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EVALUATION, MODIFICATION & APPLICATION OF ROADHEADERS IN UNDERGROUND URANIUM MINES

PREPARED FOR

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

MORRISON-KNUDSEN COMPANY, INC.
BOISE, IDAHO

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This study evaluates the use of roadheaders in underground mining operations. Roadheaders were found to be widely used in mines as construction support units, as development miners, and as stoping machines. Roadheaders were found to have mechanical and electrical problems, to suffer reduced productivity when integrated into the mining cycle, and to create dust problems. High capital costs and low utilization and availability cause high amortization costs per ton.

This report identifies the roadheader operating problems and offers suggestions for improved mechanical and electrical design as well as manufacturer and owner responsibilities for improved availability. The development of a complex integrated excavation and ground support system is not warranted until the roadheader itself is made much more reliable.

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FOREWORD

This report was prepared by Morrison- Knudsen Company, Inc., Boise, Idaho under USBM Contract H0282024. The contract was initiated under the Mineral Resources Technology Program. It was administered under the technical direction of the Twin Cities Research Center with Mr. David Veith acting as Technical Project Officer. Mr. David Askin was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period September, 1978 to September, 1980. This report was submitted by the authors on September 26, 1980.

Reference to specific brands, equipment, or trade names in this report is made to facilitate understanding and does not imply endorsement by the Bureau of Mines.

There were no patents issued or potentially patentable work completed as part of this contract.

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EVALUATION, MODIFICATION, AND APPLICATION OF ROADHEADERS IN UNDERGROUND URANIUM MINES

BY

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ABSTRACT

The U.S. Bureau of Mines awarded a contract to Morrison-Knudsen, Inc., to evaluate the use of roadheaders in underground mining operations. Roadheaders were found to be widely used in mines as construction support units, as development miners, and as stoping machines. However, roadheaders were found to have mechanical and electrical problems, to suffer reduced productivity when integrated into the mining cycle, and to create dust problems. Also high capital costs and low utilization and availability cause high amortization costs per ton.

This report identifies the roadheader operating problems and offers suggestions for improved mechanical and electrical design as well as manufacturer and owner responsibilities for improved availability. The development of a complex integrated excavation and ground support system is not warranted until the roadheader itself is made much more reliable.

I. INTRODUCTION

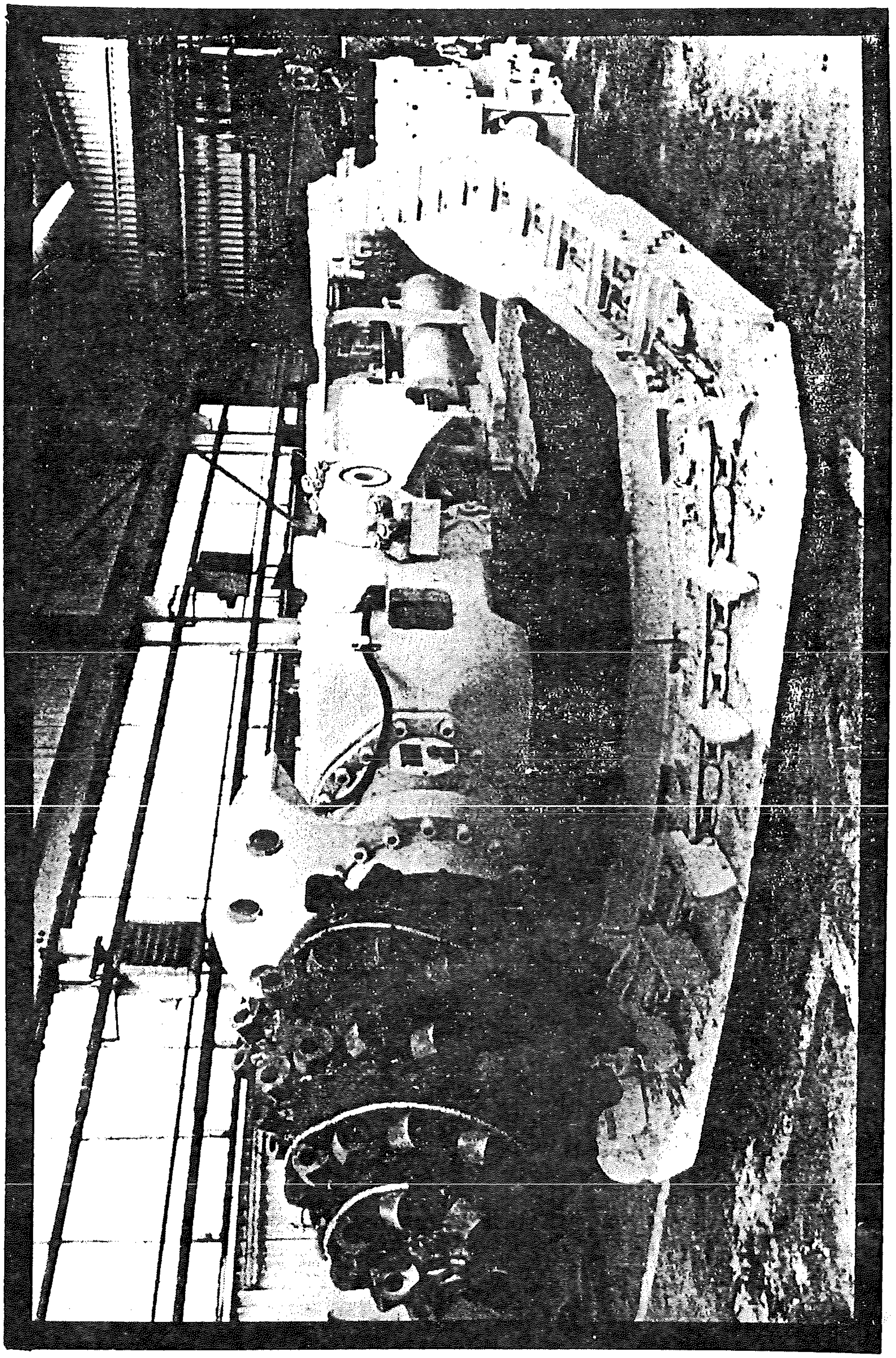
In anticipation of continued demand for uranium supplies, the United States Bureau of Mines (USBM) awarded a research contract, H0282024, to Morrison-Knudsen Company, Inc., to evaluate the use of roadheaders in underground uranium operations. The evaluation was to include suggestions for improved roadheader design parameters, modified mining systems to incorporate roadheaders, and ancillary equipment to augment roadheader usage.

Traditionally, all uranium mines have depended on conventional drill and blast methods for both development and ore production. Rising labor costs accompanied by a limited supply of skilled miners has caused the mining companies to search for a better, more mechanized method of mining. Recent USBM studies have identified the application of coal mining equipment in noncoal deposits as a means of mechanizing these mines. A roadheader continuous miner originally developed for coal mining application has had limited operating success in underground uranium mines of the sandstone type. Roadheaders manufactured by two companies, Dosco Overseas Engineering Ltd. of England (DOSCO) and AEC, Inc. of the U.S.A. (AEC), have demonstrated the best production capabilities while being operated in several uranium mining operations. Figures 1 through 4 are examples of roadheaders currently in use.

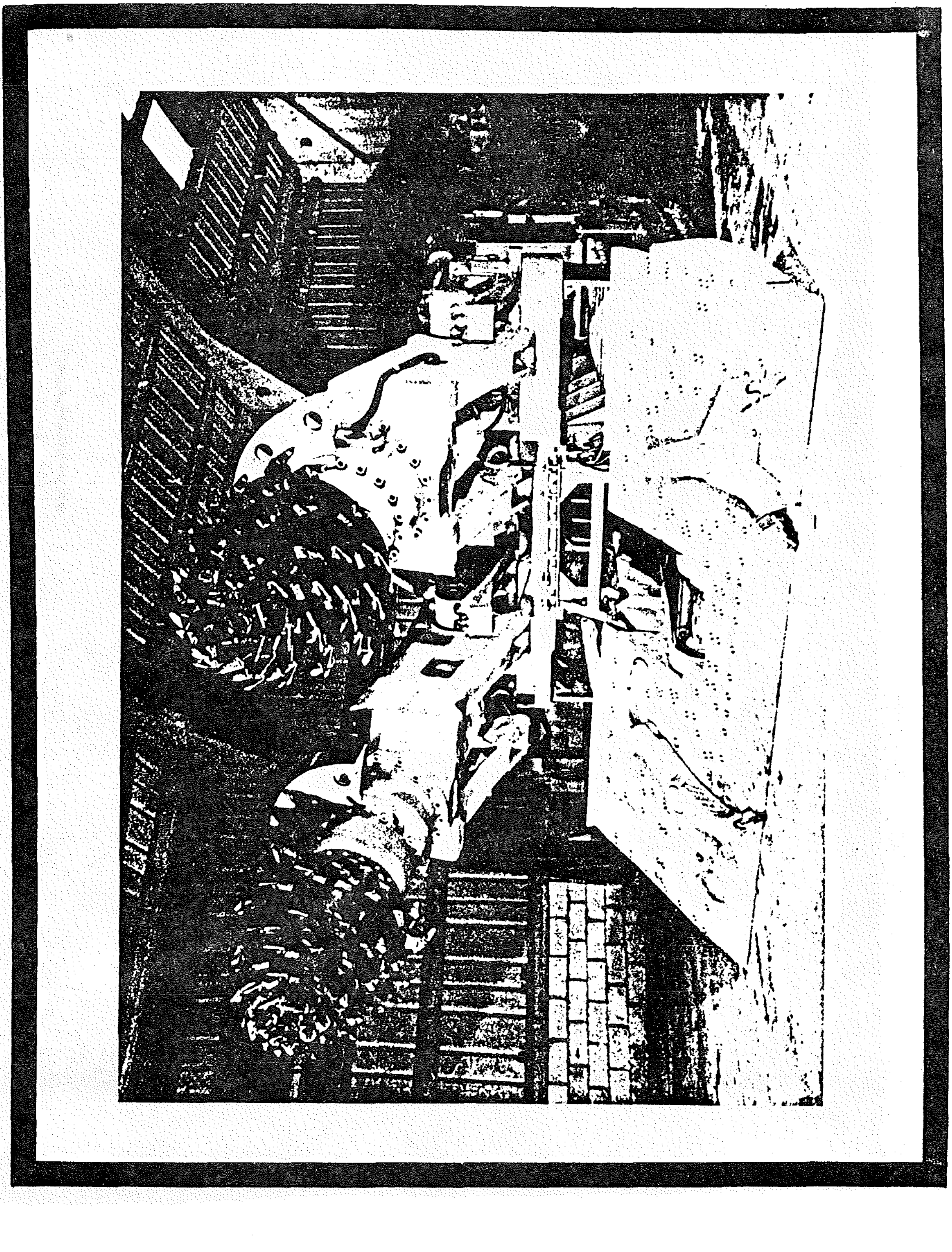
A roadheader is a mining machine suitable for driving tunnels, entries, or drifts in relatively soft rock and capable of excavating, within limits, a variable cross-section. The roadheader consists of milling or ripper type heads mounted on a pivoted boom (or booms) and a loading and conveying system, all of which is carried on twin crawlers. In operation, the boom moves horizontally and vertically across the heading, cutting rock from the face. The excavated material falls to the floor where it is gathered by arms or an encircling conveyor onto the discharge conveyor for transfer to the haulage system.

Limitations to the use of roadheaders have been primarily due to machine design and overall mining method restrictions. Roadheaders have shown in short term testing to be as productive or more productive than conventional drill and blast methods. However, recurring problems such as the inability of the rock handling system to function properly under wet conditions, mechanical and electrical downtime, inability to effectively integrate ground support time, and dust generation have restricted the use of roadheaders as a primary mining and development unit.

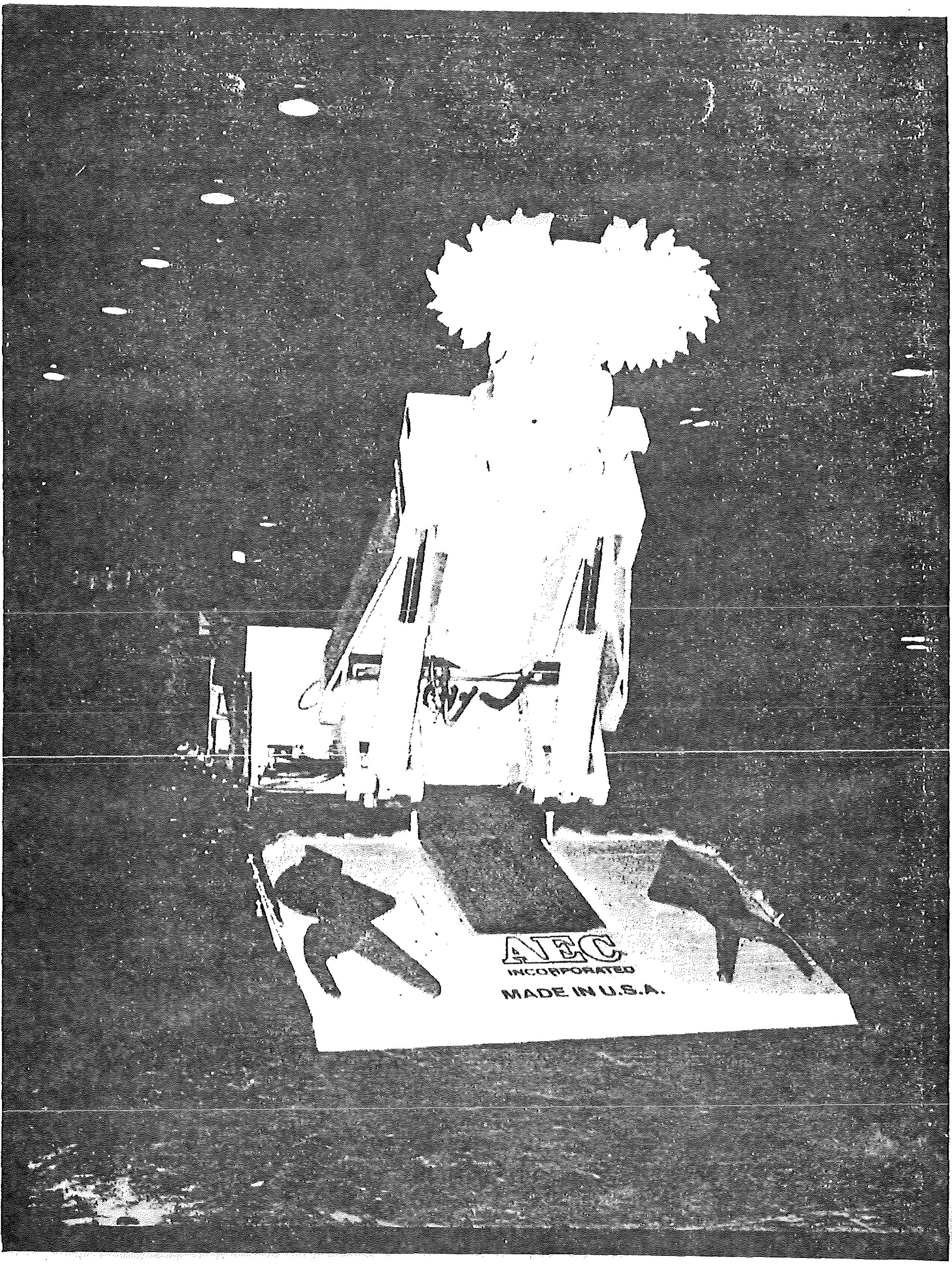
The purpose of this study was to determine the extent to which roadheaders are used in the mining industry, the problems encountered, modifications already made to the original designs to adapt the units to underground uranium mining, and the potential for application of the modified roadheaders in underground uranium mines.



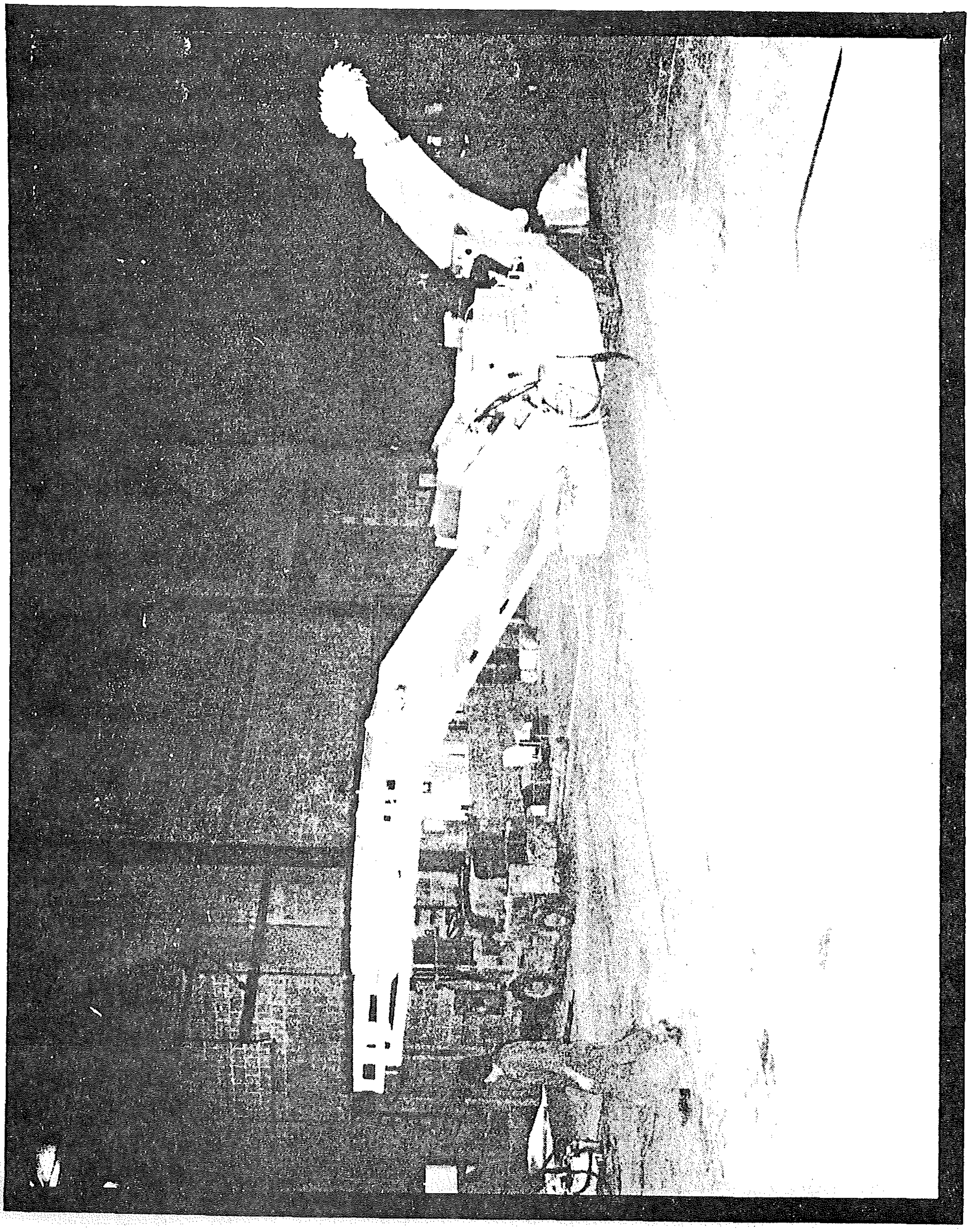
DOSCO ROADHEADER
MODEL LH150
FIGURE 1



DOSCO ROADHEADER
MODEL TB600
FIGURE 2



AEC ROADHEADER
MODEL 290M FRONT VIEW
FIGURE 3



AEC ROADHEADER
MODEL 290M SIDE VIEW
FIGURE 4

The work under this contract was completed in two phases. Phase I reviewed current roadheader usage in sandstone uranium deposits, including the extent to which they are used in development and production work, and the operating and maintenance problems encountered with this equipment. The Phase I report included discussions of the advantages and disadvantages of roadheaders compared to conventional drill and blast techniques, and included operating cost and production comparisons.

After approval of the Phase I Report, Phase II of the study was initiated to determine equipment and mining method modifications which would improve the capability of the roadheader in underground uranium mining. This Final Report includes data and observations from both phases of the study, all conclusions and recommendations, and a discussion of future areas of research for equipment modifications, concepts, and new mining systems using roadheaders as the primary development and mining unit.

II. CASE HISTORIES

2.1 INTRODUCTION

Twelve mining companies that have used or are using roadheaders in uranium ore development or mining were contacted for authorization to visit their mining operations to observe the machines in normal working conditions, view the work accomplished with the roadheaders, and review any existing data relevant to their application. Six of the companies cooperated in the project. Additional information was gained from two companies that are mining under contract operating agreements for one of the six cooperating companies, and from two companies that are planning to use roadheaders in mines that are currently in the development stage. Site visits were made to mines in New Mexico, Colorado, Utah, Wyoming, California, and Saskatchewan, Canada.

With the exception of AEC's roadheader operating at the Mount Taylor Mine, all of the roadheaders used in uranium mining to this date have been first generation equipment models, and all of the observations and data contained in this report are based on these models. The number of roadheaders being manufactured at the present time is extensive when compared to the choices available a few years ago.

In most conventional ore mining operations, a crew will be assigned two or more headings. Usually the crew can move from one heading to another with little or no delay since the drilling equipment is small and the loading and hauling equipment can be moved at a high tramming rate. For ventilation a small fan and cloth tubing is used. This cannot be accomplished with the roadheaders because of their low tramming speed and the time required to transfer the rigid ventilation tubing. As a consequence, in multiple headings the roadheader is usually not as productive as conventional mining methods.

In single heading rail haulage drifting, the roadheader has achieved an average advance of 6.4 feet per shift. The average advance in a single heading rail haulage drift driven by conventional methods is 4.9 feet. In a single heading trackless haulage drift, the roadheader has achieved an average of 8.1 feet per shift. An average of only 6.5 feet can be driven by a conventional mining crew in a similar heading. A typical crew in a conventional heading is composed of a miner and a helper. The roadheader crew will be composed of three men; the operator, the cable tender, and a helper.

One of the major advantages that is offered by the roadheader is that almost complete ore-waste segregation can be accomplished. If the heading does not present a full face of ore, the ore and waste can be mined and shipped as separate products. This is not possible in the conventional heading since the total face must be drilled and blasted at the same time.

The ore and waste are mixed by blasting in the conventional heading, and the two products are mucked out together resulting in ore dilution.

The mining height in conventional drilling and blasting usually depends on the skill of the miners and the ground conditions. Normal stoping with one-yard load-haul units or slushers is held to a maximum height of six feet. The mining height for roadheaders is determined by the equipment size and the room necessary to install ventilation tubing. The average mining height for roadheaders is nine feet.

2.2 DECLINE SHAFT DEVELOPMENT

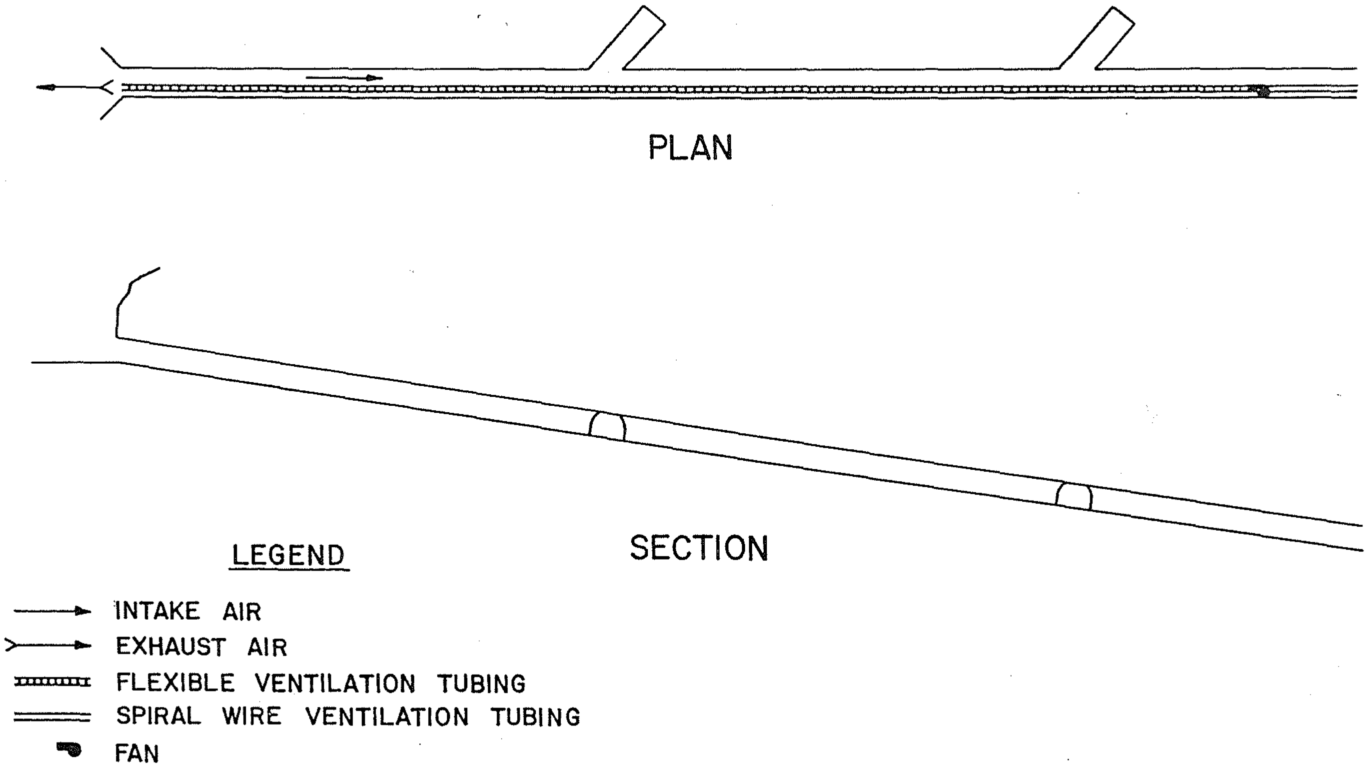
A roadheader has been utilized in driving part of three decline shafts in the vicinity of Naturita, Colorado. All three of the shafts were sunk through a predominantly siltstone facies in the upper portion of the Morrison Formation. The shafts had identical cross sectional dimensions, 9 feet high and 12 feet wide. Figure 5 illustrates a typical plan and section of the layout of the shafts. Turnouts were excavated at approximately 200-foot intervals to facilitate vehicle traffic and for installation of a steam generating unit, which, since it was used for dust suppression, had to be near the working face.

Muck haulage from the roadheader to the surface was accomplished with a variety of mobile diesel-powered haulage equipment. Trucks designed for underground usage in the 5 to 10-ton capacity range were the principal means of transporting the waste material, although 2 and 5-yard load-haul-dump units were used for cleanup and occasionally for primary haulage during periods when the trucks were out of service.

TABLE 1. - Roadheader shaft data

Shaft No.	Grade (%)	Total Length (ft)	Roadheader Portion (ft)	Conventional Portion (ft)
1	-18	1760	0-700	701-1760
2	-15	1812	0-1400	1401-1812
3	-16	1550	1251-1550	0-1250

One of the shafts was driven through relatively incompetent rock, and extensive timbering was required for ground support. Heavy wood and steel sets were installed on 5-foot centers and the back and ribs tightly lagged to prevent caving. Material handling in this shaft caused considerable delay because all of the timber had to be carried over the roadheader. Another delay factor introduced by the bad ground conditions was the loss of efficiency due to the limited mining cycle. Only enough opening for one



TYPICAL LAYOUT - DECLINE SHAFT
FIGURE 5

lead of timber could be excavated, and then the advance was halted until permanent ground support could be installed. Ground conditions in the other shafts allowed the roadheader to be used more efficiently in that more opening could be excavated before ground support consisting of rock bolts, mats, wire mesh and an occasional timber set was required. These shafts were normally advanced in 12-foot increments during the mining cycle. Rock bolts were installed on a random pattern with the spacing being varied as the ground conditions changed. Shotcrete was applied to the back and ribs of one shaft to prevent the rock from weathering and sloughing.

Similar ventilation systems were employed at all three shafts. An exhausting axial flow fan assembly was used to supply air to the heading and to exhaust dust and diesel fumes away from the face. The fan was positioned near the face and moved forward at 50 to 100-foot intervals. Intake air was coursed through the shaft and exhausted through a 24-inch diameter, flexible ventilation tubing. A spiral wire ventilation tube was maintained from the fan to the face.

The average rate of advance varied from 60 feet per month in the timbered shaft to 159 feet per month in the shaft that was supported with rock bolts and shotcrete. The highest rate of advance achieved in one month was 265 feet. The lowest rate of advance, 50 feet, occurred in the timbered shaft and was caused by a combination of bad ground, substantial mine water inflow, poor roadway conditions, and equipment failures.

A typical crew was composed of three men, one roadheader operator, and two truck drivers. The three-man crew was responsible for all mining functions including excavation, muck haulage, ground support, and installation of service lines as well as minor preventive maintenance on a daily basis. Maintenance personnel were assigned as needed for maintenance and repair of equipment. The operations were scheduled to work two shifts per day and five days per week.

2.3 DRIFT DEVELOPMENT

After achieving only limited success in ore development and mining, most of the operators assigned the roadheaders to waste development drifting in relatively dry areas of the mines. The waste development drifts are used for sublevel haulage and as access drifts to the ore bodies. Normally, these drifts were driven at a constant grade, and the size of the opening was not important unless bad ground conditions were encountered.

The roadheaders used in driving waste headings were all operated in generally the same manner, using load-haul-dump units, trucks, shuttle cars, and lightweight frame conveyors to transport muck away from the roadheaders in mobile and rail haulage drifts. Several operations have attempted to dump the broken rock behind the roadheaders and then clean it up with load-haul-dump equipment. In all instances this effort has failed because the muck was pushed forward and the roadheader could not be backed away from the face to install ground support. A short trailing conveyor, mounted on wheels, is commonly towed by the roadheaders to elevate the muck into trucks.

A flexible conveyor that could be curved horizontally as well as vertically was installed in one operation to transport broken rock from the roadheader to rail cars. The conveyor was supported on gantry frames that rode on temporary rails mounted outside of the standard haulage rails. The flexible conveyor was attached to the roadheader and was towed along the gantry rails as the loading advanced. The belt was loaded by the roadheader and was capable of transporting 100 tons per hour. The conveyor was approximately 100 feet long, and a train of empty cars could be stationed under it. Cars were loaded as the roadheader advanced and the train was pulled.

The roof conditions at this mine were good and the roadheader was permitted to advance without the installation of any ground support, although in a few localized areas behind the face, spot bolting with wire mesh was required. The heading was advanced at an average rate of 10 feet per shift. A push-pull ventilation system was used at this operation. The system included a blowing fan located at the fresh air intake for the mine level, an exhausting fan and rigid tubing located near the face, and a Microdyne dust collector. The air was forced through a flexible ventilation tubing to the heading where it was directed across the face and into the exhaust tubing and fan. The air was then passed through the Microdyne dust collector to remove the airborne dust particles after which the air was returned to the open drift to be exhausted. The dust collection system was not completely effective and the entire crew was required to wear respirators.

Ground support in development drifting has consisted mainly of rock bolts with wire mesh, although some drifts have required timber sets because of poor ground conditions. Most drifts have been ventilated by an exhausting fan connected to rigid tubing extended to the face. The intake air follows the drift, flows across the face, and is exhausted through the tubing. Both the dust created by the roadheader and the fumes from the mobile equipment were exhausted in this manner.

Although productivity records and time studies were provided by several companies, most of the studies were of short duration and probably could not be considered as being representative of the total roadheader application. A set of time study data and daily mine logs were available for a twenty-one month roadheader application. The results of this study are summarized in Table 2, with the details following in Tables 3 through 5.

TABLE 2. - Roadheader operation summary

(DEVELOPMENT WORK)

Calendar Period	21 months
Operating Time	2 shifts
Advance (10' x 10' nominal)	2145 feet
Average Advance	8.06 feet/shift
Total Excavation	13,646 tons
Average Excavation	51.30 tons/shift
Bits Consumed	821 bits
Average Bit Requirement	0.38 bits/foot
Average Bit Life	16.6 tons/bit

Average Shift Distribution:	Minutes	%	Acc.%
Roadheader Production	45,350	39.3	39.3
Delays:			
Ground support	36,405	31.5	70.8
Roadheader downtime	11,335	9.8	80.6
Ventilation	9,315	8.1	88.7
Move air and water lines	3,300	2.9	91.6
Miscellaneous delays	3,255	2.8	94.4
Drill probe holes	2,895	2.5	96.9
Hard ground delays	1,845	1.6	98.5
Auxiliary equipment delays	1,755	1.5	100.0
Necessary Delays:			
Lunch	7,980		
Travel to and from job	4,245		
TOTAL	127,680		

TABLE 3. - Roadheader drift statistics

Month	Shifts	Feet Advance	Average Feet/Shift	Tons Nominal[1]	Tons Actual	Average Tons/Shift
1	7	35	5.00	219	231	33.0
2	19	130	6.84	812	805	42.4
7	22	151	6.86	944	949	43.1
8	21	210	10.00	1312	1567	74.6
9	22	188	8.54	1175	1228	55.8
10	22	224	10.18	1400	1364	62.0
13	20	171	8.55	1069	1101	55.0
14	19	133	7.00	831	780	41.0
15	20	170	8.50	1062	1030	51.5
18	20	165	8.25	1031	1006	50.3
20	44	346	7.86	2162	2184	49.6
21	30	222	7.40	1388	1401	46.7
Total	266	2145	8.06	13405	13646	51.3

---

[1] 10' x 10' @ 16 ft^3/ton = 6.25 tons/foot

TABLE 4. - Time required for mining functions in roadheader drifting (Min.)

	Roadheader								
Month	Run[1] Time	Down Time	Ground Support	Ventilation	Air-Water Lines	Misc.[2] Delay	Drill Probe Holes	Drill[3] Hard Ground	Aux. Equip. Delay
1	945	315	975	360	30	180	0	0	150
2	3,645	135	2,310	735	150	225	750	0	210
7	2,895	2,085	3,240	675	270	150	195	0	15
8	3,960	0	3,300	720	240	90	705	0	120
9	3,495	825	3,555	645	345	210	60	0	435
10	4,185	360	3,435	855	345	90	300	0	0
13	3,780	315	3,075	840	360	180	0	0	135
14	2,130	810	2,595	795	345	60	0	1,395	135
15	3,375	1,050	2,415	510	435	660	255	0	0
18	3,870	390	2,730	825	120	165	600	0	0
20	8,105	3,325	5,670	1,110	450	480	0	0	0
21	4,965	1,725	3,105	1,245	210	765	30	450	555
TOTAL	45,350	11,355	36,405	9,315	3,300	3,255	2,895	1,845	1,755
Avg. Per Shift	170	45	135	35	15	15	10	5	5

Shift Totals:	Production	170
	Delays	265
	Lunch	30
	Travel	15
		480

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[1] Time for routine preventive maintenance, cutter bit change, and advance of ventilation during mining cycle is included in the roadheader operation time.

[2] Includes equipment downtime and time consumed in safety meetings, power failures, supply handling.

[3] Downtime caused by encountering high compression strength rock that could not be mined with the roadheader and had to be drilled and blasted.

TABLE 5. - Bit consumption in roadheader drifting

Roadheader Drifting

Month	Bits Used	Feet Advance	Bits Per Foot	Tons	Tons Per Bit
1	7	35	0.20	231	33.0
2	107	130	0.82	805	7.5
7	65	151	0.43	949	14.6
8	139	210	0.66	1567	11.3
9	122	188	0.65	1228	10.1
10	127	224	0.57	1364	10.6
13	36	171	0.21	1101	30.6
14	30	133	0.30	780	26.0
15	40	170	0.24	1030	25.8
18	14	165	0.08	1006	71.9
20	74	346	0.21	2184	29.5
21	60	222	0.27	1460	24.4
TOTAL	821	2145	0.38	13646	16.6

2.4 STOPE DEVELOPMENT AND STOPING

Most of the roadheaders owned by uranium mining companies were purchased with the original concept that they would be used as continuous miners for stope development and extraction within ore zones. The mine operators felt that productivity would be increased, ore dilution eliminated, and ground control problems created by blasting reduced. Several of the operations achieved these goals to some extent, but most of the attempts to use the machines for ore mining have realized only limited success. As a consequence, most of the roadheaders are currently being used for waste development drifting.

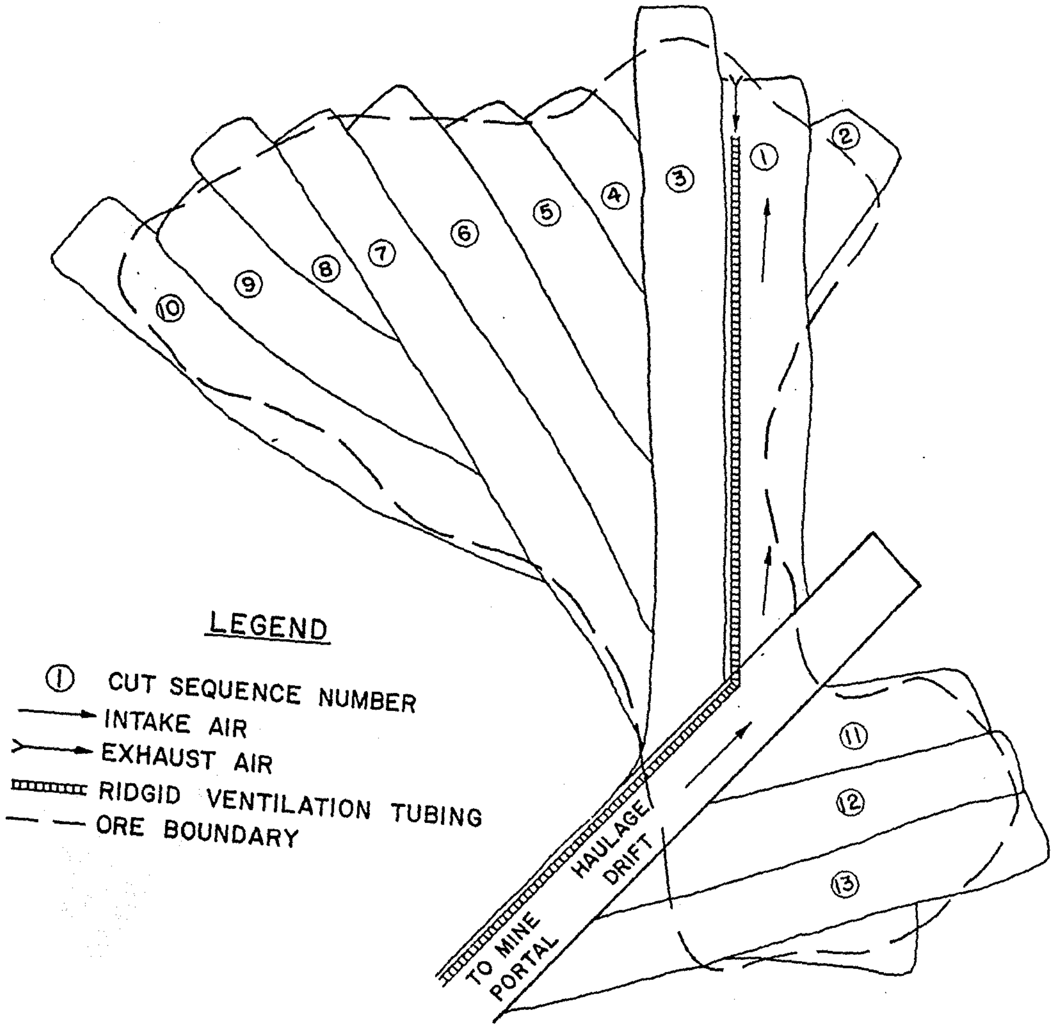
Four mining methods were observed in the uranium mines using roadheaders for stoping. The first two (Figures 6 and 7) were employed in adit or portal mines which were developed in existing open pit highwalls. The latter two (Figures 8 and 9) methods are used at vertical shaft mines where sublevel rail haulage transports the ore from ore passes to the shaft pocket. The methods shown on Figures 6, 7 and 8 generally follow the same mining plan in which a stope development or haulage drift is driven into the ore body and then a series of slots are mined from development drift at an angle.

The mining plan shown on Figure 9 is different from the other approaches and closely follows the method used in continuous miner sections in coal mines. Entries and cross cuts were driven throughout the ore body and then the pillars were split and extracted in a series of short cuts. All of the development drifting and pillar extraction shown on the four mining plans was accomplished with roadheaders.

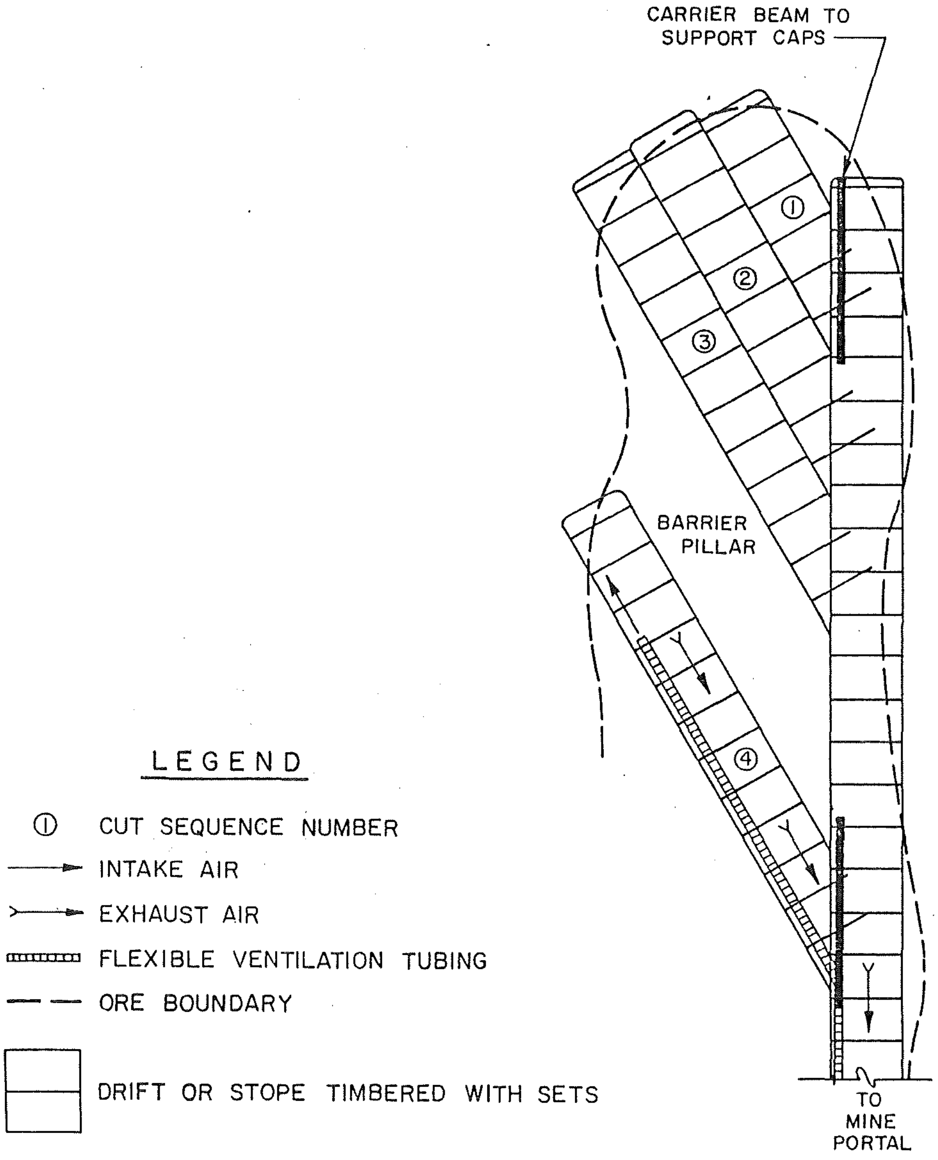
2.4.1 Haulage

Load-haul-dump units rated at one, two and five yard capacity, and a variety of trucks rated at three, five and ten tons capacity have been used for ore transportation in all of the roadheader stopes. The ore was hauled to surface stockpile areas at the portal mines, and to an ore pass in the shaft mines. In all roadheader stoping attempts, the operators have found that the haulage equipment used was not adequate. The production capability of the roadheader exceeded the haulage capability, and the roadheader was frequently standing idle while waiting on the haulage equipment to change out or return from dumping.

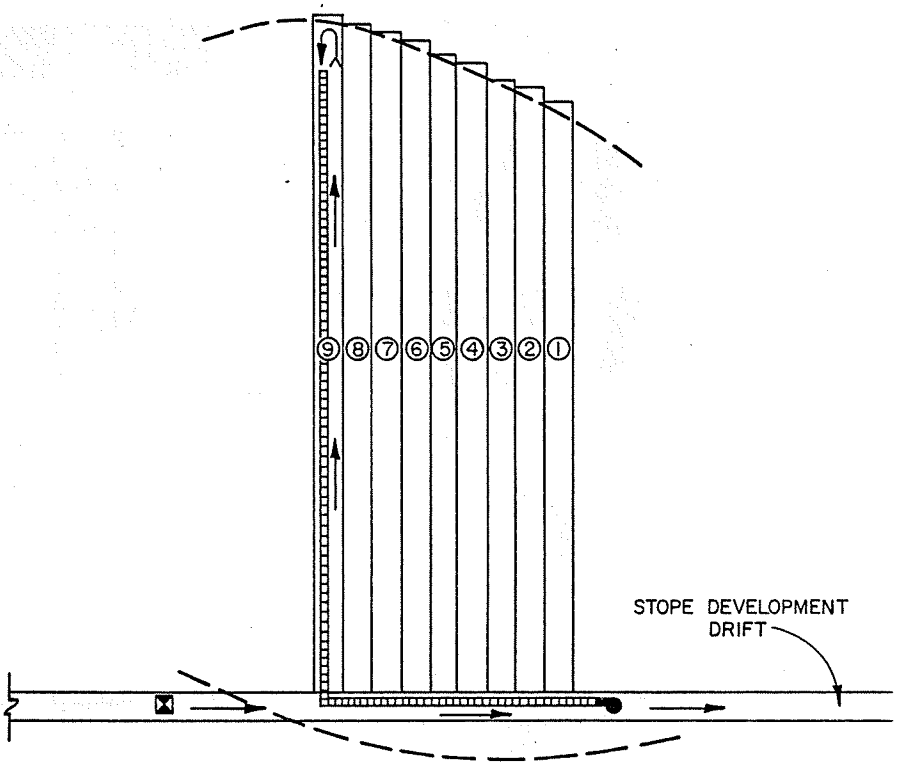
Several of the mine operators have considered using a conveying system in stope mining, but at this time no suitable conveyor has been devised. The erratic deposition of uranium, both vertically and horizontally, prohibits the use of standard conveyors. In order to keep the workings in ore, the development drifts are seldom driven on a constant line or grade. Another problem involved with the use of a conveyor is the lack of ability to sort ore and waste without installing a complex chute arrangement at the conveyor head sheave and additional conveyors to handle each product.



ROADHEADER STOPE SHOWING MINING SEQUENCE
FIGURE 6



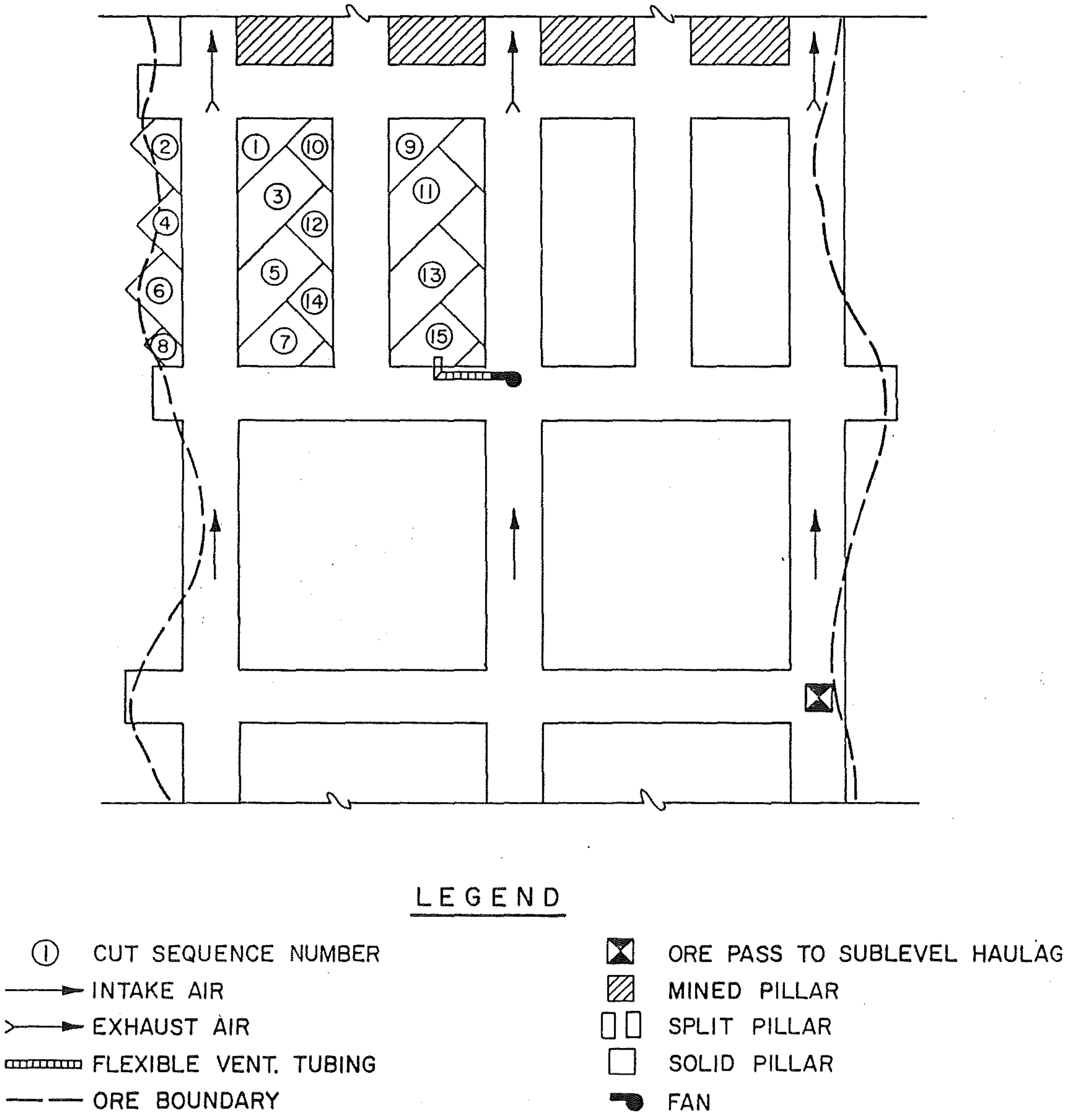
ROADHEADER STOPING METHOD IN INCOMPETENT GROUND
FIGURE 7



LEGEND

① CUT SEQUENCE NUMBER
→ INTAKE AIR
>→ EXHAUST AIR
▥ RIGID VENTILATION TUBING
● FAN
⊠ ORE PASS TO SUBLEVEL HAULAGE
— — ORE BOUNDARY

ROADHEADER STOPE ADAPTED FROM SLOT MINING METHOD
FIGURE 8



ROOM AND PILLAR ROADHEADER STOPE
FIGURE 9

2.4.2 Ground Support

The ground support methods used in stoping have ranged from an occasional stull to the installation of drift sets on close centers. Ground support for the stoping plans shown on Figures 6 and 8 consisted of rock bolts and wire mesh on the back and rib of the active slot, with stulls placed on five-foot centers in the adjacent mined-out stope. The roadheader was advanced ten or twelve feet and then backed away from the face to allow the rock bolts and wire mesh to be installed.

Timber sets were required for ground support throughout all of the stoping area shown on Figure 7. A development drift, located at the edge of ore and supported by timber sets on six-foot centers, was driven to the end of the ore body. After drilling exploration longholes to determine the extent of the ore, a carrier beam was installed to support three sets of caps. The posts were then removed from beneath the caps on one side of the drift. Retreat mining continued for three timbered slots, each of which required a carrier beam, after which a barrier pillar was left. Because of the unstable rock in this mine, the roadheader could be advanced only 6 feet and then permanent ground support had to be installed.

Rock bolts and wire mesh were installed to support the back and ribs of the development drifts, cross cuts, and pillar split drifts shown on Figure 9. The pillar extraction plan requires only occasional breaker stulls to protect the roadheader operator during stope mining. The pillar cuts are short and designed so that the operator remains under ground support installed during stope development drifting.

2.4.3 Ventilation

A positive or blowing ventilation system was used for all development and stoping at one mine because of the soft rock. The roadheader created very little dust at this mine, and dust control was accomplished by use of water sprays mounted on the roadheader. Two of the mines used negative pressure ventilation through rigid tubing throughout all of the mining operations, and one mine used negative pressure during development and then changed to positive pressure during stoping.

TABLE 6. - Roadheader operation summary

Stoping work

Calendar Period	19 months
Operating Time	183 shifts
Advance (10' x 10' nominal)	1691 feet
Average Advance	9.24 feet/shift
Total Excavation	10,660 tons
Average Excavation	58.2 tons/shift
Bits Consumed	537 bits
Average Bit Requirement	0.32 bits/foot
Average Bit Life	19.9 Tons/bit

Average Shift Distribution:	Minutes	%	Acc.%
Roadheader Production	32,400	40.8	40.8
Delays:			
Ground Support	26,175	32.9	73.7
Drill Probe Holes	5,400	6.8	80.5
Ventilation	5,190	6.5	87.0
Roadheader Downtime	3,000	3.8	90.8
Auxiliary Equipment Delays	2,940	3.7	94.5
Move Air and Water Lines	2,295	2.9	97.4
Miscellaneous Delays	2,025	2.6	100.0
Subtotal	79,425		
Necessary Delays:			
Lunch	5,490		
Travel to and from Job	2,925		
TOTAL	87,480		

2.4.4 Manpower

The manpower required to operate a roadheader stope was typically composed of the roadheader operator and a helper, while the number of haulage equipment operators varied with different slope configurations.

Although productivity records and time studies were provided by several companies, most of the studies were of short duration and probably could not be considered as being representative of the roadheader stoping application. A set of time study and daily mine logs was available for a seventeen-month roadheader application. The results of this study are summarized in Table 6, with the details following in Tables 7 through 9.

TABLE 7. - Roadheader Stoping Statistics

Month	Shifts	Feet Advance	Average Feet/Shift	Tons Nominal[1/]	Tons Actual	Average Tons/Shift
3	20	145	7.25	906	919	46.0
4	21	176	8.38	1100	966	46.0
5	21	182	8.67	1138	1149	54.7
6	21	185	8.80	1156	1208	57.5
11	18	176	9.77	1100	1105	61.4
12	23	164	7.13	1025	1029	44.7
16	20	228	11.40	1425	1548	77.4
17	22	225	10.23	1406	1371	62.3
19	17	210	12.35	1312	1365	80.3
Total	183	1691	9.24	10552	10660	58.2

[1/] 10' x 10' @ 16 ft^3/ton = 6.25 tons/foot

TABLE 8. - Time required for mining function in roadheader stoping

Month	Roadheader Run[1] Time	Roadheader Down Time	Ground Support	Drill Probe Holes	Venti- lation	Aux. Equip. Down	Air- Water Lines	Misc.[2] Delays
3	3,180	195	3,015	1,245	615	135	30	240
4	3,360	345	2,895	675	555	645	435	150
5	3,690	285	3,735	30	750	285	150	180
6	3,525	645	2,595	0	480	1,800	30	60
11	3,075	180	2,610	615	615	30	210	480
12	3,735	180	3,195	1,350	600	0	690	240
16	4,590	0	2,775	375	540	0	330	90
17	4,305	300	3,300	645	570	45	270	135
19	2,940	870	2,055	465	465	0	150	450
TOTAL	32,400	3,000	26,175	5,400	5,190	2,940	2,295	2,025
Avg. Per Shift	180	15	145	30	30	15	10	10

		Minutes	Percent
Shift Totals:	Production	180	37.5
	Delays	255	53.1
	Lunch	30	6.3
	Travel	15	3.1
		480	100.0

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[1] Time for routine preventive maintenance, cutter bit change, and advance of ventilation during the mining cycle is included in the roadheader operation time.

[2] Includes equipment downtime and time consumed in safety meetings, power failures, supply handling.

TABLE 9. - Bit consumption in roadheader stoping

Month	Bits Used	Feet Advance	Bits Per Foot	Tons	Tons Per Bit
3	21	145	0.14	919	43.8
4	61	176	0.35	966	15.8
5	116	182	8.64	1149	9.9
6	71	185	0.38	1208	17.0
11	75	176	0.43	1105	14.7
12	51	164	0.31	1029	20.2
16	50	228	0.22	1548	31.0
17	41	225	0.18	1371	33.4
19	51	210	0.24	1365	26.8
TOTAL	537	1691	0.32	10660	19.8

2.5 Operating Problems Encountered with Roadheaders and Support Equipment

All of the roadheader applications have experienced essentially the same operating problems regardless of the type of rock being mined or the type of work being performed. Operators tend to attribute all of the downtime to the roadheaders, but the data recorded by one company over a period of 21 months indicates that other factors also enter into downtime and loss of efficienty. Table 10 indicates that, for a 21-month study at one mine, the downtime for the roadheader was only a small portion (30 minutes) of the average shift. As noted previously, routine maintenance and bit changes were considered as part of operating time for this study.

TABLE 10. - Average Roadheader Shift

	Minutes	Percent
Operating	175 minutes	36.5
Ground Support	140	29.2
Roadheader Down	30	6.2
Ventilation	30	6.2
Drill Probe Holes	20	4.2
Move Air and Water Lines	15	3.1

Travel to and from Site	15	3.1
Auxiliary Equipment Down	10	2.1
Miscellaneous Delays	10	2.1
Drill and Blast Hard Ground	5	1.1
Lunch	30	6.2
TOTAL	480 minutes	100.0

2.5.1 Machine Downtime

The sandstone host rock in which uranium occurs is broken into small, sharp and angular pieces by the cutting and shearing action of the rotating cutter head. These highly silicious particles create an abrasive substance that causes extreme wear to all metal surfaces exposed to the flow of rock. The roadheader excavation, loading, and conveying devices are constantly subjected to abrasion and cause more than one half of all downtime charged to the machine. Table 11 summarizes the downtime caused by each of the roadheader components, as compiled from the records of a 21-month study at one mining operation.

Two types of gathering heads have been used in uranium mining. One loads the broken rock with gathering arms and discharges it with a chain conveyor. The other uses an encircling flight conveyor for loading and a short belt conveyor for discharge. Information from the mine operators indicates both systems contribute approximately an equal amount of downtime.

Routine preventive maintenance on roadheaders is required on every operating shift to prevent excessive wear of bearings, gears, and other working parts. At most of the mines, the roadheader operator completes this work during the ground support cycle while the machine is idle. At other operations, the work was accomplished on non-operating shifts by maintenance personnel. No statistical data was available to determine the actual amount of time spent on preventive maintenance.

Data compiled during this study indicates that the amount of time required for ground support is nearly equal to the amount of time utilized in production mining with the roadheader. Consequently, most operators have attempted to use the machines in multiple headings, mining in one heading while installing ground support in other headings. These attempts have not been very successful because of the slow tramming speed of the machines, and having to shift the ventilation from one heading to another. As a result, some operators have resorted to working only one heading and backing the machine away from the face while rock bolts or timber is installed. This forces the operation to assume a cyclic nature, and the roadheader is idle for a major portion of the available time. Several

TABLE 11. - Summary of downtime caused by roadheader components

Month	Chain Conveyor	Power Cable & Elect.	Hydraulic System	Tracks	Cutter Head & Turret	Shear Pins	Major[1] Maint. Service	Welding[2]
1	315	0	0	0	0	0	0	0
2	90	45	0	0	0	0	0	0
3	15	0	30	0	0	30	0	120
4	75	0	270	0	0	0	0	0
5	0	0	0	0	0	0	285	0
6	120	390	15	0	15	45	60	0
7	1335	30	0	720	0	0	0	0
8	0	0	0	0	0	0	0	0
9	90	0	735	0	0	0	0	0
10	0	0	165	0	0	15	0	180
11	0	180	0	0	0	0	0	0
12	0	0	180	0	0	0	0	0
13	0	0	315	0	0	0	0	0
14	810	0	0	0	0	0	0	0
15	870	180	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	300
18	0	0	0	0	0	0	60	330
19	870	0	0	0	0	0	0	0
20	2670	250	0	0	405	0	0	0
21	840	885	0	0	0	0	0	0
TOTAL	8100	1960	1710	720	420	90	405	930
Per cent of downtime	56.5	13.7	11.9	5.0	2.9	0.7	2.8	6.5
Minutes per shift	18	4	4	2	1	1	1	2

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[1] Routine preventive maintenance time included in production time.

[2] Welding required on machine frame and loading head.

companies have tried to install rock bolt drills on the machines, but none of the drills has been completely successful.

All of the roadheader machines currently employed in uranium mining applications use the same traction motors for crowd movement during excavation as well as tramming. Slow forward movement is necessary during the cutting cycle to avoid stalling the cutter head, and all of the machines are geared to this slow speed, both forward and backward. As a result, a great amount of lost time is experienced during transfer from one working location to another. The mobility of the machines is also reduced by the loading conveyors that are attached to some of the machines. It is difficult to maneuver the roadheader around curves or corners with an attached trailing conveyor. One operator stated that 32 hours were required to move a roadheader 1300 feet out of a decline shaft. Another operator reported that eight hours were required to back a machine 900 feet out of a portal mine.

Two different types of bits have been used on roadheader cutter heads. All of the machines were originally equipped with heads designed for drag or flat radial bits. Most of these cutter heads have now been replaced with ones designed to use conical or point attack bits. The bit blocks or holders attached to the cutter head are subject to severe wear and must be replaced or built up with hard face welding on a regular basis. The attack angle of each bit holder is extremely critical and correct placement requires careful welding. Some downtime has been experienced at all roadheader operations because of cutter head repair. Downtime has also been experienced in changing worn bits. Wet shaley material tends to pack around the bit and inside the bit holder. Removal of a packed bit is sometimes very difficult. At one operation, the roadheader was being used in a shale heading, and the operator had to remove the worn bits with a cutting torch on several occasions. Information received from one company indicates that the drag bit is more productive in shale while the conical bit is more productive in sandstone.

A large amount of dust is generated by the cutting action of the roadheader, the broken rock falling from the face and the loading and conveying apparatus during rock excavation. To exhaust the airborne dust and supply ventilation for personnel, most companies use a negative pressure ventilation system that must be maintained in close proximity to the working face. Oval shaped, rigid duct tubing connected to an axivane fan is commonly used for this purpose. Most of this tubing is fragile, cumbersome, difficult to handle, and requires a considerable amount of time to install properly. The tubing must be advanced during the mining cycle, and the statistics gathered from the operators are not representative of the time actually consumed in this mining function. The time was normally charged to the roadheader mining cycle, and no distinction can be made for the time needed to add ventilation tubing. Some mining operations in soft ground can use blowing or positive pressure ventilation through flexible ventilation tubing. Time for addition of tubing is minimal in these operations where dust is not a problem.

All of the roadheader machines have many points that must be lubricated on each working shift. On some of the units, a few of the lubrication points are concealed behind protective covers and others are located in almost inaccessible positions in the machine. The roadheader operator normally lubricates the machine during the ground support cycle, and no data is available to indicate the actual amount of time required. If a central lubrication system could be installed on the machines, the operator could be employed in other work during the time saved, and possibly the crew size could be reduced. In addition, more effective and thorough lubrication could be expected from a central system, and reduced maintenance should be achieved.

Power for movement of the cutter head boom and raising and lowering of the loading devices is provided by hydraulic pumps and cylinders on all of the models of roadheaders observed. In addition to these hydraulically powered functions, one machine uses hydraulic pumps and motors for traction and for operating the conveyor. The downtime attributed to hydraulic component failures for the least complex machine amounted to 11.9 percent of all roadheader downtime, or about 4 minutes per shift. No data was obtained to indicate the downtime caused by hydraulic components on the machine with the more complex system.

Many of the roadheaders presently being operated in sandstone uranium mines were manufactured in Europe, and the time lag in obtaining repair parts is sometimes extensive. All of the operators of either domestically or foreign manufactured units have experienced downtime while waiting for delivery of spare parts. One operation sustained three weeks of downtime while waiting parts delivery. Another operator stated that a ten-day delay had been incurred while waiting for parts. Delays of two to four days have been common for most of the operators.

2.5.2 Performance

Performance data has been supplied from various mining companies that have used roadheaders in their uranium operations. As with most time data, the mining functions have been identified differently by each mining company. However, the major operating mine functions and delays can be identified and a correlation of production shown. The breakdown detail of each segment of the mining cycle varies with each operation due to the availability of trained observers. In addition, the operating conditions vary from mine to mine as well as from one drift to the next in the same mine. For this reason, while the study data can vary over a short interval, a balance is achieved over longer intervals or for several operations.

In any production summary, the results should be in units that are readily comparable from one mine to the next. In the uranium industry, tons produced and feet of advance are the most widely used units of production. In this report the production is given both in feet of advance and tons mined. The in-place density generally used in the uranium mines to calculate tonnages is 16 cubic feet per ton of rock.

Time and motion studies are prepared in a wide range of detail and accuracy. The major items included in the time studies are usually production, ground support, and delay times. While the delay time pinpoints the mechanical weaknesses of the roadheader and the haulage systems, the reduction of ground support time offers the greatest potential for increasing the productivity of a roadheader mining system.

2.5.3 Manpower

The roadheader crew size and training period varied at each mine. Crew selection and motivation were a major factor in the performance at each operation. In mines where experienced miners were used to operate the new equipment, a motivation problem existed since the miners suffered a loss in earnings under an incentive contract bonus system. Better overall performance was obtained in these mines when inexperienced or partially trained operators were selected.

In the various systems observed, the crew size varied from two to five men, depending on the haulage system utilized and the ground support requirements. In some operations a mechanic was assigned to the roadheader at all times. Given reasonable mining conditions, a three-man crew should be adequate to perform the cutting, haulage and ground support operations.

Finding trained mechanics was a major problem for all the roadheader operations. Although the roadheaders mechanically are relatively simple when compared to large domestically manufactured continuous coal mining units, the roadheader mechanic must be trained for maintenance and repair. This was a problem for uranium operations since their mechanics had never worked on a continuous miner of any type. Usually the training of mechanics was performed by a service representative who was under contract to the roadheader equipment manufacturer. As a result, adequate time and training materials were not always provided for the necessary maintenance training.

2.5.4 Mining Selectivity

A roadheader has the flexibility of varying both the height and width dimensions within specified equipment capabilities. The cutting sequence presently being used permits mining the entire opening width to a partial face height before excavating the broken rock. This capability has been utilized in some operations for separation of ore and waste. The width dimensions of the loading aprons can be specified to meet the opening size requirements, and the two dimensions should be matched. This will not only reduce spillage, but also permit complete cleaning of the floor area with less operating time.

2.5.5 Cutter Heads and Spare Parts

Both the milling-type and ripper-type cutter heads have been used on the roadheader. The milling-type cutter is a cone-shaped head that rotates in line with the axis of the cutter boom. The cutting force is exerted in a sideward direction and does not effectively utilize the weight of the machine. In many cases, hydraulic jacks are added to stabilize the machine. The ripper-type cutter head has the same cutting action as the American-type continuous miners. The cutting action rips the rock directly onto the gathering arms and loading head. The ripper-type cutting action better utilizes the weight of the machine and does not require stabilizing jacks. Most manufacturers offer interchangeable cutter heads.

All the companies that have purchased a roadheader have also purchased a large supply of spare parts with the machine. The spare parts items were selected on the basis of the manufacturer's recommendations and have not necessarily represented replacement needs. Maintaining parts for only one or two machines requires a large capital charge per machine. A supply service problem also exists since the machines are manufactured in foreign countries, and the parts warehouses are being maintained in the eastern United States. These logistics have caused long delay times for some operators located in remote areas of the western United States.

2.5.6 Muck Handling Capabilities

The roadheader performs two separate mining functions: cutting rock from the face and loading and transferring the broken rock from the floor to a haulage system. In soft rock the roadheaders can easily perform the cutting function. The second function is more difficult regardless of the rock type.

The maximum loading capacity estimated by one roadheader manufacturer is 50 tons per hour. This loading rate has not been achieved in any uranium mine, because the rock could not be mined that fast and, therefore, the conveyor trough could not be completely filled.

Roadheaders are equipped with either a gathering arm and chain conveyor loading system, or with an encircling conveyor system. The gathering arm and chain conveyor system has a loading head or apron and two loading arms that move the rock onto a chain conveyor. The loading arms are powered through the chain conveyor by electric motors. The encircling conveyor system utilizes a flight conveyor to move the broken rock from an apron to a transfer located at the back of the machine. The major problem with the gathering arm and chain conveyor system is the wear of the conveyor and the sprockets used to drive it. Based on a one shift per day operation, the estimated life of a conveyor chain is six months. The gathering arm gears should be replaced once each year, and the gathering arms built up with hard face welding every month. The major complaints about the flight conveyor are its inability to handle blocky rock and that mucking and loading on a down slope are difficult.

Several mine operators have made modifications to the standards machines. The existing conveyors have been lengthened, sheet metal duct work has been installed over the conveyor, and the cutter heads have been exchanged and modified by changing the bit placement patterns. One mine operator installed a rubber conveyor belt in place of the chain conveyor and moved the electric motors used to drive the system from the back of the conveyor to a location beneath the loading head.

2.5.7 Dust Generation

An extremely difficult problem encountered by the operators of the roadheader machines is the control of respirable dust created by the cutting head, loading mechanism and conveyors.

Visual observations as well as airborne dust surveys indicate that the greatest amount of dust is created when the roadheader is cutting near the top of the mine opening. Sampling by one company indicates that approximately five times as much dust is created when cutting near the upper portion of the face as is created when cutting at the bottom of the face. The samples were collected near the cutting head, and the dust count was 1020 million particles per cubic foot at the top of the face, and 213 million particles per cubic foot at the bottom. No data was available to determine the dust emitted by the loading and conveying devices, but visual dust from these sources has been observed.

In order to abate the airborne dust problem, the mine operators have tried many configurations of nozzles to spray water on the falling rock and trap the dust before it becomes airborne. The roadheader manufacturer can supply standard spraying devices that are incorporated into the machines. In addition, the operators have installed not only additional sprays but also more effective nozzles than those originally supplied. The modified systems usually include additional nozzles mounted near the cutter head and several nozzles mounted over the loading device. The use of water for dust abatement has not been entirely successful because the nozzles do not emit enough small water droplets to wet the dust. The water droplets were normally coarse, and not all dust particles can be brought into contact with the water. Several commercial wetting agents were tested with the water sprays, but the results of these tests were not conclusive.

An electrically powered steam generator has been used at three of the operations. One operation reported that the steam had no apparent effect on the dust and use of the steam generator was discontinued. The other two operations reported that the steam was every effective in dust abatement, but no dust sampling records were available to verify the reports.

Several devices have been tested in attempts to protect personnel from airborne dust. Hoods using filtered and compressed air to create an artificial atmosphere, and variety of respirators have been tested. The hood tested by one company did provide a dust-free atmosphere for the roadheader operator, but its use was discontinued. The hood was bulky, the operator had limited visibility, and his mobility was restricted by the air supply hose. Respirators for personnel working near the roadheaders were required at all the operations visited.

2.6 PRESENT USE OF ROADHEADERS

Roadheaders are being widely used in the mining industry as underground construction support equipment, as primary development, and as production units. Descriptions of several mining operations that employ the newer roadheader models follow:

- A deep potash operation is using a roadheader as a construction unit for excavating headroom to install ventilation overcasts or conveyor drive and transfer stations. The roadheader cuts the high intersections by using the broken muck as a ramp to reach the desired height. The muck is loaded using a 5-yard^3 load haul dump unit (LHD) which dumps into mined-out rooms. Rock bolts are installed only when slabbing occurs. The average production rate is 25 tph (approximately 400 ft^3/hr) using a 3-man crew.

- The roadheader is used both for mine development and for ore production in a borate operation. The production system is basically a room and pillar mine plan where the roadheader is moved from heading to heading. The ground support in the room and pillar section consists of rock bolts and mats. In the drift development arched steel sets are installed for ground support. The muck is dumped on the ground by the miner and loaded by a 5-yd^3 LHD into 20-ton trucks. Cutting rates in the production operation have attained 150-tph, but haulage limitations reduce production to approximately 100 tph.

- In several coal mining operations, roadheaders are used to excavate rock for overcasts and to install rail and conveyor systems. A new model roadheader is presently being used to take up three feet of sandstone floor to provide headroom for a haulage drift. The rock strength has been estimated at 17,000 to 18,000 psi with a production rate averaging 115 tons/shift (about 1,800 ft^3/shift). There is no delay for ground support, as the roof bolts were installed during the coal mining phase.

- A new uranium mining operation is using a modified roadheader as a development and production unit. High mine temperatures and water inflows have reduced the operating performance. The supervisor crew is being trained to operate the machine for familiarity. The primary objective will be to develop a ventilation system. The rock strength has been tested at 5,000 to 6,000 psi and the ground requires rock bolts and wire mesh for support. The roadheader is equipped with a transfer conveyor designed with sufficient height and reach to dump directly into a 10-ton truck.

III. ECONOMIC COMPARISONS

3.1 INTRODUCTION

A cost estimate was prepared which compares the roadheader with the conventional drill and blast mining system. Two mining operations, haulage development and stope development with pillar recovery, were evaluated in this study. In the mine haulage drifting operation, the roadheader and the drill and blast systems were compared for both rail and rubber-tired haulage support units. In the stope mining evaluation, three alternate combinations of method and equipment, roadheader, slusher, and slusher-LHD, were evaluated and compared.

This section is presented in four parts: component costs, drift development costs, stope production costs, and a summary.

3.2 COMPONENT COSTS

The cost estimate for each alternative mining comparison is summarized in three cost categories; labor, equipment, and supplies. This section describes the components that are included in each item.

All costs presented in this study are direct costs. No general mine costs are included in the estimate. General mine costs include expenses for mine services, hoisting, muck disposal, raise development and supervision. All costs are as of July, 1979 and were prepared from telephone quotes supplied by various manufacturers and mine operators.

3.2.1 Labor Costs

In a majority of the uranium mining operations, both the skilled miners and the support laborers are paid a production bonus. This production bonus is paid on units of work completed at a fixed price per unit.

For this study, the costs were calculated with the criteria that the conventional mining workers would be paid a production bonus while the roadheader crew would be paid straight day's pay, following the current practices.

Table 12 totals the hourly and contract pay for the roadheader and conventional crew. The hourly rates include the base hourly rate, fringes (vacation, holidays and sick leave), contract bonus, payroll taxes and insurance. These rates were obtained from an operating mine. The contract bonus is an average rate for the entire mine.

TABLE 12. - Hourly and contract labor rates

Item	Contract Miner	Roadheader Miner
Base Rate	$ 8.24	$ 8.24
Fringes	1.09	1.09
Subtotal	$ 9.33	$ 9.33
Production Bonus	6.15	0.00
Subtotal	$15.48	$ 9.33
Payroll Taxes and Insurance	3.44	2.07
Total Cost per Hour	$18.92	$11.40

Repair and service hours for each piece of equipment were obtained both from operating records maintained by Morrison-Knudsen and from mine operator's records. The maintenance labor costs were calculated for each alternate mining estimate and are included in each cost comparison estimate under the labor unit. The maintenance labor costs were calculated using a straight day's pay rate for the maintenance hours required for each piece of equipment.

3.2.2 Equipment Ownership Costs

Equipment hourly ownership costs were calculated by dividing the equipment purchase price by the expected operating hours. Table 13 summarizes the equipment purchase price for the large item units, the estimated operating life for, and the ownership cost per hour.

3.2.3 Supply Costs

Expendable supplies are materials which are consumed in the daily mining operation. Table 14 lists the unit prices for the most common items consumed in uranium mining.

The expendable supply item costs are based on allowances for actual material consumed in each mining activity. In addition to the expendable supply costs, maintenance supplies, repair parts, and outside overhaul service costs have been included in the total supply costs. These costs are based on the operating history of each piece of equipment and are calculated as a dollar cost per operating hour.

3.2 DRIFT DEVELOPMENT COST ESTIMATE

Two mining conditions were projected for drift development operations: one was wet, requiring rail haulage, and the second was a dry drift where rubber tired haulaged units could be used. For each operating condition, alternate mining production capabilities and costs were prepared for both the roadheader and the conventional drill and blast system. Following is a description of each mining system, together with the estimated costs for each.

TABLE 13. - Equipment Ownership Costs

Item	Cost*	Operating Hours**	Cost per Hour
Roadheader	$200,000	7,000	$28.57
LHD (2yd^3 bucket)	91,300	10,000	9.13
Diesel Truck (5 ton)	29,600	10,000	2.96
Locomotive	69,000	15,000	4.60
Ore Cars	6,700	10,000	0.67
Rail Mounted Overhead Loaders	27,300	10,000	2.73
Fan (25 Hp)	5,400	20,000	0.27
Slusher with Scraper	19,000	30,000	0.63
Rock Drill	3,400	2,000	1.70
Impact Wrench	1,740	2,000	0.87

* These are engineering price quotes obtained through telephone conversation with the equipment manufacturers. All costs are on a July, 1979 base.

** Operating hours are the useful life in hours that the equipment works. An example calculation is:

Roadheader Hours - 2.8 hour/shift x 2 shift/day x 250 days/year x 5 years = 7,000 hours

TABLE 14. - Supply costs - expendable materials

Item	Purchase Price per Unit
Roadheader Cutter Bits	$9.17 each
Rock Bolts	4.62 each
Steel Mats (rock bolting)	0.36 pound
Wire Mesh	0.27 square foot
4" Water Line	4.95 foot
6" Air Line	8.11 foot
2" Water Line	1.65 foot
Ditch Liner	3.57 foot
Wood Ties	0.33 board foot
60# Track Switch	2,500.00 each
60# Track	600.00 ton
Track Bolts and Plates	20.00 pair
Steel Ties	12.00 each
Spikes	0.40 each
Stulls	4.84 each
Slusher Cable	0.46 foot
Explosives	0.54 pound
Blasting Caps	0.85 each
24" Vent Tube Fiberglass	10.50 foot
24" Flexible Vent Tubing	1.87 foot

3.2.1 Rail Drift Development (wet conditions)

In wet mining conditions, diesel powered locomotives pulling mine cars transport the muck from the face to the shaft station or some other dump location. The mine development plan includes advancing a single main haulage drift with spur drifts extending beneath the ore zone.

In comparing the two mining systems, the roadheader cuts a 10 foot x 10 foot drift approximately 12 feet deep per cycle. However, expected advance is only slightly more than one-half a cycle per shift or about 6.5 feet. The conventional drill and blast operation advances the 10 x 10 drift in 6-foot rounds. Both systems consume the same amounts of rock bolts, wire mesh, air and water lines, rail and ties, track switch, and ditch liner.

Table 15 includes production capacity and design criteria used in estimating the cost of the two alternate mining systems developing a rail haulage drift.

TABLE 15. - Production criteria (wet mining conditions - rail haulage)

Item	Roadheader	Conventional
Crew Size	3	2
Labor Rate	Straight Pay	Bonus Pay
Drift Advance per Shift	6.5 feet	5.0 feet
Shifts Operated per Day	2	2
Equipment Lists:	Roadheader Transfer Conveyor Rock Drill Impact Wrench Auxiliary Fan	Air Powered Overshot Loader Rock Drill Impact Wrench Auxiliary Fan

Using this criteria, costs were calculated on a per foot of drift advance and include all supplies required for installation of a finished drift. Not included are costs for the general mine services, hoisting, muck disposal, and supervision.

Table 16 summarizes the cost comparison for developing a rail haulage drift using the roadheader and the conventional drill and blast system.

TABLE 16. - Cost comparison - drift development (wet mining conditions)

	Cost Per Foot				
System	Oper. Labor	Maint. Labor	Equipment	Supplies	Total
Roadheader	$42.15	$ 7.08	$15.23	$99.69	$164.15
Drill and Blast	60.06	6.17	5.50	100.17	171.84

The results show that the roadheader is slightly less expensive than the conventional system in this application. The additional equipment costs for the roadheader system are offset by the increased productivity - 6.5 versus 5.0 feet per shift.

3.2.2 Trackless Drift Development (Dry)

In drift development in dry mining conditions, rubber tired haulage units are used in place of locomotive and mine car haulage systems. The drift layout and cross-section dimension are the same for both conditions.

Supply costs are lower in the dry drift development because no rail or drainage ditches are installed. All other supply costs are identical for the two mining conditions.

Production capacity and design criteria used in estimating the cost of the roadheader and conventional drill and blast drift development are summarized in Table 17.

TABLE 17. - Production criteria (dry mining conditions - rubber tired haulage)

Item	Roadheader	Conventional
Crew Size	3	2
Labor Rate	Straight Pay	Bonus Pay
Drift Advance per Shift	8.1 feet	6.0 feet
Shifts Operated per Day	2	2
Equipment Lists:	Roadheader	LHD 2-Yd^3 Bucket
	Two 5-Ton Trucks	Rock Drill
	Transfer Conveyor	Impact Wrench
	Rock Drill	Auxiliary Fan
	Impact Wrench	
	Auxiliary Fan	

These criteria were used to prepare cost estimates for the roadheader and the conventional drill and blast system. Not included are costs for the general mine services, hoisting, muck disposal and supervision. These costs are totaled in Table 18.

TABLE 18. - Cost comparisons - drift development (dry mining conditions)

	Cost Per Foot				
System	Oper. Labor	Maint. Labor	Equipment	Supplies	Total
Roadheader	$33.70	$ 5.44	$12.84	$78.40	$130.38
Drill and Blast	49.51	2.74	2.40	67.75	122.40

The roadheader is slightly more expensive than conventional in this comparison. Under the dry conditions, the conventional system has higher productivity and lower equipment and supply costs.

3.3 STOPE PRODUCTION

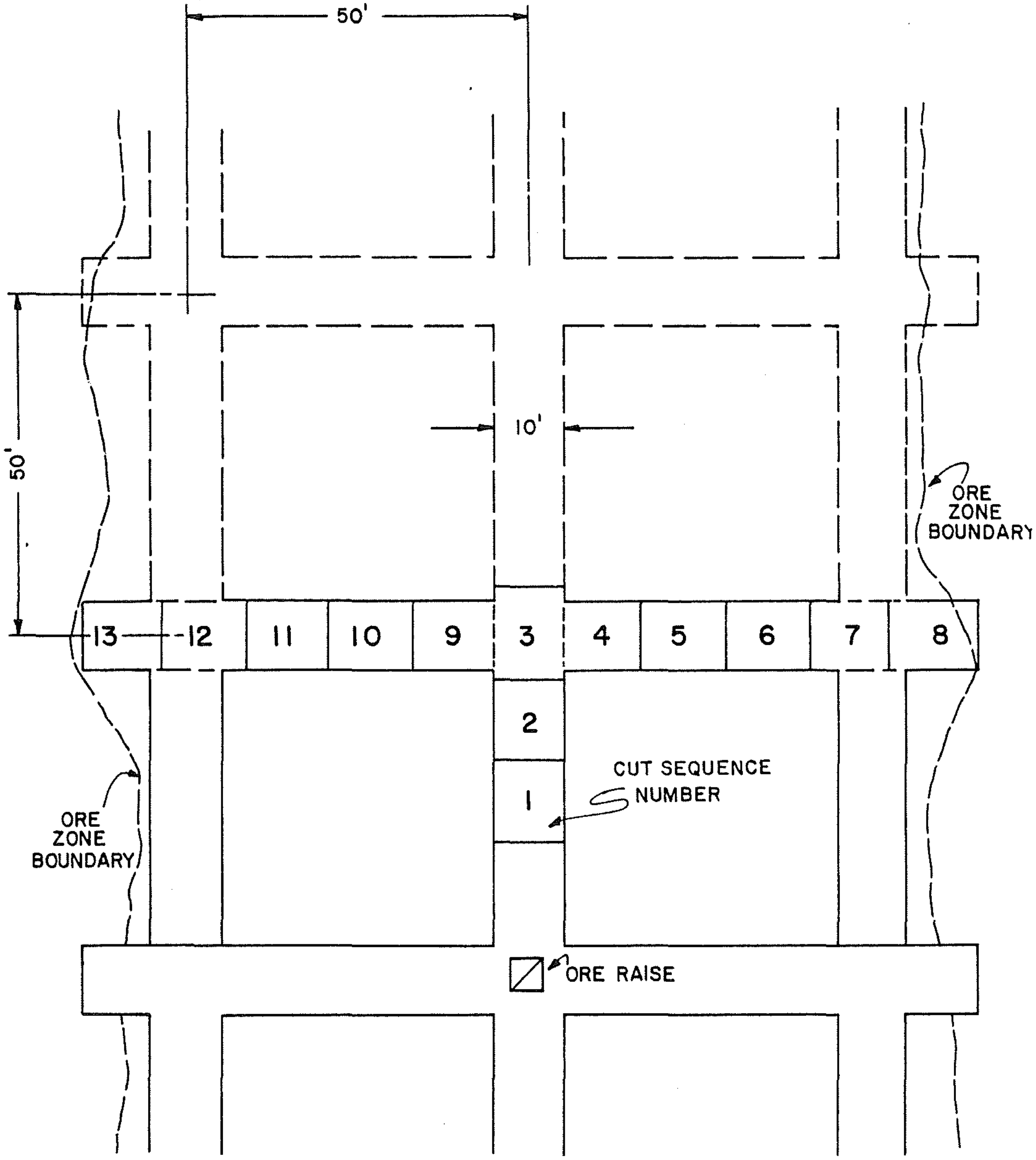
The second mining situation where the roadheader has been utilized in the uranium industry is in ore production or stope mining. In stope mining, the mine plan used is similar in most cases with the variations being in the selection and utilization of equipment. For this study, costs were estimated for three alternate equipment systems: the roadheader, a slusher operation, and an LHD and slusher combination.

Following is a description of each stope mining system along with the production criteria for each system. The costs are summarized in three categories: labor, equipment, and supplies with the results expressed in dollars per ton mined.

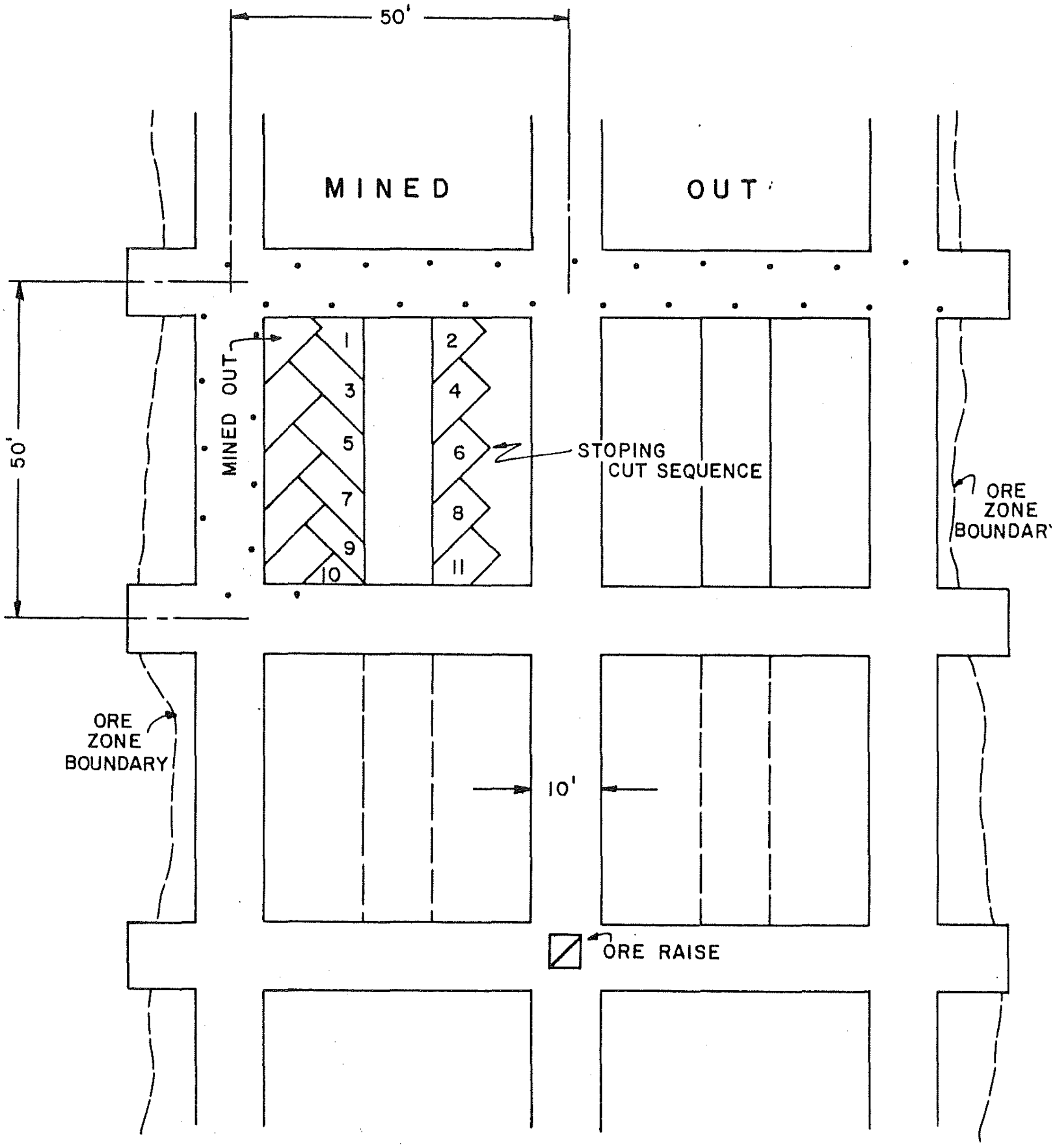
3.3.1 Roadheader Stope Mining

The stope mining operation is separated into two mining functions or sequences. The first sequence includes developing 10 foot x 10 foot drifts in a room and pillar plan extending to the boundary of the ore body. (See Figure 10.) The final sequence is the recovery of the pillars that were blocked out as the initial development drifts were extended. (See Figure 11.)

In developing the rooms, the roadheader advances 12 feet in one cycle then backs away from the face, allowing the crew to install the ground support consisting of wire mesh and rock bolts. By advancing only 12 feet per cycle, the roadheader operator is always working beneath permanent ground support.



ROADHEADER STOPE DRIFT DEVELOPMENT
FIGURE 10



ROADHEADER STOPE PILLAR RECOVERY
FIGURE II

The first step in the pillar recovery operation is to split the pillar by driving a 10 x 10 drift through the middle of the pillar. Next the roadheader makes wing cuts from each side of the remaining partial pillar. By using this mining sequence, the pillar can be recovered without exposing the roadheader operator to unsupported ground conditions. Ground support installed in the pillar mining cycle consists of stulls installed in the wing cuts and access drifts.

The criteria and production capacities used in preparing the cost estimate is summarized in Table 19.

TABLE 19. - Roadheader stope production criteria

Item	Development	Pillar Recovery
Ore Thickness	6 Feet	6 Feet
Mining Height	10 Feet	10 Feet
Mining Width	10 Feet	Variable
Ore Tons Mined	2,962	2,280
Total Tons Mined	4,938	3,800
Tons Mined per Shift	51.3	58.3
Crew Size	3	3
Equipment Requirements:		
- Diesel Trucks (5-Ton)	2	2
- Rock Drill (Rock Bolting)	1	-
- Impact Wrench	1	-
- Fan (25 Hp)	1	1
- Auxiliary Conveyor	1	1

Table 20 contains the cost estimate for the roadheader operating in a stope mining operation.

TABLE 20. - Roadheader stoping costs summary

Operation	Tons	Labor	Equipment	Supplies	Total
Stope Drilling	3,938	$24,658	$8,089	$43,092	$75,839
Split Pillars	1,000	6,262	2,054	10,944	19,260
Pillar Recovery	3,800	20,596	6,726	21,432	48,754
Total Costs		$51,516	$16,869	$75,468	$143,853
Unit Costs-Total	8,738	$5.89	$1.93	$8.64	$16.46
Unit Costs-Ore	5,242	$9.83	$3.22	$14.39	$27.44

3.3.2 Slusher Stope Mining

In several mining operations, three-drum slushers are used both to advance the stope development drifts and to mine the pillars. The slusher equipment is used to advance drifts on a room and pillar plan whereby 6 foot x 6 foot drifts are extended to the limits of the ore block. (See Figure 12.) After the stope is fully outlined by the drifts, the next step is to recover the pillars by using a slabbing system which is extended on a diamond pattern. (See Figure 13.)

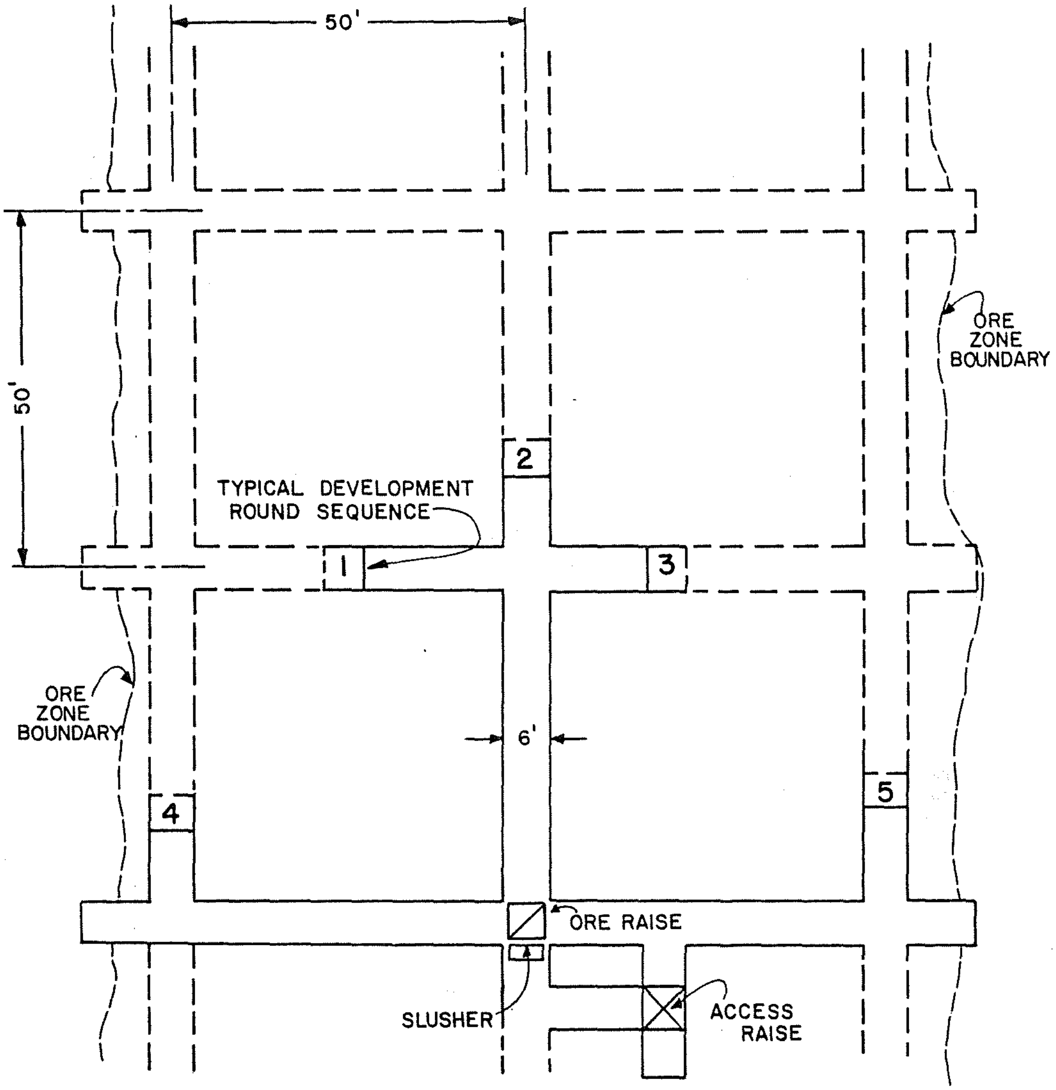
Initial development of the slusher stope begins with excavating ore and manway raises from the track drift to the ore zone. Raise costs are not included in this cost estimate. After the two raises are completed and the slusher installed, the drift development begins at the area nearest the raise and extends to the limits of the ore blocks. The final operation is slabbing the pillar and slushing the ore to the raise.

Ground support is required at the drift intersections. Rock bolts and mats are used in this area. In pillar recovery operation, stulls are installed in the drift and along the ribs of the pillar to be slabbed.

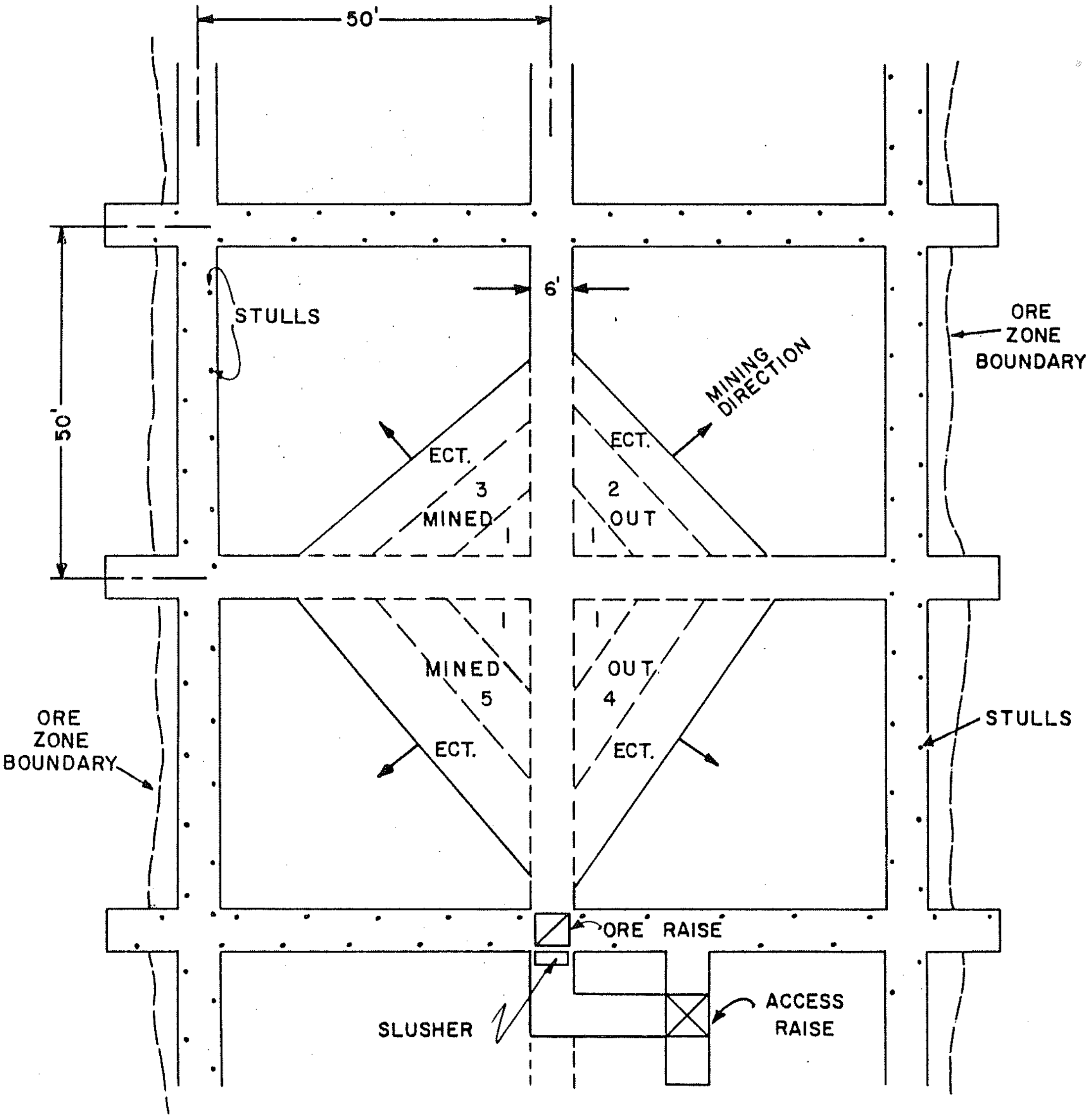
Table 21 contains the criteria and production capacities used in preparing the cost estimate for the slusher mining system.

TABLE 21. - Slusher stope production criteria

Item	Development	Pillar Recovery
Ore Thickness	6 Feet	6 Feet
Mining Height	6 Feet	6 Feet
Mining Width	6 Feet	Variable
Ore Tons Mined	1,418	3,824
Tons Mined per Shift	33.8	50.0
Crew Size	2	2
Equipment Requirements:		
- Rock Drill	1	1
- Fan	1	1
- Impact Wrench	1	-
- Slusher	2	2



SLUSHER STOPE DRIFT DEVELOPMENT
FIGURE 12



SLUSHER STOPE PILLAR RECOVERY
FIGURE 13

Table 22 includes the cost estimate for the full slusher stope operation.

TABLE 22. - Slusher stoping cost/summary

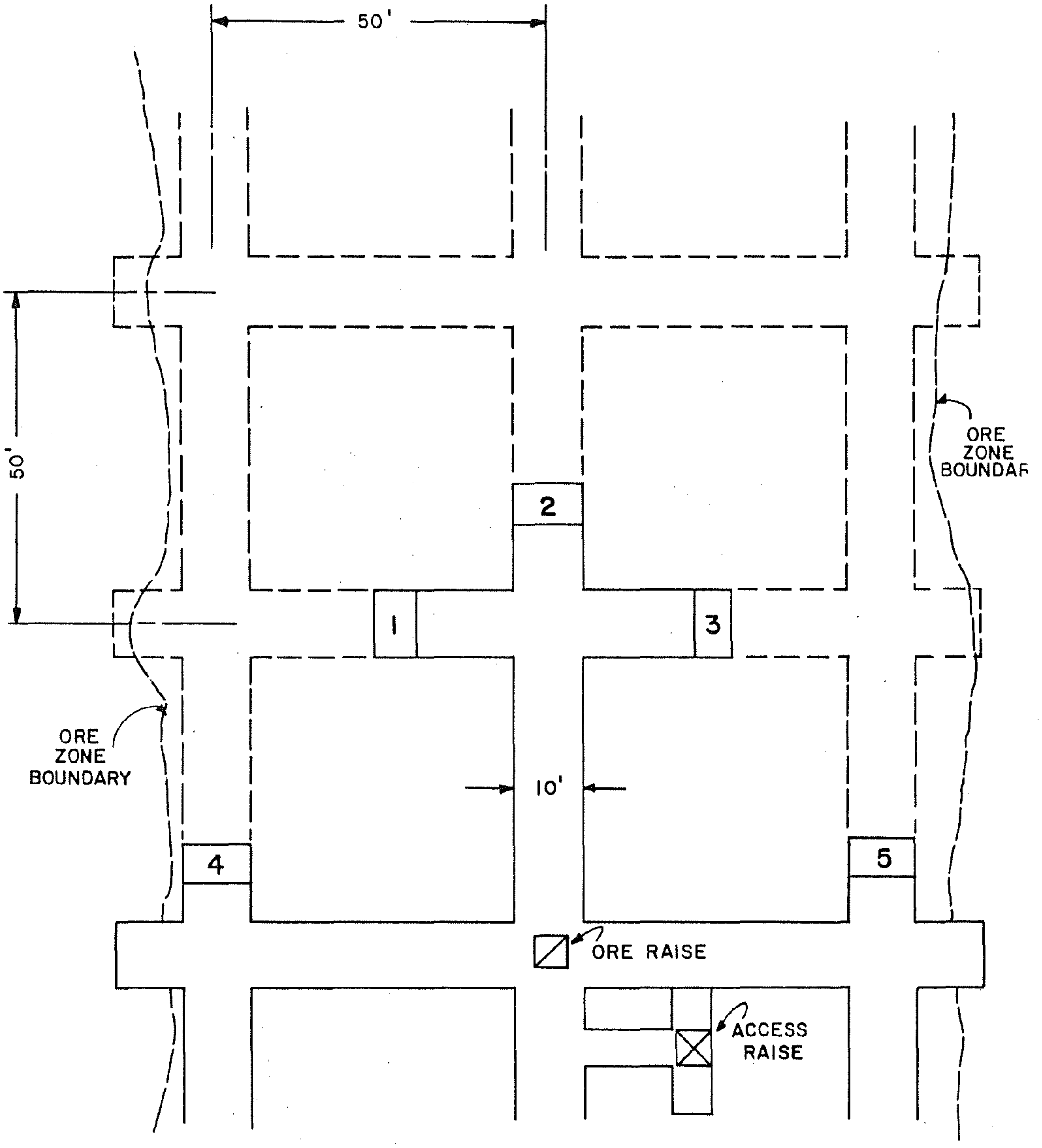
Operation	Tons	Labor	Equipment	Supplies	Total
Stope Drifting	1,418	$11,088	$409	$11,019	$22,516
Pillar Recovery	3,824	22,868	688	11,396	34,952
Total Costs		$33,956	$1,097	$22,415	$57,468
Unit Costs-Ore	5,242	$6.48	$0.21	$4.27	$10.96

3.3.3 LHD and Slusher Stope Mining

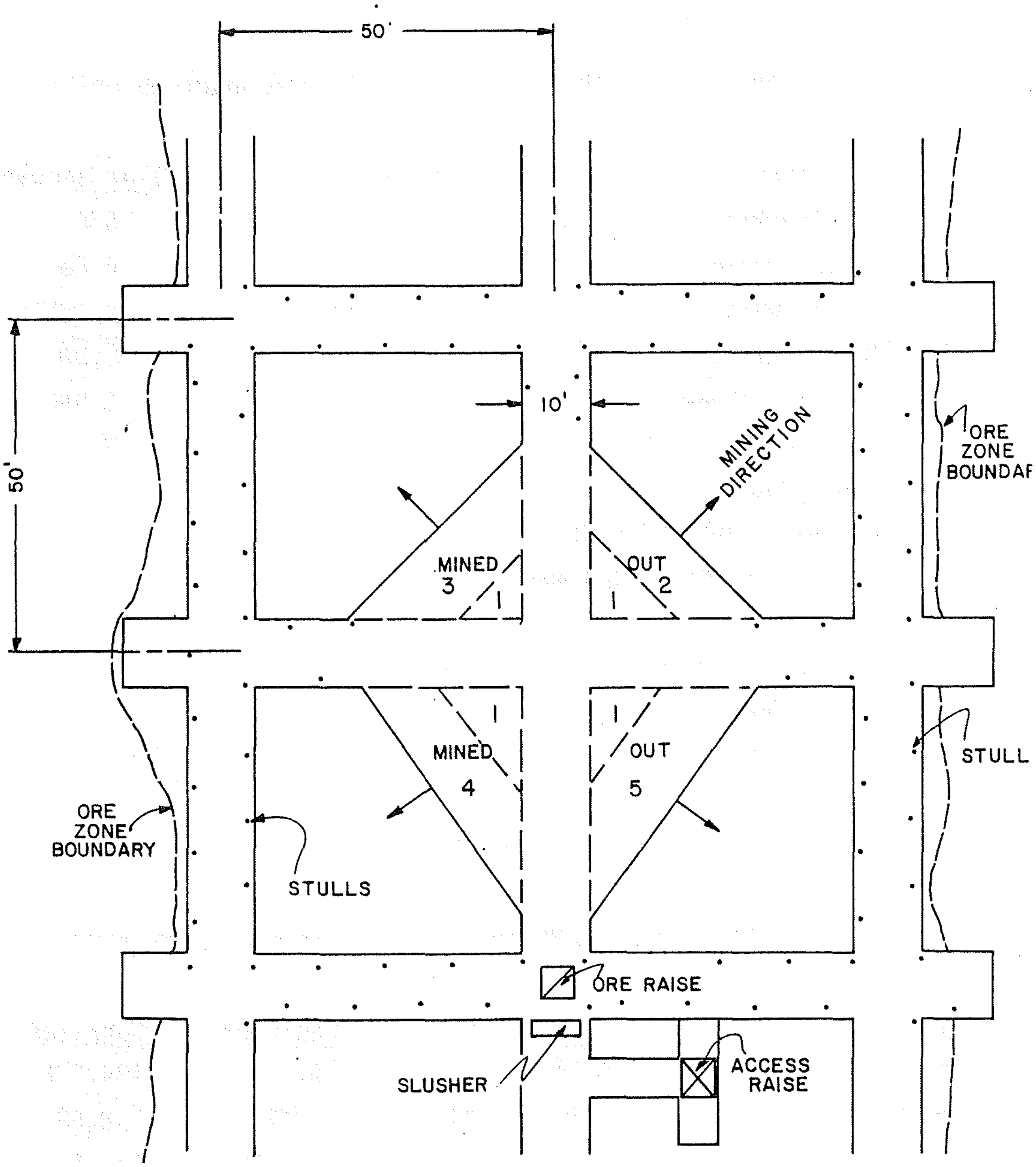
LHD units can be used for drift development of a room and pillar mining pattern, after which the pillars can be mined with a slusher. (See Figure 14.) The LHD equipment is capable of a higher development production capability than the slusher equipment. In the pillar recovery phase, a slusher is installed and the pillars are slabbed using the diamond plan developed for the slusher system. (See Figure 15.)

An LHD unit has the operating advantage of increased flexibility and maneuverability in mining a stope where several drifts are being worked simultaneously. In addition, large tonnages can be blasted with only a small increase in explosives cost. The disadvantages of an LHD include a minimum mining height of eight feet and increased ventilation requirements. The eight foot mining height causes ore dilution in many stoping areas.

Ground support for the drift development phase includes bolting the back using wire mesh. In the pillar recovery mining, stulls are installed in the drift and along the pillars that are being slabbed to provide protection for the miners.



LHD SLUSHER STOPE DRIFT DEVELOPMENT
FIGURE 14



LHD SLUSHER PILLAR RECOVERY
FIGURE 15

Men, supplies, and ore travel through manway and ore raises. Access for the LHD is by a ramp from the haulage drift to the stope elevation. No costs are included for this development work.

The criteria and production capacities used in preparing the cost estimate are included in Table 23.

TABLE 23. - LHD and slusher stope production criteria

Item	Development	Pillar Recovery
Ore Thickness	6 Feet	6 Feet
Mining Height	8 Feet	6 Feet
Mining Width	10 Feet	Variable
Total Rock Mined (Tons)	3,150	2,880
Ore Tons Mined	2,363	2,880
Tons Mined per Shift	50.0	50.0
Crew Size	2	2
Equipment Requirements:		
- LHD (2-Yd^3 bucket)	1	-
- Fan	1	1
- Rock Drill	1	1
- Impact Wrench	1	-
- Slusher	-	2

Table 24 includes the cost estimate for the LHD Slusher stope operation.

TABLE 24. - LHD and slusher stoping costs summary

Operation	Tons	Labor	Equipment	Supplies	Total
Stope Drifting (LHD)	3,150	$17,470	$1,292	$34,278	$53,040
Pillar Recovery	2,880	17,222	518	8,582	26,322
Total Costs		$34,692	$1,810	$42,860	$79,362
Unit Costs/Total Tons	6,030	$5.75	$0.30	$7.11	$13.16
Unit Costs/Ore Tons	5,242	$6.62	$0.34	$8.18	$15.14

3.4 SUMMARY

Table 25 compares the costs for mining with a roadheader with those for the conventional drill and blast system. The cost estimate includes the costs for developing a haulage drift in both wet and dry mining conditions.

TABLE 25. - Drift development cost summary

A. Rail Haulage (Wet)

	Cost Per Foot			
	Labor	Equipment	Supplies	Total
Roadheader	$49.23	$15.23	$99.69	$164.15
Drill and Blast	66.17	5.50	100.17	171.84

B. Rubber Tired Haulage (Dry)

	Cost Per Foot			
Roadheader	$39.14	$12.84	$78.40	$130.38
Drill and Blast	52.25	2.40	67.75	122.40

In the two cases evaluated, the roadheader is less expensive in the wet mining conditions where track haulage is required. In the dry mining conditions, the drill and blast system is less expensive. This is due to the higher production or footage of advance obtained by the conventional drill and blast system when operating in the dry conditions.

Of the two mining systems, the roadheader has demonstrated a higher production capability in more adverse mining conditions. This is mainly due to the rock breaking mechanism that reduces ground disturbance. A second advantage is the ability of the roadheader to vary the amount of open ground exposed as desired.

Table 26 compares the production costs for mining an ore zone using the three types of mining equipment.

TABLE 26. - Stope mining cost summary

			Cost per Ton			
		Tons	Labor	Equipment	Supplies	Total
Roadheader	Total	8,738	$5.89	$1.93	$8.64	$16.46
	Ore	5,242	9.83	3.22	14.39	27.44
Slusher	Ore	5,242	6.48	0.21	4.27	10.96
LHD-Slusher	Total	6,030	5.75	0.30	7.11	13.16
	Ore	5,242	6.62	0.34	8.18	15.14

These cost estimates indicate that the slusher stoping system is the most economical of the three systems evaluated. This is mainly due to the low capital costs of the slusher system. In addition, not only is the production rate of the slusher system comparable to the roadheader in the pillar recovery mining operation, but also the minimum mining height required for the slusher system reduces the ore dilution in thin ore zones.

The LHD-slusher system is the second most economical system for stope production. The biggest advantage of this system is the higher production capacity during stope development followed by the production efficiencies of the slusher pillar mining. Ore dilution is a problem with LHD equipment. The minimum mining height of 8 feet will cause some dilution in thin ore bodies during drift development.

The roadheader is the most expensive of the three stoping systems evaluated, a result of both high capital costs and low productivity. The roadheader has a record of low utilization, approximately 2.8 hours per 8.0 hour shift or about 35%. Also, the ten-foot mining height greatly increases the total tonnage to be handled. It is true that selective mining is possible with a roadheader system, and thus grade dilution can be minimized. Nevertheless, the costs incurred in mining the additional tons must be borne by the ore tons produced. In a six-foot ore zone, a ten-foot mining height will raise the cost per ton by about 67%. Newer roadheader designs may reduce the required mining height and consequently remove this cost disadvantage.

IV. PROBLEM AREAS

4.1 INTRODUCTION

Mine operations problems with presently available roadheaders can be placed in four categories:

1. Integration into the mining cycle, particularly ground support.
2. Mechanical problems.
3. Electrical problems.
4. Dust generation.

In addition, the high capital costs of roadheaders as compared to conventional mining methods must be offset by either higher production or lower operating costs.

4.2 INTEGRATION INTO THE MINING CYCLE

Roadheader productivity is severely restricted by the need to relinquish cutting time for necessary ground support work. Table 27 summarizes an average shift for a 21 month period at an underground uranium mine. During this period, both drifting and stoping work was done. Note that the ground support time is nearly equal to the mining time, and that the other delays are relatively small compared to the ground support time.

4.3 MECHANICAL PROBLEMS

The mechanical problems of roadheaders currently in service include:

1. The chain type discharge conveyor, of the single (center) chain drive type, has been extremely troublesome. Rocks cause the chain flights to bind against the conveyor sides, resulting in broken flights and/or chains.

TABLE 27. - Average roadheader shift

	MINUTES PER SHIFT	PERCENT
Roadheader Mining	175	36.5
Ground Support	140	29.2
Roadheader Downtime	30	6.2
Ventilation Work	30	6.2

Lunch	30	6.2
Drill Probe Holes	20	4.2
Move Air and Water Lines	15	3.1
Travel to and from Job	15	3.1
Haulage Equipment Down	10	2.1
Miscellaneous Delays	10	2.1
Drill and Blast Hard Ground	5	1.1
Total Shift Time	480	100.0

Tons Mined per Shift	54
Tons Mined per Operating Minute	0.308
Tons Mined per Shift Minute	0.113
Tons Mined per Year:	
@ 250 shifts/year	13500
@ 300 shifts/year	16200
@ 500 shifts/year	27000

2. The gathering arms break due to under design and impact loading. Wear on the gathering arms has been excessive due to the abrasiveness of the material being handled.

3. Lubrication systems are poorly designed, and automatic lube systems are troublesome and do not function adequately.

4. On some units the loading arms and conveyor are interlocked and powered by the same drive mechanism. This arrangement makes it harder to adjust and repair the combined system.

5. The conical bits on the cutter heads seize in place and do not rotate, thereby defeating the self-sharpening feature.

6. Carrying and return idlers on center rubber belt conveyors have seized, thereby accelerating wear on both the idlers and the conveyor belting.

4.4 ELECTRICAL PROBLEMS

Electrical problems, while few in number, were usually severe in that major downtime resulted.

1. Switch gear components were installed incorrectly (vertical units being installed horizontally) or improperly specified (no load contacts closing under load).

2. Electric motors which power the gathering arms and the crawlers failed due to operating in or under water.

3. Electrical installations, such as connectors, could not withstand the high vibration induced when the unit was operating.

4.5 DUST GENERATION

Since introduction of the roadheaders in uranium operations, several spraying, dust collection and ventilating systems have been used to control any dust generated. Several of the systems, along with the results, are described below:

1. A dust collection system was used whereby the return air was cleaned and returned to the drift where the men are working. The collection system did not reduce the dust count to a sufficiently low level to permit men to work in the drift. Another problem was that, in a 10' x 10' drift, the size of the collector unit required that cutouts be excavated to house it.

2. Various arrangements of both water and steam spray systems have been utilized with limited success. Wetting agents have been added to the spray water, and did improve the ability of the water droplets to attach to the dust particles. The steam dust control system was tested at several operations, but the field results did not demonstrate that this system was superior to water sprays. From all field reports, available dust suppression or collector systems have not permitted the exhaust air to be recirculated to the working heading.

3. At present, the only acceptable ventilation system exhausts the dust laden air directly to the return airway. The most widely used system includes an auxiliary fan and rigid duct. In stoping areas where a return airway has been developed, curtains have been successful in controlling the exhaust air.

V. CONCLUSIONS

In recent years, uranium mine operators have experimented with roadheaders as a means of increasing productivity. To date the roadheaders have not shown the consistent productivity necessary to be used as the prime production unit. Equipment limitations and mine plan restrictions have been the prime contributing factors.

The first roadheaders were designed to operate in coal and soft rock formations. These machines were used in Europe for development and construction work in underground coal mines. In the United States, roadheaders have been used in construction and in uranium mining operations. As the need to improve performance arose, the later models were capable not only of cutting at a higher production rate, but also of cutting rock up to 10,000 psi compressive strength. Improvements in the conveyors, tramming, and other components have reduced the mechanical failure rate. With further improvements in the equipment capabilities and development of an integrated mining system, the productivity of these mechanized mines should improve.

In selected mining applications the roadheaders have demonstrated the ability to exceed the producitivty rates of the conventional drill and blast system. From these results the overall potential for future use of the roadheader in uranium mining appears to be good. It remains to be proved if the increase in productivity will offset the increased capital costs of the roadheader.

Many downtime problems seem to be inherent in the present machines. Most of the equipment problems can be minimized through equipment modifications. Application of the roadheader in mining situations that are planned specifically for the machine, rather than fitting it into an existing mining system, should minimize operating delays.

Negative employee acceptance of a new approach to mining has caused loss of efficiency at some of the operations. The assignment of new employees to the roadheader has been used to overcome this detriment to the operation. Interest expressed by most operators indicates that more of the machines will be used in the future. Management personnel at two new mines that are currently being developed stated that roadheaders will definitely be used in the mines because of anticipated high ambient temperature and ground control problems.

VI. RECOMMENDATIONS

Roadheaders have enjoyed limited success in uranium operations in the United States. This study has identified many of the problems that have hampered the wide acceptance of roadheaders. To improve the overall performance of the roadheaders, a three-phase development program is proposed. The three areas of improvement include:

- Equipment manufacture, maintenance and crew training
- General equipment design and modifications
- Mining System design and equipment productivity

6.1 EQUIPMENT MANUFACTURE, MAINTENANCE AND CREW TRAINING

A cooperative effort by both the roadheader manufacturer and the mine operator is required to achieve high unit availability in the minimum length of time after delivery of a machine to the mine site. Agreeement should be reached between the two parties at the time the unit is ordered, on responsibility for definite items that will affect availability.

The equipment manufacturer has certain responsibility in the manufacture and service of the equipment sold. Following are some ares where the manufacturer has the responsibility for fabrication and service of the equipment:

1. Quality workmanship at the factory.
2. Completely assemble and field test all components under full load in all motions at the factory.
3. Deliver adequate number of operating and maintenance manuals and parts books with the machine. Timeliness is important for the establishment of the maintenance program and the procurement of repair parts.
4. Provide services of an operator trainer for at least 15 days.
5. Provide services of a technical representative for 30 days to train mechanics and electricians in the proper servicing, troubleshooting, repair work and component replacement techniques.
6. Provide services of a qualified engineer to design, implement and document field modifications as the needs arise.
7. Maintain adequate levels of repair parts at nearby facilities.

The mine operator's responsibilities include operating, maintenance and service of the roadheaders. Following are some of the items that will improve the overall roadheader operation:

1. Train operating and maintenance crews for proper opeation, servicing, troubleshooting, and repair of the units.
2. Provide good shop facilities as an absolute necessity. If the units are operating in wet underground mines, a well-ligthed, dry, clean, and equipped shop should be constructed underground.

3. Actively support the concept of preventive maintenance by establishing the preventive maintenance program before the unit goes into operation and actively following the program after production starts.
4. Stock critical components, such as cutter heads, on site to facilitate a component removal and exchange-repair system.
5. The roadheader crew should be included in an incentive bonus pay system if the remaining miners are under such a system.

6.2 GENERAL EQUIPMENT DESIGN AND MODIFICATIONS

This section describes the roadheader design modifications that should be incorporated in a prototype machine. These changes should improve the operating performance plus reduce the delays due to mechanical breakdowns and repair time. Some of the newer roadheader models have incorporated several of these modifications. While any design is a compromise of sorts, the following equipment modifications would improve the operating performance of the roadheader.

Equipment modification recommendations are presented in three categories:

- General design
- Mechanical modifications
- Electrical modifications

6.2.1 General Design

1. The operational and dimensional requirements of the customer must be considered. This includes providing adequate flotation for the expected ground conditions.
2. The major components for underground units must be sized so that all pieces can be lowered into the mine. Easy disassembly and reassembly of the unit are requirements for long moves within a mine. This can be partially met by providing properly sized lifting eyes on the components and quick disconnects on hydraulic lines and, where practical, electrical conductors.
3. The machine must be designed to operate in extremely wet conditions. By making various compartments watertight and ventilated, periodic cleaning of the machine by high pressure steam or cold water as part of a maintenance program would be facilitated.
4. All MSHA, OSHA, and other applicable government regulations must be followed.
5. Since routine servicing, repairs and component replacement will undoubtedly take place under adverse conditions, this work must be simplified to the maximum degree by making all items which require service readily accessible.
6. A maximum of standardization of fittings should be applied. The number of different sizes and types of fasteners, hydraulic hose, filters, etc., should be kept to a minimum.

7. Doors to compartments which require frequent access should be hinged and equipped with watertight seals.
8. Noise level should be reduced to acceptable decibel values.
9. Modified hydraulic system could provide an easy hookup of an external hydraulic pump-filter unit for the periodic cleaning of the installed hydraulic oil.
10. A minimum number of oils and lubicants should be required.
11. A high quality paint job including proper primers would prevent rusting and improve the appearance of the unit.
12. Consumable items, e.g., bits, should be readily available from local sources.
13. Protection must be provided to mitigate the effect of continuous vibration. All connections, both hydraulic hose and electric wiring, and all fasteners must be of such a design that they will not loosen as a result of being subjected to intense and prolonged vibration.
14. The concept of component exchange must be applied. The installation of all components should be designed for easy removal and replacement.

6.2.2 Mechanical Modifications

1. The maximum number of machine motions should be powered by hydraulic or air motors rather than electric motors to reduce the potential for motor stalls or shorts.
2. Variable speed tramming motors should be used, a low speed to crowd the unit during the cutting phase and a high speed for propelling the unit between various areas in the mine. If the required speeds are not attainable by variable means investigation of two separate systems should be made.
3. Conveyors should be driven from the head ends by two hydraulic motors independent from the gathering arms.
4. The Society of Automotive Engineers (SAE) Standard J753A titled "Lubrication Chart" should be followed to provide the basic data for the proper routine servicing of the unit. This standard covers embossed plates of the lubrication diagrams which should be installed on the machine in a conspicuous location.
5. The lubrication hoses and grease fittings should be collected at a minimum number of accessible blocks.
6. Rubber belt conveyor belts are usually more trouble-free than single or double chain type conveyors and should be utilized.
7. The cutter head reduction gear box should be designed to permit easy replacement of gearing for speed changes in order to minimize modification downtime.
8. The discharge point of the conveyor should be designed to provide sufficient height and to extend past the end of the machine for discharge directly into the haulage units. The conveyor should be rigid.

9. A slide conveyor support system (See Figure 16) should be evaluated to replace the roller supports currently being used.
10. SAE Standard J817A titled "Engineering, Design, Serviceability Guideline" rates equipment as to accessibility for service and repairs. This standard should be used as a guide to attain the highest possible rating for any modified roadheader.
11. Off-shelf tracks with sealed-for-life rollers should be utilized.
12. Floor lift jacks to stabilize the machine while cutting and to provide access to repair or replace tracks should be evaluated.

6.2.3 Electrical Modifications

1. The electrical installations on a roadheader operating in a wet underground uranium mine should be kept to a minimum. In the simplest configuration, only two electric motors are required: the cutter head motor and the hydraulic pump motor.

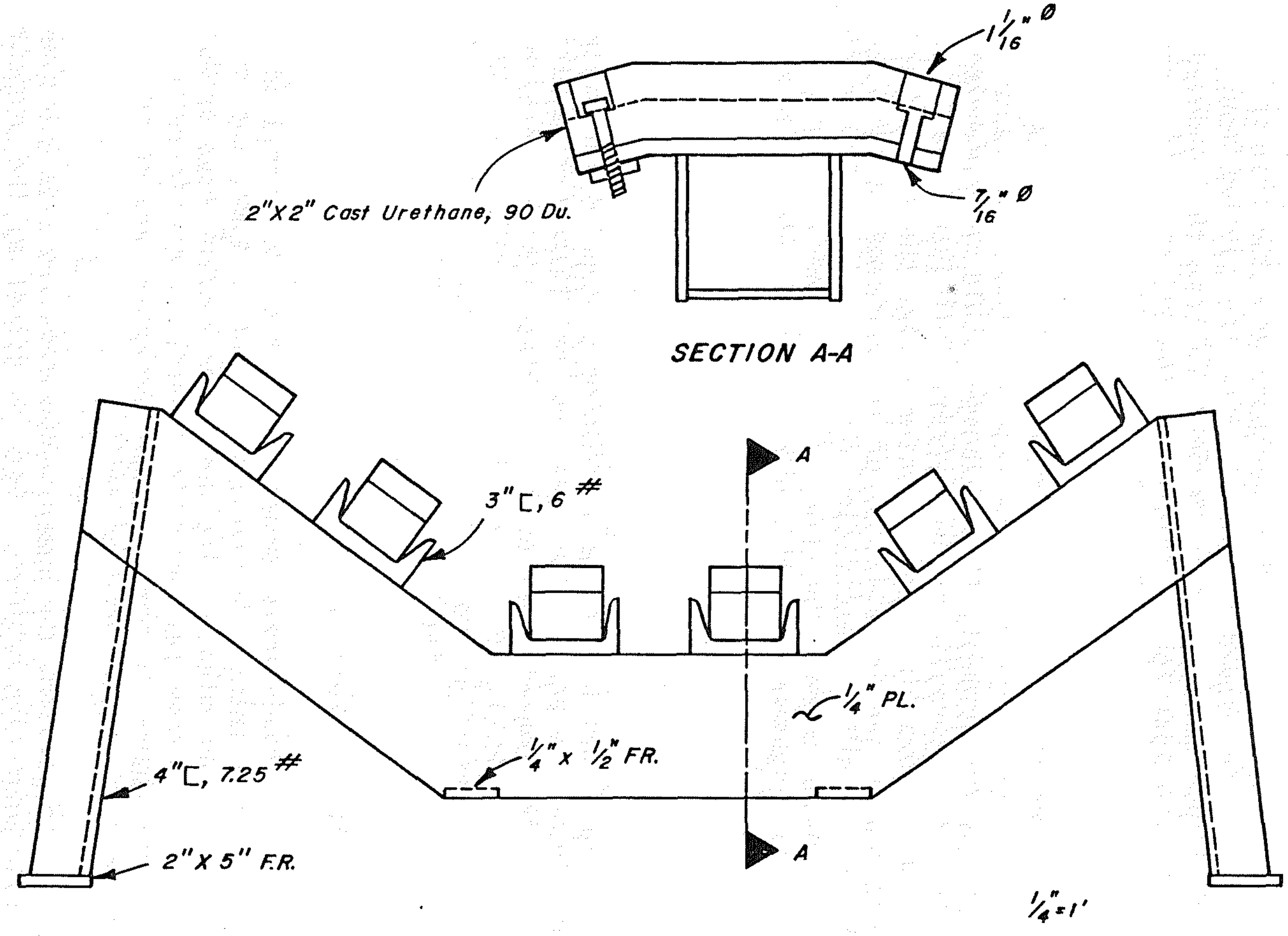
2. Cutter head motor leads and feed conductors should be joined on a terminal block in order to prevent chafing and loosening due to vibration.
3. Those electrical components which are designed to operate in a vertical position under normal conditions should be installed in a vertical position.
4. The conductors to the cutter head motor should be type GC high stranded, and should not be paralleled.
5. The ground monitor system should have proper terminating facilities in the main control cabinet.
6. The power feed cable to the machine should be of SHD-GC type.
7. The unit should fully comply with all applicable electrical codes.

6.3 MINING SYSTEM DESIGN AND EQUIPMENT PRODUCTIVITY

Time studies of the first generation roadheaders indicate the the cycle times for mining (cutting and loading) and for installation of ground support were 36% and 29% respectively. From these time studies, it is apparent that these two job tasks offer the best areas for improvement in productivity. The improvement first would involve increasing the equipment performance to better utilize the 36% operating time, and then to modifying the mining system so that the ground support time requirement can be reduced or made separate from the roadheader operation.

6.3.1 Room and Pillar Development

In multi-drift development, a room and pillar stoping operation, the multiple working areas would permit independent operation of the roadheader and installation of the ground support. This system allows the roadheader



SLIDE CONVEYOR SUPPORT SYSTEM
FIGURE 16

to excavate approximately twelve feet of drift advance, after which the roadheader is moved to another entry where the ground support has already been installed. This permits the ground support crew to bolt the newly excavated drift without interfering with the roadheader crew. This system, while presently possible, can be made effective if faster tram speeds are engineered into the newer roadheaders.

The newer roadheader machines have been equipped with two tram speeds. A slow, 5-8 feet per minute, speed is used to sump the cutting head. A high speed, 45-65 feet per minute, speed is used to tram the roadheader from operating face to the next face. This makes the 29% shift time that was used to install ground support available for production.

6.3.2 Single Entry Devlopment

In the single entry development, the roadheader would operate beneath a temporary self-advancing hydraulic ground support unit (see Figure 17). The introduction of the hydraulic support system allows the simultaneous operation of the roadheader and installation of the permanent ground support. This system permit shigher excavation equipment utilization while providing immediate ground support for the excavation drift. There are several models of support systems available which could be adapted to meet specific needs of an operation.

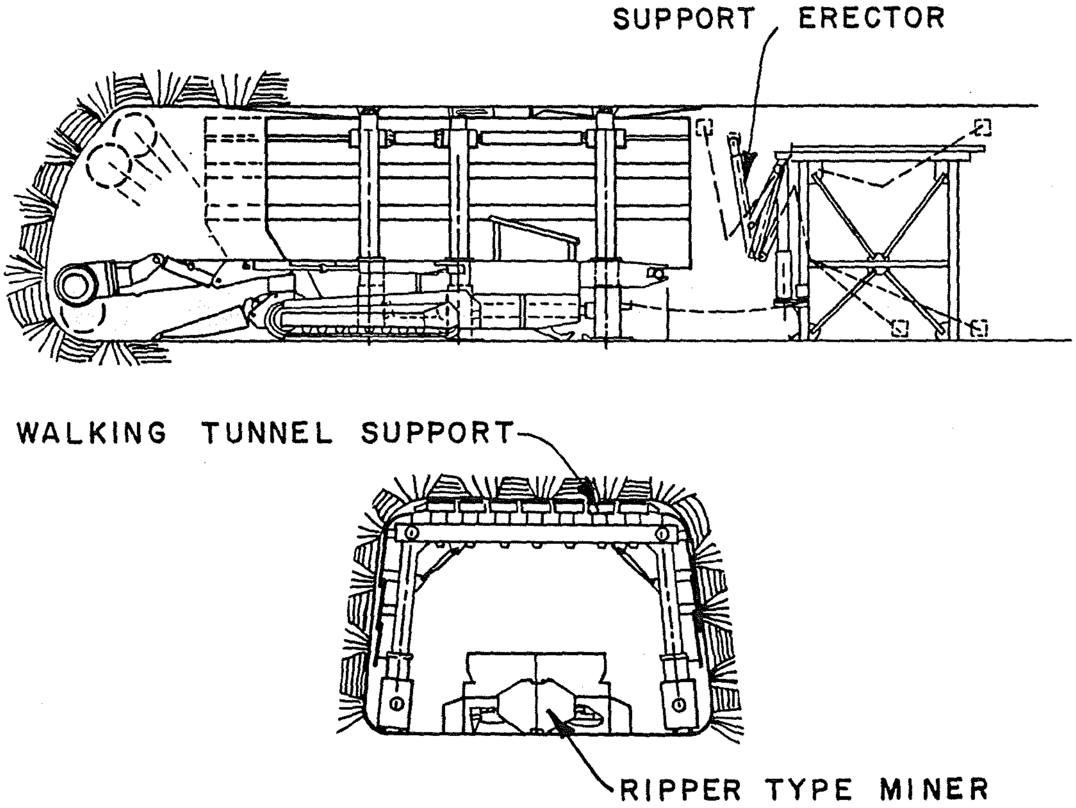
6.3.3 Mining Thin Ore Bodies

The uranium mine operators have tried to develop a stope mining system that is capable of mining ore bodies less than six feet thick with a minimum of dilution. With the conventional drill and blast system, there has been little success in reducing the mining height. As shown with coal mining in thin seams, mechanical continuous miners have adapted to the lower profile which permits operating in lower mining heights.

6.3.4 Increase Rock Cutting Capability

The first generation roadheaders produced 51 tons per shift while operating 36 percent of the shift. During this operating time, the roadheader produced .295 tons per minute. The newer roadheaders have production rates of 1.0 to 2.5 tons per operating minute. This increase in productivity can be attributed to more cutting horsepower and to the introduction of larger more efficient haulage units.

On a capital cost comparison, the newer roadheaders are 2 to 2.5 times the cost for a first generation machine. This is offset by the projects from some of the uranium mine operator of 170 to 225 tons per shift production. With continuous equipment improvements in the machined design and mine system application the roadheaders are a viable mining alternative.



INTEGRATED ROADHEADER MINING
AND SUPPORT SYSTEM
(After Kettling 1979)
FIGURE 17