Use of Boom-Type Miners

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ABSTRACT

New developments in continuous mining machines have resulted in increased versatility of excavating equipment available for use in mining evaporites and associated sedimentary rocks. The boom-type, ripper-action continuous miner provides a rugged and flexible machine for development and production that permits selective mining and excavation of openings of any shape or size larger than 6 by 6 feet. The result is lower cost and increased safety in underground operations. Actual operating and capital costs for representative installations are provided together with relevant engineering data.

TYPES OF MINING MACHINES

Ripper-type and Drum-type Continuous Miners

Since the 1940's continuous miners have been used in potash and salt mines for production and mine development purposes. In the beginning chain-type ripper miners such as the Joy 1-CM, 3-CM and 6-CM were used in mining of evaporites. Now these machines are being replaced by modern drum-type continuous miners such as the Jeffrey Heliminers, the Lee-Norse Hard-Heads, the Joy 10-CM and the Marietta Drum Miner. These crawler-mounted machines can excavate a rectangular-shaped cross-section (Fig. 1).

These machines have high production rates and relatively low investment cost. Their crawler mounting makes them flexible in use and these machines can drive 90° cross cuts. The face is accessible. Cutter bits can be inspected and changed easily. Roof support can be installed right behind the face. These are standard machines; therefore, spare parts are readily available.

The disadvantages of these miners are that on most machines the crowding force is provided by the crawlers. The machines are not braced against the roof or the side walls. The machine's weight provides the reaction force for the cutting. Therefore, only potash, salt, coal and soft rock can be cut economically. The cutter-head is laced with many bits which create a lot of dust. This makes necessary the use of expensive additional equipment such as dust collectors, scrubbers and fans. It is not possible to seal off the cutter-head to contain the dust at the face.

The machine can only excavate a rectangular-shaped cross-section. Some models can round the corners of the rectangular cross-section. Arched, horseshoe-shaped and circular cross-sections cannot be excavated, yet it is these special cross-section shapes that are required in mines with high rock pressures and bad roof conditions.

Boring-type Continuous Miners

For many years boring-type continuous miners such as the Marietta, Goodman and Joy have been used in the potash and salt mining industries. Boring-type miners equipped with two to four cutter-heads with up to 1500 hp have recorded mining rates up to 15 tpm (Fig. 2).

The advantages of these machines are their high rates of production. In addition, because of their crawler mounting the borer machines are flexible and can negotiate curves and cross-cuts. If such a machine breaks down it can be towed away and work can be continued with a stand-by machine or with the conventional drill and shoot method. Roof support can be installed behind the face. Cutter bits can easily be inspected and replaced. Some borer models are built in relatively large number and spare parts are therefore readily available.

The weight of the machine, however, provides the only reaction force for cutting. The crowding force is provided by the crawlers. Therefore, only potash, salt and extremely soft rock can be cut with boring-type continuous miners. If a borer is required to make more than one pass when driving a room or a drift, it is difficult to control the

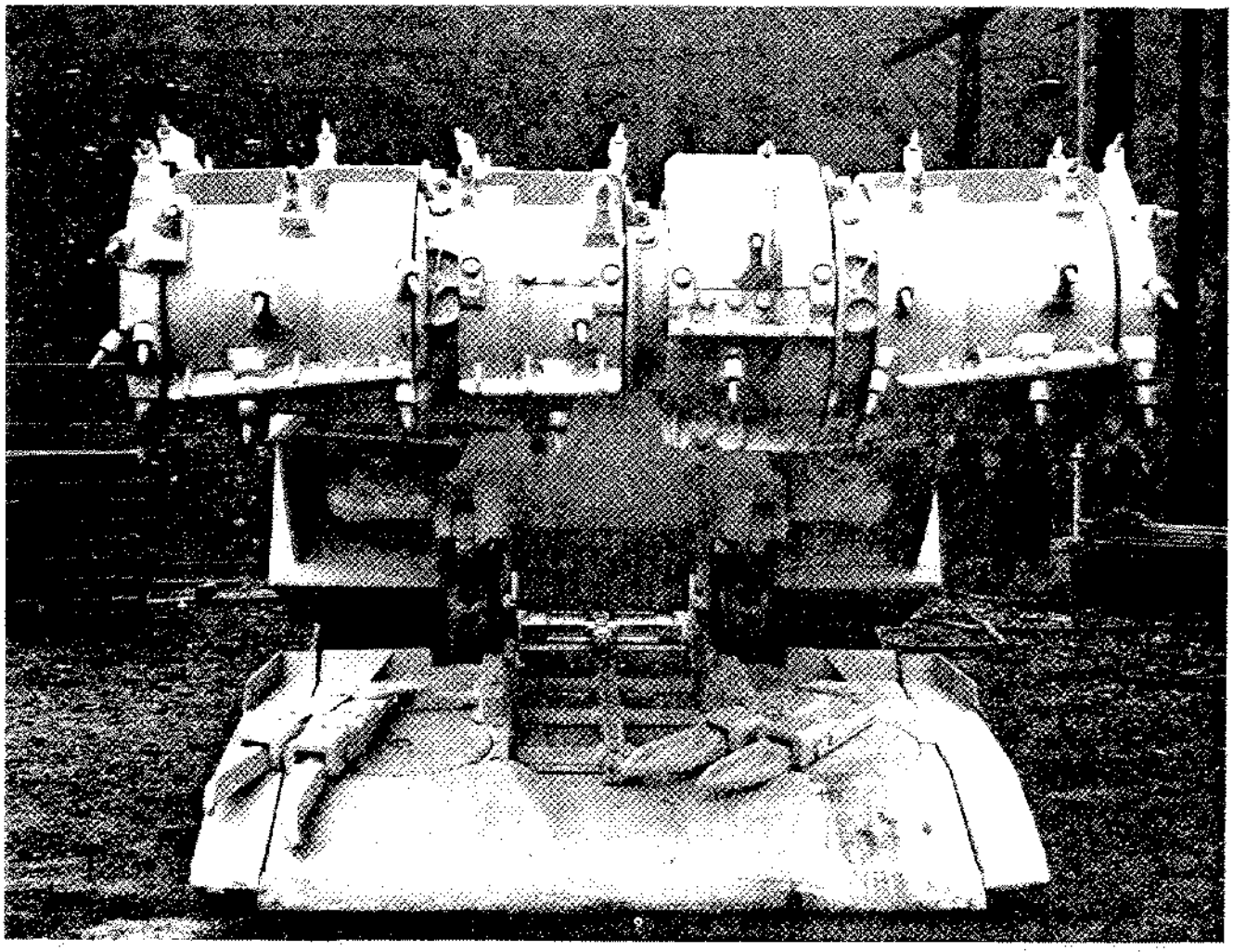

Figure 1. Lee-Norse Drum-type continuous Miner.

dust because the face cannot be sealed off. Expensive ventilation and dust suppression equipment therefore are needed. These heavy machines can only work in drifts with moderate grades and moderate sidepitches.

Tunnel Borers or "Moles"

Tunnel borers, also called "moles," have been used in the construction industries since the 1950's. The first mole was introduced in England by Beaumont in 1884 for the original attempt to drive the Dover-Calais tunnel. Major manufacturers of tunnel borers are Robbins, Jarva, Calweld, Lawrence, Dresser, Wirth, Demag and Atlas-Copco.

Although tunnel borers have been used in the construction industries for many years, it is only recently that "moles" have made inroads into the mining industries for special uses. There are several exampies of the use of tunnel borers in the American mining industry (Fig. 3).

Amax employed a 13 ft. diameter Calweld tunnel borer at its molybdenum mine at Climax, Colorado. This machine excavated in one year (1 shift/day) about 1,000 lineal feet of drift. This leased mole was returned to the manufacturer for improvements to obtain a higher rate of penetration. The rock formations at Climax which consist of granite-gneiss, biotite, magnetite and hornblende are very hard.

A 9'-8" diameter oscillator-type Calweld tunneling machine was used for driving a haulage drift at the "Mather B Mine" of The Cleveland Cliffs Iron Co. near Negaunee, Michigan. The rock to be excavated consisted of soft hematite and shale. This mole drove only 300 lineal feet of drift in one year. The ore at Mather B Mine is mined by the block caving method and therefore severe roof pressure prevails throughout the mine. The shield-type mole got squeezed and was locked in and stuck by the surrounding rock and the machine often could not move under its own power. The trial with the tunnel borer was discontinued.

Figure 2. Marietta Continuous Miner, Type 780—AW4.

In November 1971 the Cleveland Cliffs Iron Company purchased an ALPINE MINER, Model F 6-A to drive the same haulage drift where the "mole" had been employed. It took the small boom-type ALPINE MINER five weeks to drive the same length of tunnel as the "mole" accomplished in one year. Because the face was accessible with the ALPINE MINER, the weak roof and face could be controlled by forepoling, or spiling as the miners at Negaunee call it (Fig. 4).

The American coal mining industry has had several mole projects. A 17 ft. diameter Jarva mole has been used for boring mine slopes at the Oak Park mine of Consol in Ohio, Amax Coal's Wabash Mine in Illinois and U.S. Steel Corporation's Dillworth mine in Pennsylvania.

The advantages of tunnel borers ("moles") are that moles can cut hard rock and dust can be controlled easily by installing a dust shield behind the cutter-head. Large savings can be achieved in roof support and lagging compared to the conventional drill and blast method. These machines have a high rate of penetration in competent, sound and uniform rock. They provide a safe method of excavation.

The disadvantages of tunnel borers (moles) are high cost and required high horsepower. Because they are manufactured to contact the entire face at once, their structures fill the entire face area and only small changes in diameter of tunnel that a particular machine can work are possible. In addition, moles can only have circular cross-sections. Unfortunately, in most mining applications, a level floor, not the curved floor left by the borer, is required.

A tunnel borer with back-up equipment, such as trailers for a hydraulic power pack, is up to 300 ft. long. When a borer breaks down, it is stuck in the tunnel like a bullet in a rifle barrel. Because of power lines, water lines, air ducts, roof support and haulage tracks, it cannot be moved back. The cutters on the head cannot be inspected and replaced easily.

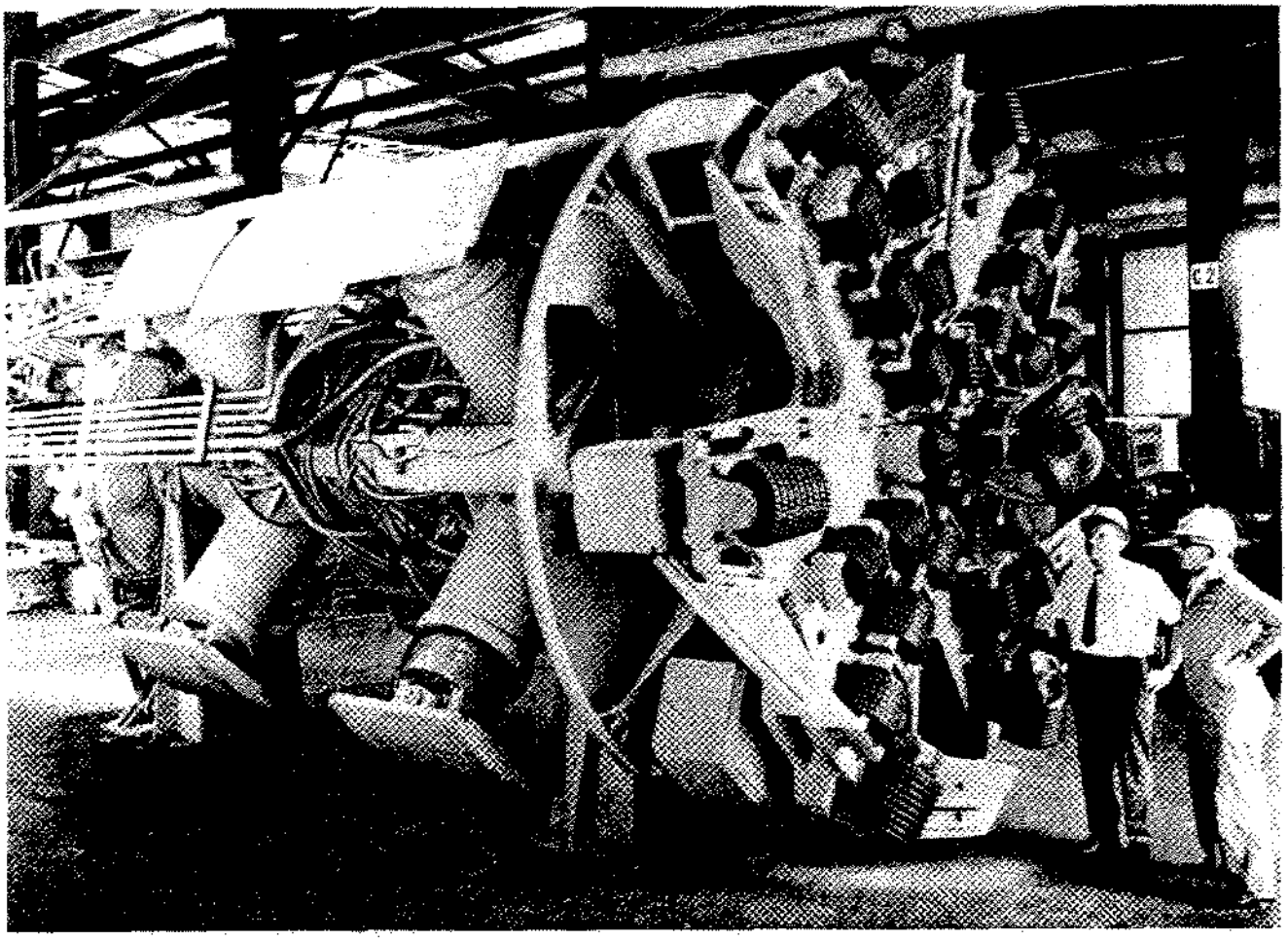

Figure 3. 13 ft. Diam. Calweld Hard Rock Tunnel Borer.

Finally, most moles are prototypes or custom built. Consequently, spare parts are not always immediately available.

Boom-type Continuous Miners

In Continental Europe, including Russia, small boom-type continuous miners or "roadheaders" have been in use since the 1960's both in the mining and construction industries. Three years ago a new mining machine based on the earlier models was introduced on the American market. It was different from domestic continuous miners such as those of Joy, Lee Norse and Jeffrey. Although this new machine weighed only some 11 tons and has a mere 104 horsepower, its manufacturer claimed that it could cut rock of a hardness far above the capability of other drum or ripper miners. This new machine, the Alpine Miner, has other unique features in that it can selectively mine coal and rock or ore and waste in a mixed face, negotiate steep slopes, and work under poor roof conditions.

THE ALPINE MINER

The first Alpine Miner was used by an American construction company, Peter Kiewit, and the machine successfully proved what the manufacturer claimed. The owner also learned that this was a well-engineered and reliable machine. Since that first success, many mining companies have purchased boom machines for development and construction work in salt, coal, rock and ore.

The main components of the Alpine Miner, model F 6-A are: (1) cutter-head, (2) cutter-boom, (3) turret for boom, (4) gathering-arm loader head, (5) chain conveyor, (6) crawler tracks, (7) frame, (8) electrical system, (9) hydraulic system, as shown in Figure 5. U.S. Bureau of Mines (U.S.B.M.) approved machines are available in 60 cycles, 440 and 550 volts, AC, three phase models.

Cutting Principle

A striking technical characteristic of the road headers is the articulated mounting of the cutter-head. The resulting flexibility simulates the action of a human arm so that

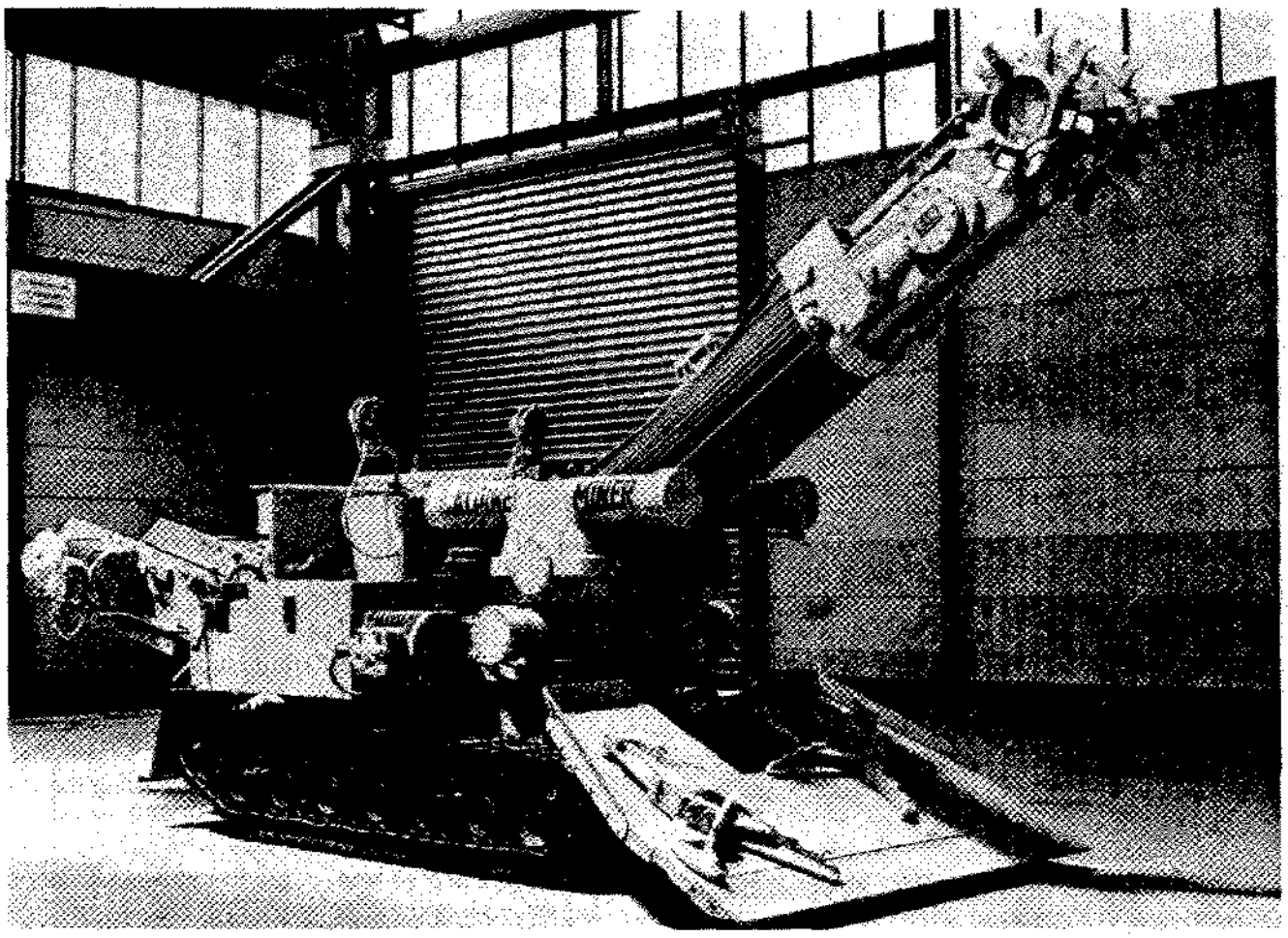

Figure 4. Ripper-type Alpine Miner.

the machine's operator can move the cutter-head freely across the face in much the same manner as a man can move his arm around. Such freedom of motion permits the operator to select the appropriate mining pattern. If he wishes, he may cut an arched roof to improve the self-supporting capabilities of the overlying rock strata, or, if the seam contains a band of waste material, the operator can use a selective pattern that enables him to cut and load rock and waste separately (Fig. 6).

The Alpine Miner is crawler mounted and has a turret and boom arrangement that gives the machine the appearance of an army tank. The cutter-head, which rips the rock or coal from the face, is mounted at the front of the boom and perpendicular to it. The turret provides vertical and horizontal motion so that the machine's operator may range the cutter-head across the face in whatever pattern is most efficient. For this, the operator has only to control a movement of a single, four-way, hydraulic control lever ("joy stick") plus on-off positions of six main electrical switches.

Conventional continuous miners cut the rock by raising and lowering of the cutter-head. This means that many bits are cutting simultaneously, thereby spreading the cutter motor's horsepower over many bits. In contrast, the Alpine Miner's cutter-head has a conical shape and only one bit cuts at a time. The full weight of the miner takes the reaction force of this bit. Thus, the Alpine machine has more horsepower and reaction weight per cutter bit than a continuous miner having up to some 500 hp driving the cutters and weighing some 50 tons. (Fig. 7) The result is that the Alpine Miner can cut harder rock than other machines despite its lower horsepower and weight. This machine can be equipped either with flat bits or plumb bob-type bits.

Flexibility

A main advantage of the Alpine Miner is the low weight of its component parts (maximum 3,800 lbs.) and their small dimensions (maximum 51-1/2" X 31-1/2" X 31-1/2"). Because the machine is not overpowered, its rate

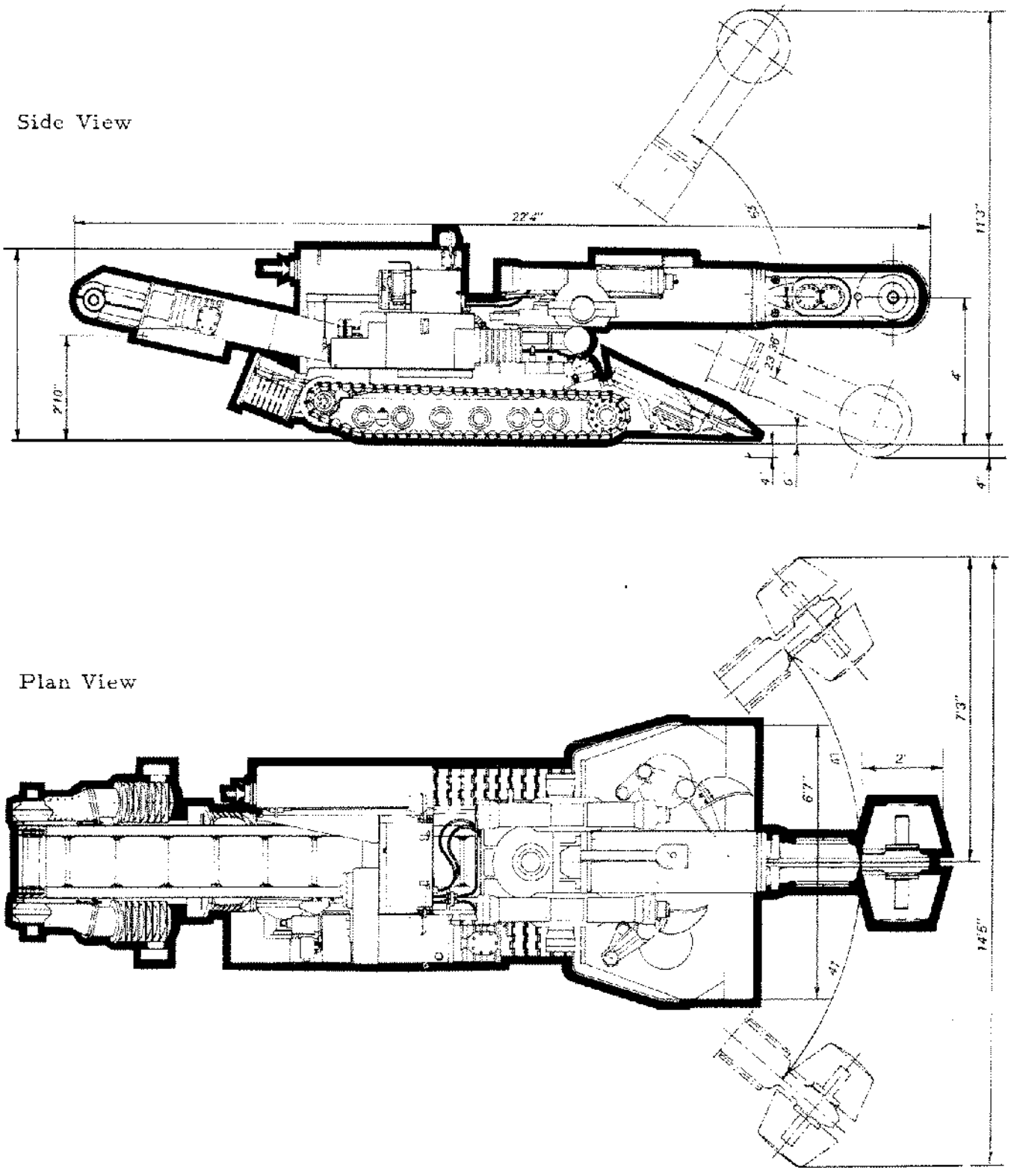

Figure 5. ALPINE MINER, F6--A "Rock Eater" Ripper Miner with Articulated Head.

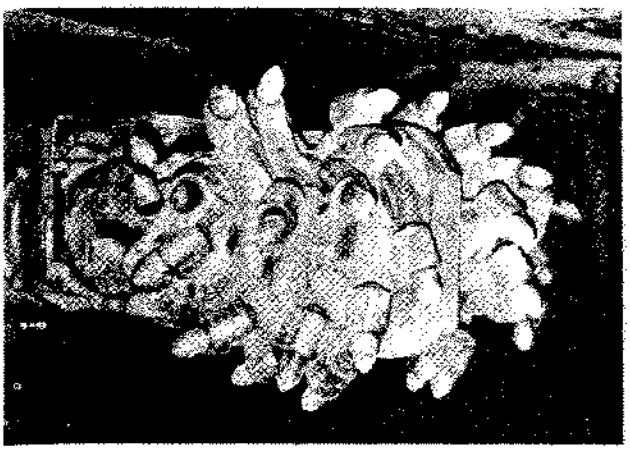

Figure 6. Ripper-type Cutter Head for Rock Mining.

Figure 7. Drum-type continuous Miner with Bit Lacing for Rock Mining.

of production can be handled by the back up systems in development areas and the timbering or roof-bolting crew doesn't delay face advance. Equipment utilization of more than 50% of the shift time is normally experienced with Alpine Miners. This contrasts to average machine utilization of domestic continuous miners, which as reported by the U.S. Bureau of Mines, was some 28% in 1969.

The Alpine Miner's weight of about 11 tons and ground pressure under the track of only 14 psi enables the machine to work on soft or wet floors. The miner can make a 90° turn for driving of cross-cuts in any heading of normal dimensions and still be able to load into shuttle cars. When located in the center of an entry, the miner has the following cutting ranges:

Width: 6'-7" to 14'-5" (without boom extensions)
Height: Max. 11'-2" (without boom extensions)
Min. 5'-0"

As the Alpine Miner can cut any size and shape of cross-section (rectangular, horseshoe, circular, trapezoidal) it can be used for excavation of stations, chambers, under-passes, etc. The road header has been used successfully for drivage of slopes, both up or down grade.

The machine's narrow, articulated cutter-head permits selective mining. For example, as dirt bands can be mined separately with the narrow cutter-head of the Alpine Miner the ore will not be diluted. This lowers the cost of ore preparation and reduces the amount of ore lost in preparation plant rejects.

Low Investment Cost and Increased Safety

In 1973 a standard, U.S.B.M. approved Alpine Miner cost about $96,000. This low cost is made possible by large scale production line manufacture of these machines.

The Alpine Miner's frame is only 4'-5" wide; the cutter head is only 2 or 3 feet wide. This permits the face crew to set support and roof bolts right at the face. No man has to work under unsupported roof and the machine also can be under supported roof. As 70% of the accidents in a mine occur in the area 25 feet behind the face, the Alpine Miner will greatly improve the safety for the face men and introduction of this machine should please both the federal and state mine inspectors. The following section has reports on interesting development projects in the American mining industry.

SELECTED MINING TESTS OF THE ALPINE MINER

Construction of 16% Slope and Storage Bin

In 1972, International Salt Company purchased an Alpine Miner, F 6-A for driving a 16% down grade slope at their Retsof salt mine in New York. The mining company previously had tried to undercut the rock with a chain-type cutter bar and then blast the rock. The rock could not be cut with the cutter bar.

The machine was also used for excavation of a storage bin. There are plans to use the machine for scaling roof in other mines of International Salt Company.

TABLE I

Project Data

Application:	Slope, 16% downgrade Length 470 lineal feet and Level drift, length 225 lineal feet
Cross section:	Rectangular, 14'-6" x 9'- 0"
Rock:	Shale, sandy shale, salt
Support:	Roof bolts
Haulage:	Belt conveyor discharging into front-end loader
Rate of Penetration:	8-10 ft./shift
Cutter bits:	Plumb-bob type

Development Drift in Talc

A major U.S. Talc company ran an interesting test between an Alpine Miner F 6-A and another boom-type miner, the English made Dosco Mark 2A. The test was run during development of a new mine in which a 14-1/2 ft. by 11 ft. haulage drift was advanced from the surface to along the hanging wall some 700 lineal feet. The 25 ton Dosco Mark 2A powered with 155 hp was out-performed by the smaller and less powerful Alpine machine by 30% in production. When "hard chlorite cinder" (5,000-8,000 psi unconfined compressive strength) had to be penetrated, the Dosco's cutter-head could not stand the stress and one-third of the cutter-bit blocks were broken off the head. The Dosco was pulled off the job and replaced by an Alpine Miner that encountered no difficulties in cutting the material. The trial was finished successfully by the Alpine Miner which was purchased by the mining company.

This test showed that the ripper-type cutter-head design which is used by all American manufacturers of continuous miners and by Alpine Miners is superior to the radial or milling-type cutter-head employed by Dosco (Fig. 8) which rotates in line with the axis of the cutter-boom. With the ripper-type cutting principle, the full weight of the machine provides the support reaction for the cutter-head. The cutting force of the Dosco head is exerted mainly sideways and this prevents utilization of the full weight of the machine as a counter force. When cutting harder rock, the Dosco miner therefore, has to be braced against the side walls with hydraulic jacks ("stelling"). The retracted width of the braces of 12 ft. makes the machine unmaneuverable in the drift (Fig. 8).

These two different cutting principles result in another important feature. While the Alpine Miner (Fig. 9) cuts a smooth sidewall, roof and bottom, the Dosco miner provides "saw tooth" shaped walls and bottom which makes it almost impossible to use shuttle cars or other rubber-tired haulage equipment behind the miner.

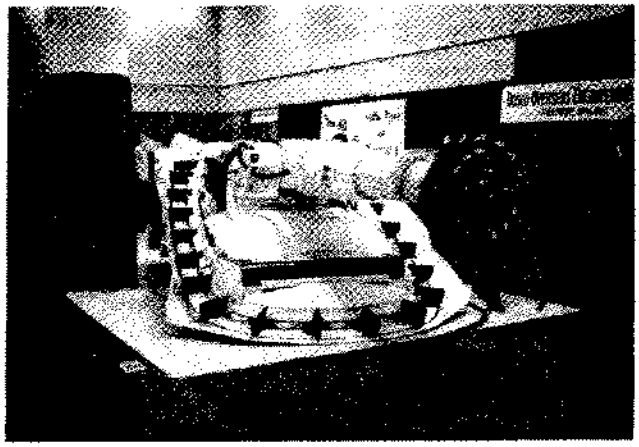

Figure 8. Milling-type DOSCO Mark 2A Roadheader.

Figure 9. Ripper Miner Cutting Rock.

16° Up-grade Slope in Rock

In 1972, Henderson County Coal Company used an Alpine Miner Model F 6-A for driving a 16° up-grade slope in rock at the Retiki Mine near Clay, Kentucky. This slope was driven from the bottom of No. 9 coal seam to the surface and is to be used for the transfer of heavy equipment and for a belt conveyor. The Alpine Miner cut a 14 ft. by 7 ft. high cross-section which was increased to 16 ft. height.

TABLE II

Project Data

Mining Company:	Henderson County Coal Co.
Location:	Retiki Mine, Clay Kentucky
Application:	Slope 16° upgrade
Cross section:	14 x 17 ft., rectangular
Rock:	Shale with limestone bands Sandstone (32 ft. thickness; 100 ft. length)
Support:	Roof bolts
Haulage:	Chain conveyor pans, load into 36" belt and then into battery powered scoop tractor
Rate of Penetration:	8 ft. 12 ft./shift
Cutter bits:	Kennametal U43

NEW DEVELOPMENTS IN MACHINE DESIGN Alpine Miner, Model AM 50

The Alpine Miner, Model F 6-A is a job-proven, successful, mining machine which encouraged the design of a stronger and heavier machine capable of cutting harder rock and providing higher production. The new machine is the AM 50, a 27 ton, heavy, ripper-type continuous miner with a total of 254 hp. This machine will cut any type of rock that is associated with salt and coal seams. No other continuous miner has achieved similar results. Twenty of the new Alpine Miners, Model AM 50, were shipped to customers during the first half of 1973. The first two machines in the United States were delivered in the same period. (Fig. 10).

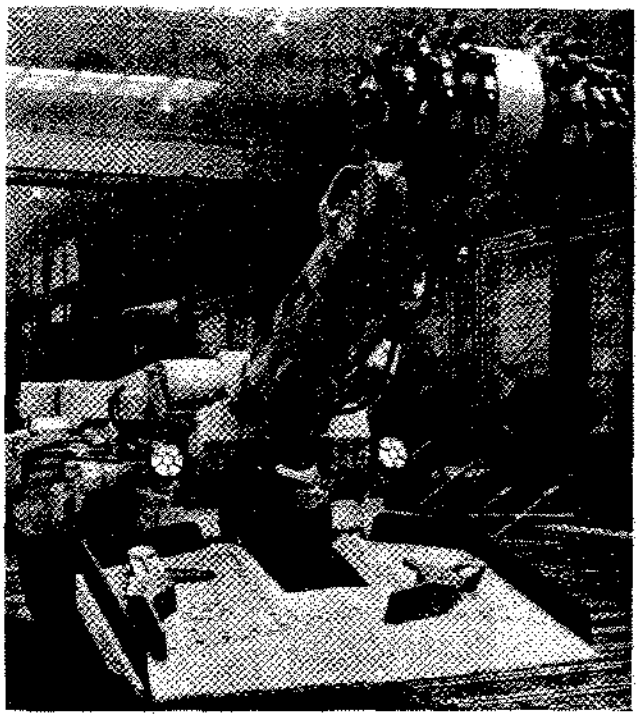

Figure 10. Alpine Miner, AM-50 "Super Rock Eater".

Alpine Multi-Head Miner

Alpine cutter booms can be mounted on a jumbo-type rig (Fig. 11). Such a rig can be used for driving large cross-section tunnels and rooms in a single pass. Large cross-section rooms can be used for underground storage of LNG, radioactive waste, etc.

Alpine has developed cutter-boom kits for mounting on

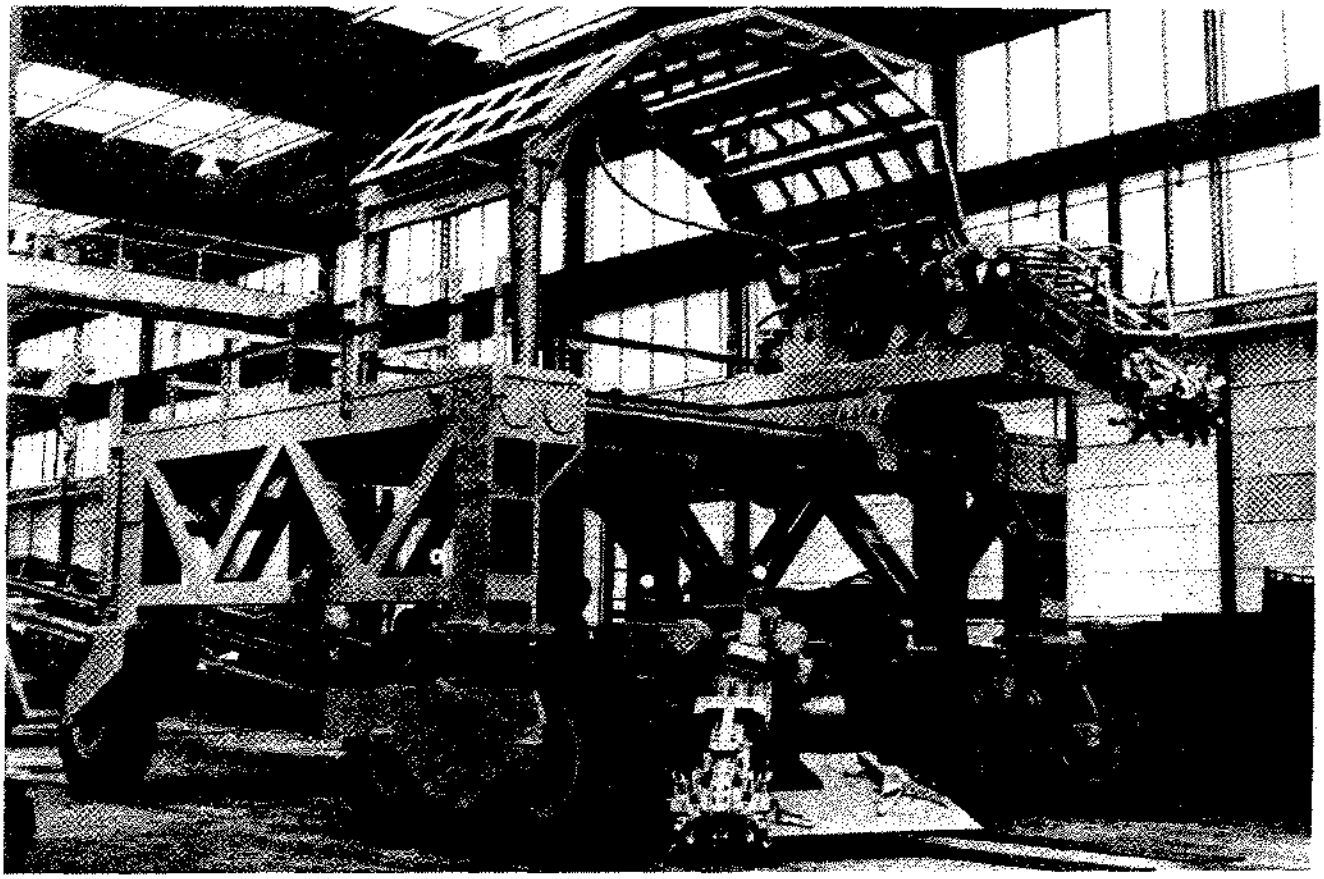

Figure 11. Gantry mounted Alpine Multi-Head Miner.

trucks and power shovels (Fig. 12 and 13). These mobile machines can be used for scaling roof or for mining of ore in high rooms and underground workings.

For the excavation of large cross-section rooms and for scaling jobs a diesel-powered, self-propelled machine, the Alpine Miner, Model ART 200 was developed (Fig. 14). Unfortunately, these machines generally have lower rates of production when compared to standard drum-type and boring-type continuous miners. They can only cut soft and medium-hard rock when compared to tunnel borers (moles). Boom-type miners based on the milling principle have additional disadvantages that were mentioned previously.

On the other hand, Alpine machines for soft rock have low cost of investment. They produce less dust than do standard continuous miners and can cut harder rock than drum-type and boring type continuous miners. Selective mining is possible and they are highly flexible machines that can negotiate steep grades and tight cross-cuts. They cut any size and shape cross-sections (circular, horseshoe, arched, rectangular). Because of smooth cutting action, these machines do not destroy the self-carrying capacity of the roof and lighter support or wider support spacing is thereby achieved. This results in large savings in support cost when compared to the conventional drill and blast method. Roof support can be installed right at the face, thus no man has to work under unsupported roof. These machines have short delivery and good spare parts availability because of production line manufacture.

CONCLUSION

Continuous miners, tunnel borers and boom-type continuous miners have been described. The project reports show the versatility of applications of boom-type continuous mining machines. Although Alpine Miners weigh less than other continuous miners, they can cut rock in which drum-type, oscillating and borer miners cannot work economically. The machine's capability of cutting any desired pattern of cross-section and selectively mining of ore and waste, permits mechanization of work which previously could be done only manually.

More than 200 Alpine Miners are in service throughout the world. About 40 machines are in use in North America and Mexico. The superior cutting principle makes

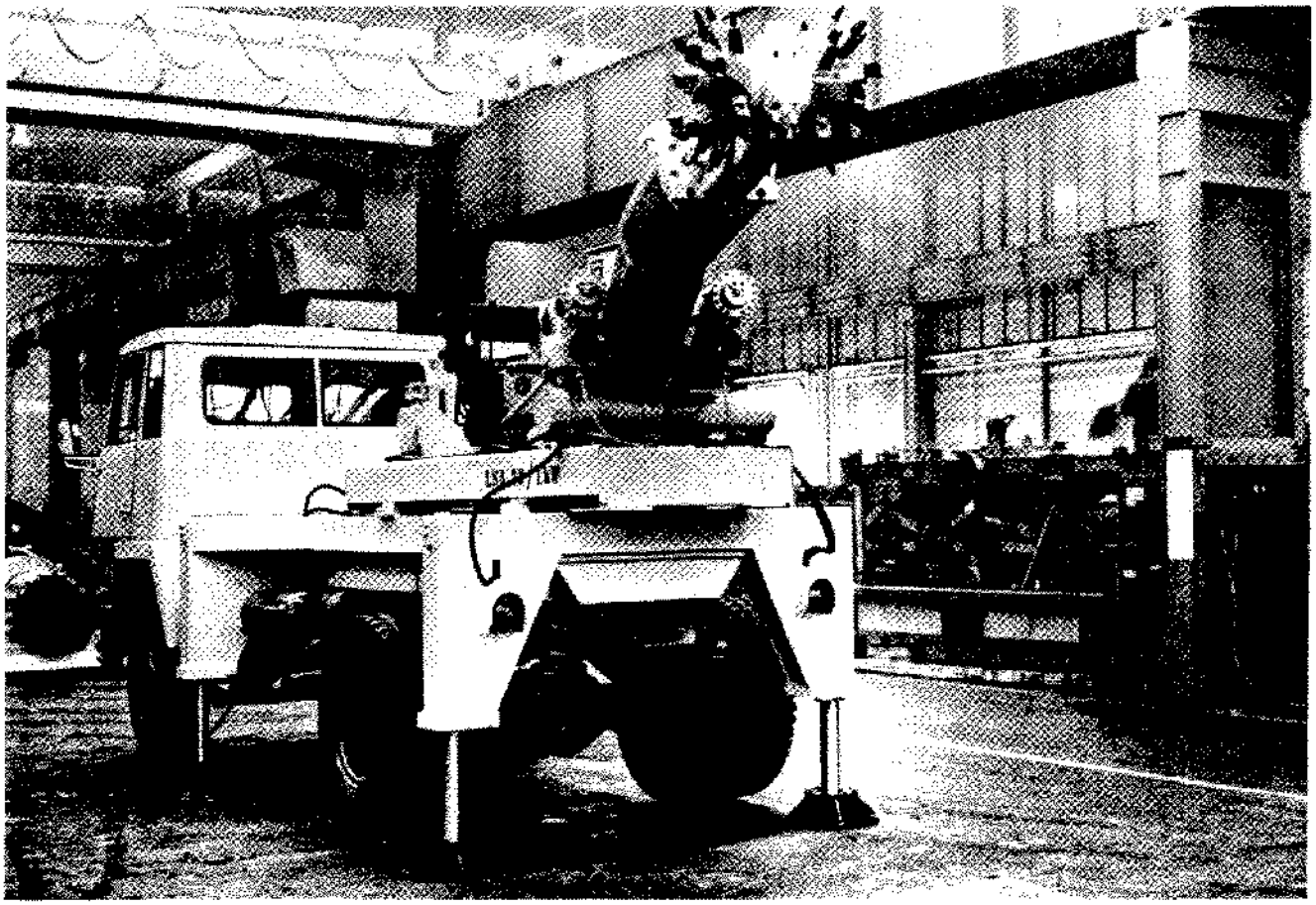

Figure 12. Truck mounted Alpine Ripper Miner.

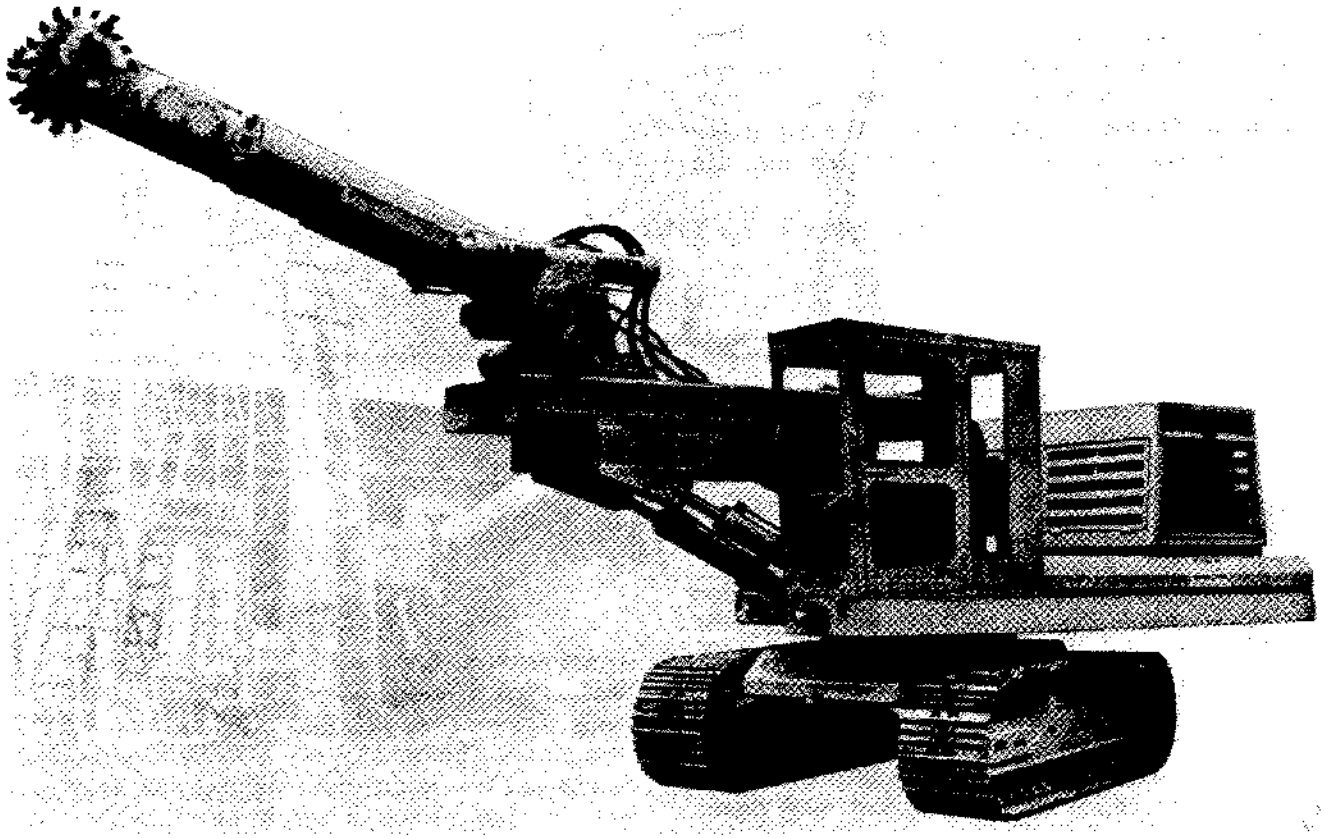

Figure 13. Shovel mounted Alpine Ripper Miner.

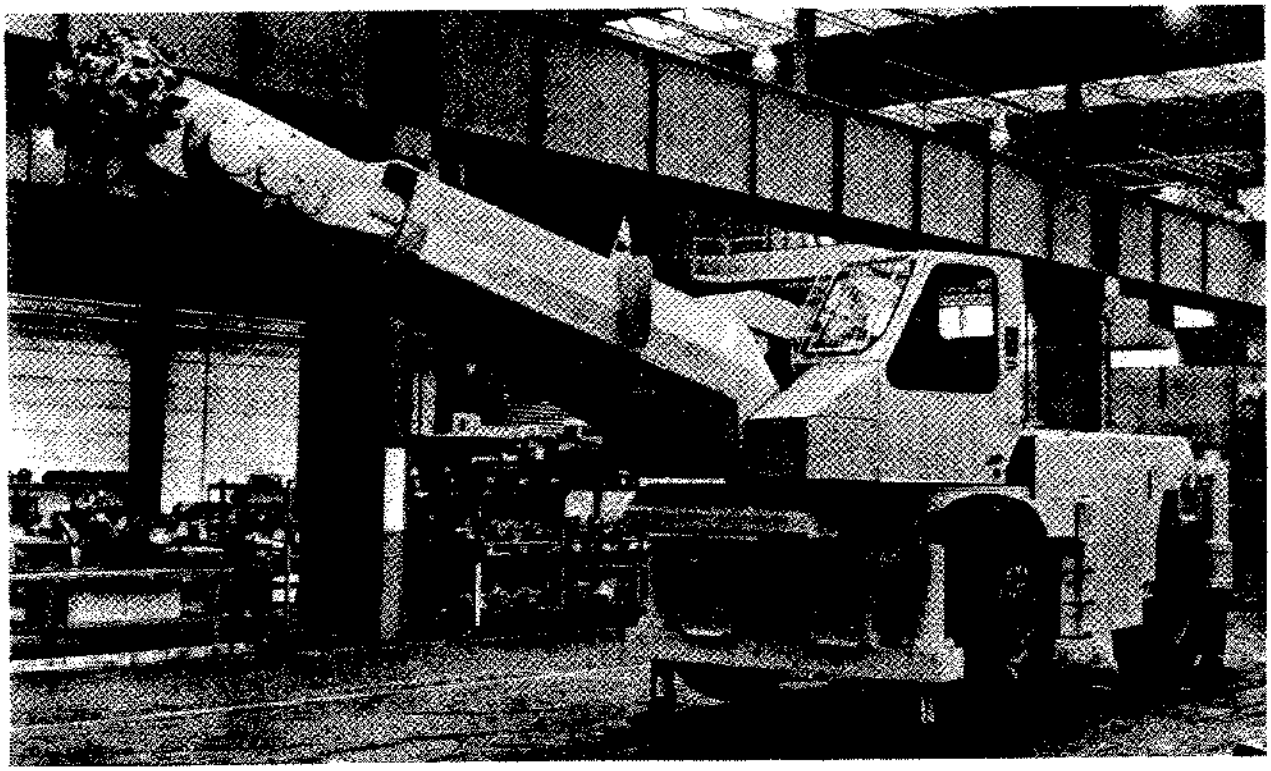

Figure 14. Rubber-tired Diesel-hydraulic Alpine Art 200 Miner.

boom-type miners the favorite rock cutting machines. Low operating costs combined with modest capital cost produces significant savings for companies that require rugged and flexible continuous miners. The Alpine Miner's fine safety records will benefit the face men and please federal and state mine inspectors.