outside Alcove Protection Plug No. 1 and tie into the existing 90-pound rail: Lay new rail over existing rail spurs and on top of alcove slab.

Lay new 90 lb rail, 1,000' ÷ 200 ft/sh = 5 shifts

Total Labor = 71 manshifts.

9. Remove the vent line and fan in the north N Extension drift from the slow alcove intersection to the N.05 Utilities drift:

Remove 150' of 36" vent line with fan = 2 shifts.

Total Labor = 29 manshifts.

10. Enlarge the opening through the N Extension Drift Protection Plug: Enlarge the opening to 14' wide by 16' high by drill/blast techniques.

Drill/blast opening = 2 shifts
Muck and clean up area = 1 shift

Total Labor = 43 manshifts.

11. Enlarge the opening through the N Extension drift Gas Seal Plug: Enlarge the opening to 14' wide by 16' high by drill/blast techniques.

Drill/blast opening = 2 shifts
Muck and clean up area = 1 shift

Total labor = 43 manshifts.

12. Enlarge the opening through the N Extension drift Friction Plug: Enlarge the opening to 14' wide by 16' high by drill/blast techniques.

Drill/blast opening = 2 shifts
Muck and clean up area = 1 shift

Total Labor = 43 manshifts.

13. Prepare all switches/crossovers in the path of the TBM and configure that rail as "main line" rail to the portal storage area. Rehabilitate the rail system throughout:

Complete rail check and rehab = 4 shifts, concurrent with other activities.

Total Labor = 57 manshifts.

14. Conduct thorough walk-out and inspection of the TBM path to include cleanup as required: Items known to require removal are 26" fiberglass vent line from the Extension DPP to the N.06 drift.

Make TBM path ready for transport = 2 shifts

Total Labor = 29 manshifts.

SUBTOTAL TIMEFRAME, ALTERNATIVE 1, ITEM A = 41 SHIFTS

SUBTOTAL LABOR, ALTERNATIVE 1, ITEM A = 584 MANSHIFTS.

B] PREPARATION AND REMOVAL OF THE TBM

1. Prepare the immediate area around the TBM for removal: General clean up of the area removing all non-essential equipment, trash, etc.

   Area prep, clean up = 3 shifts, concurrent with other activities.

   Total Labor = 50 manshifts.

2. Remove five trailing decks from the tunnel complex: Removal of those decks requires removal of some equipment and potential modification of the cross-sectional area of some of the decks. Items to be removed are; sections of fiberglass vent line, steel vent line, vent fan, vent fan mufflers, hydraulic fluid tank and pumps, hydraulic valve control station, some electrical componentry, and the tail conveyor pulley and motor. Height of the highest item on trailing deck No. 3 is 17'. The trailing decks are approximately 16' wide and 11' 6" high without equipment mounted on top of the decks.

   Remove five decks = 10 shifts

   Total Labor = 165 manshifts.

3. Remove the muck conveyance system: This consists of the main belt conveyor and the secondary conveyor plus muck chutes and bins.

   Conveyor removal = 3 shifts

   Total Labor = 50 manshifts.

4. Walk the TBM to the widened area at the intersection of the north N Extension drift and the crosscut to vent raise No. 2: Self-propelled walk of approximately 600 feet. Drop off muck buckets, the three main shield sections, the two front gripper pads and the front support pedestal.

   Prep TBM and walk 600' = 12 shifts

   Total Labor = 198 manshifts.

5. Remove the sixth trailing deck and disconnect electrical power: Remove all unnecessary equipment from the TBM to minimize cross-sectional profile.

   Remove unnecessary equipment = 5 shifts, concurrent with other activities.

   Total Labor = 83 manshifts.

6. Place the TBM onto rail dollies for transport to the portal: Fabricate and install necessary support structures to dollies and install necessary stabilizer members.

Prep TBM for transport to portal = 15 shifts

Total Labor = 248 manshifts.

7. Transport the TBM to the portal: This includes returning underground and salvaging the muck buckets, grippers, shields and pedestal.

Transport to portal = 2 shifts
Remove misc. equipment = 5 shifts

Total Labor = 116 manshifts.

SUBTOTAL TIMEFRAME, ALTERNATIVE 1, ITEM B = 47 SHIFTS

SUBTOTAL LABOR, ALTERNATIVE 1, ITEM B = 776 MANSHIFTS.

TOTAL LABOR, ALTERNATIVE 1 = 1,360 MANSHIFTS.

TOTAL COST ESTIMATE, ALTERNATIVE 1 = $952,000.

ALTERNATIVE 2

A] PREPARATION OF THE TUNNEL COMPLEX FOR THE TBM REMOVAL

1. Upgrade the rail system from the vent raise No. 2 crosscut to the N.22 LOS drift: The rail is currently supported only by steel ties. Lay wood ties the entire length of rail.

1,400' of re-rail ÷ 150 ft/sh = 9.3 shifts

Total Labor = 133 manshifts.

2. Remove the 48-inch vent line, north Extension drift, from CS 75+55 to the N.22 LOS intersection, 1,490 feet: This includes one fan. The height of the vent line is approximately 11' 6" top of rail to bottom of line.

1,310' of vent line to remove ÷ 200 ft/sh = 6.6 shifts

Total Labor = 94 manshifts.

3. Remove the north N Extension drift convection wall: Connect to the convection wall with a locomotive and pull the wall down. Utilize cutting torches and spading hammers and manually remove any remanent wall components.

Rough removal of the wall = 1 shift
Final clean up of area = 0.5 shift

Total Labor = 21 manshifts.