Development of Continuous Boring Machines for Salt and Potash Underground Mining

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ABSTRACT

A description of the methods used for the development of full face continuous mining and loading machines, starting with the use of laboratory test apparatus, then building an underground portable field test machine to furnish the necessary fundamental data required for the design of the ultimate 60 ton, 500 H.P. production machine. Included will be a description of the underground application of the machine.

Having designed, developed and built approximately 75 successful Boring type Continuous Miners for underground coal production by 1957, we started preliminary studies on producing similar machines for mining material other than coal. We received considerable encouragement from one of the major salt mining companies, and largely because of their courage and very real interest, we decided to go after the salt problem first.

We envisioned a machine similar in appearance and embodying the same general broad principles present in our coal machine (Figure 1). That is, it should be:

1. Equipped with two overlapping circular boring heads, each cutting a pattern of annular kerfs of sufficient depth and spacing to allow the breaking out of the cores between kerfs by mechanical means.
2. Tractor mounted to give adequate flexibility for fitting the machine into any of several possible mining systems.
3. Of sufficient weight to provide the required thrust for kerf cutting and core breaking.
4. With mining heads designed to produce the minimum amount of fines of 12 mesh by 0.
5. Equipped with sufficient continuous horsepower capacity, both electrical and mechanical, to produce up to 800 tons per shift on a two and in some cases a three shift basis.

Arrangements were made to quarry and have shipped to our Chicago experimental lab several samples of salt ore measuring 2' x 2' x 3'. Care was taken to cut these samples from the mine floor, in the salt which had been machine undercut, to avoid blasting fractures. We designed and built a rather crude but thoroughly workable test machine for these samples (Figure 2). The purpose of this machine was to measure the forces required to cut kerfs approximately 3" wide in the ore sample using various arrangements and kinds of cutter bits. Depth of cut made by each bit was in increments of 1/10" - 2/10" - 3/10" and 4/10". Cuts were made parallel to, at right angles to, and at a 45° angle to the bedding planes of the ore. Strain gauges on the bit holder connected to a continuous chart occilograph registered in graphic form the pounds required to pull the bit through the sample, and simultaneously the pounds thrust required to keep the bit cutting at the pre-set depth. This data was then assembled onto one page graphs covering each series of kerfs cut (Figure 3).

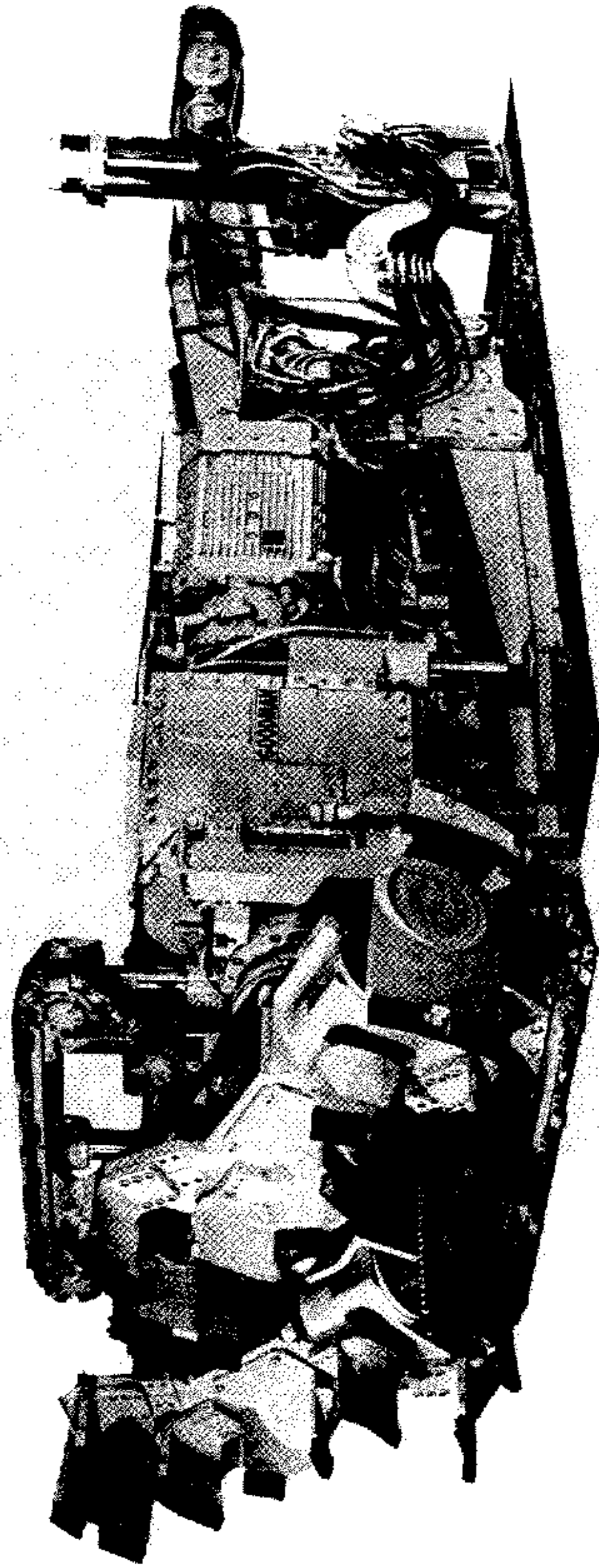


Figure 1.

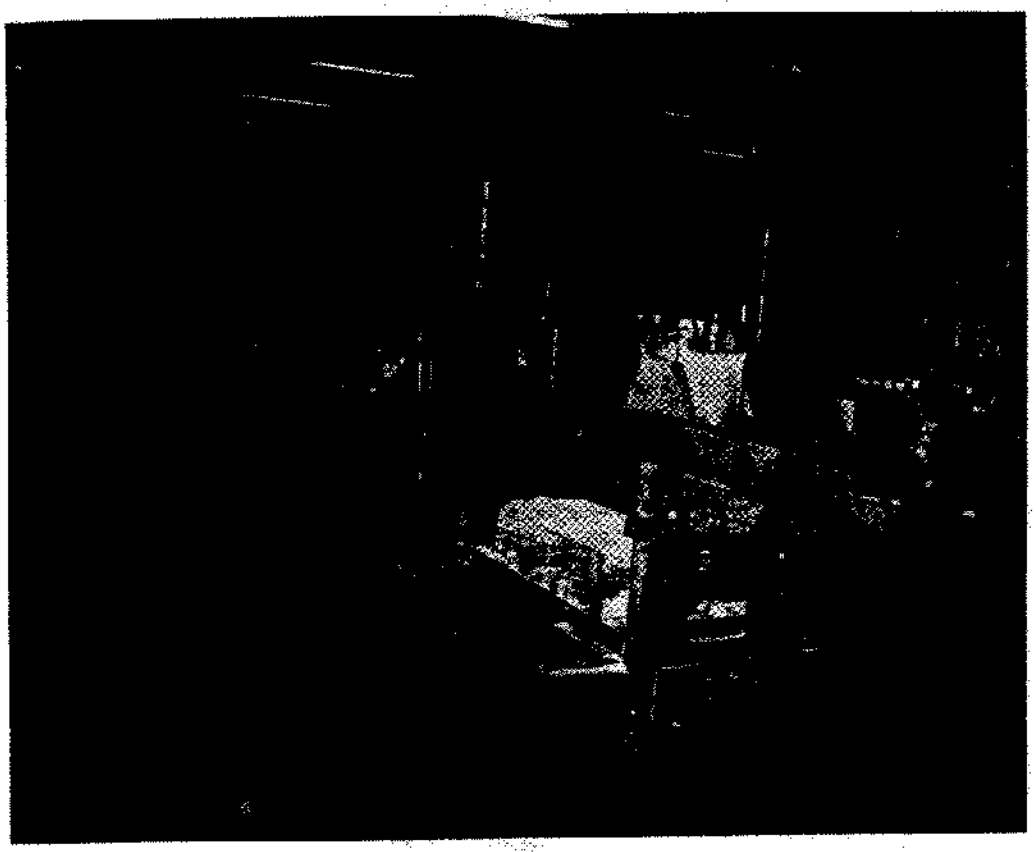
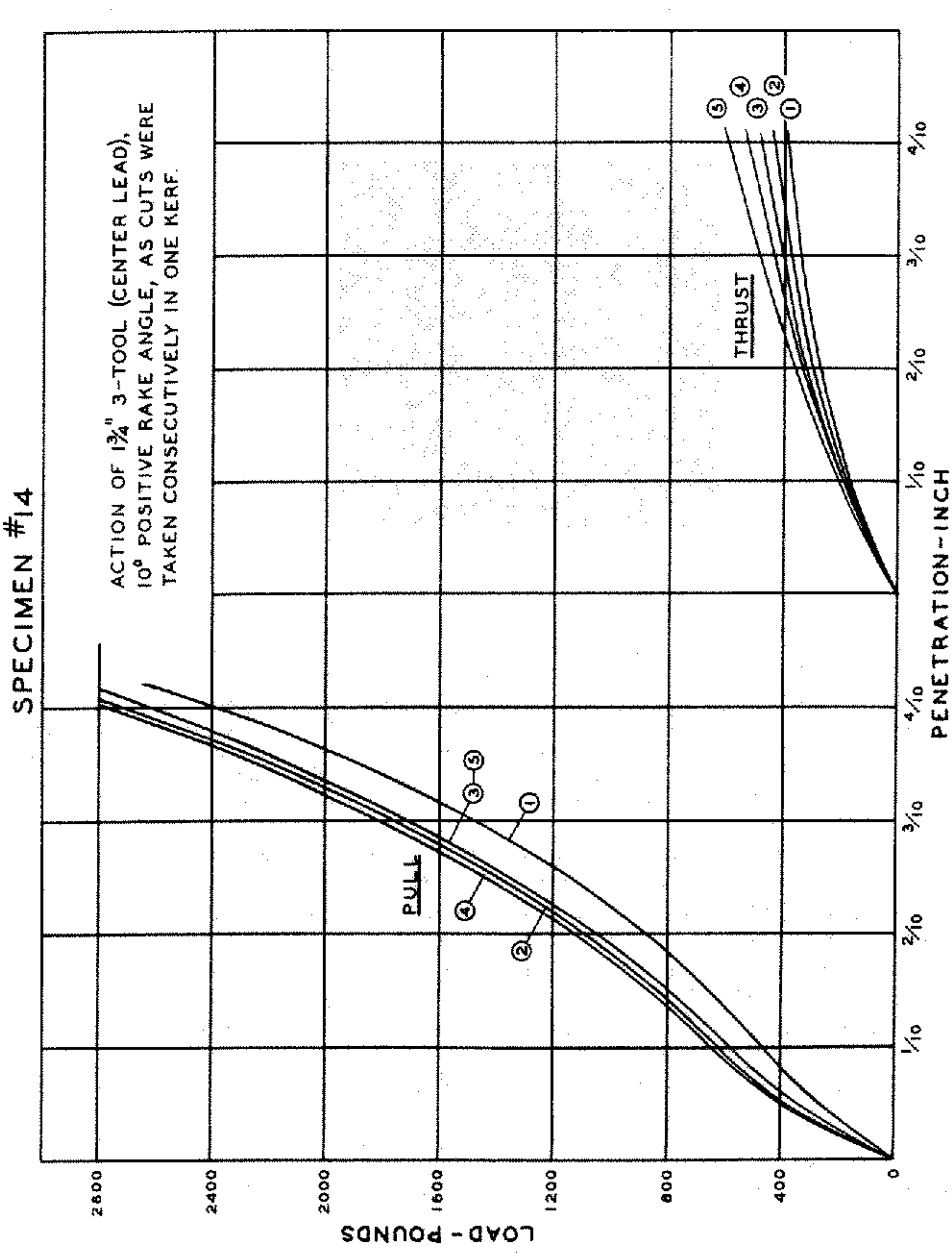


Figure 2.



SPECIMEN #14
ACTION OF 1¾" 3-TOOL (CENTER LEAD), 10° POSITIVE RAKE ANGLE, AS CUTS WERE TAKEN CONSECUTIVELY IN ONE KERF.
PULL
THRUST
LOAD - POUNDS
PENETRATION - INCH
0
400
800
1200
1600
2000
2400
2800
1/10
2/10
3/10
4/10
1
2
3
4
5
3-5

Figure 3.

All kerfs were cut to a depth of approximately 6" and spaced so that the cores varied in width from 4" to 9" (Figure 4). We then equipped the test apparatus with a fixture, allowing us to try several designs of core breaking rollers. These rollers were made with various angles of splitting edges, different diameters, and with several different edge forms, including some that were serrated.

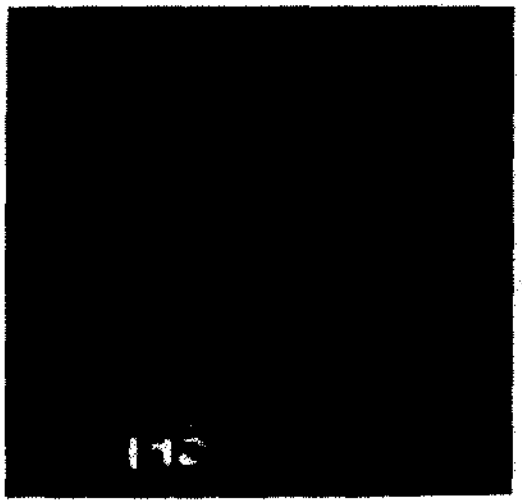


Figure 4.

Forces required for the core breaking performances were collected by occilograph and recorded on charts in a similar manner as the previously described cutter bit forces.

Evaluation of the above data allowed us to make calculations showing approximate requirements that would have to be built into a full sized mining machine. The results were encouraging enough to warrant taking another step. Although the work on the samples indicated that a full scale machine might be built, there were several unknown factors that could be determined only by going underground to the actual salt faces with a boring head designed from the data collected in the laboratory. The unknowns were:

1. We could not tell if the samples contained fracture planes resulting from blasting. If present, our core breaking calculations would be way off.
2. Work on the samples could not give us more than a very rough idea of the percentage of fines that we should expect from a full face machine.
3. In cutting the samples, we could not possibly evaluate what to expect in the way of cutter bit wear and ultimate bit cost.
4. We needed to collect data on the frequency of torsional vibration in the main rotor shaft so that we could properly design these shafts.
5. We expected to encounter hard clay seams and some anhydrite in salt seams, not inherent in the lab samples.

Consequently, we designed and built a semi-portable underground test machine and shipped it to a mine operating in the Michigan Salt Basin near Detroit in April of 1957 (Figure 5). This machine bored a total of twenty 3' diameter holes, each 6' deep, in various locations of pillars and room faces in the mine (Figures 6, 7 and 8).

This machine was equipped with a 3' diameter, 3 spoke cutting head. Fixtures were made allowing us to bolt or clamp a great variety of cutter bit patterns and core breaking wheels onto

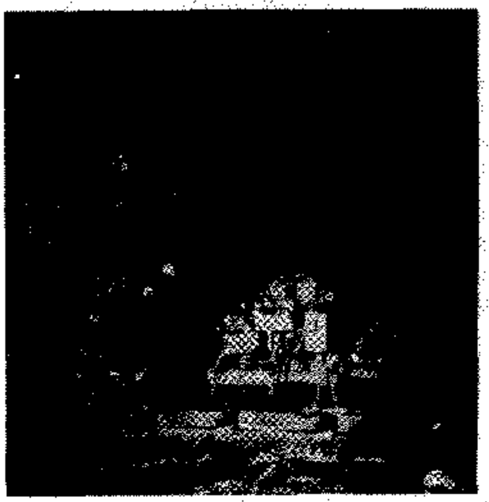


Figure 5.


Figure 6.


Figure 7.

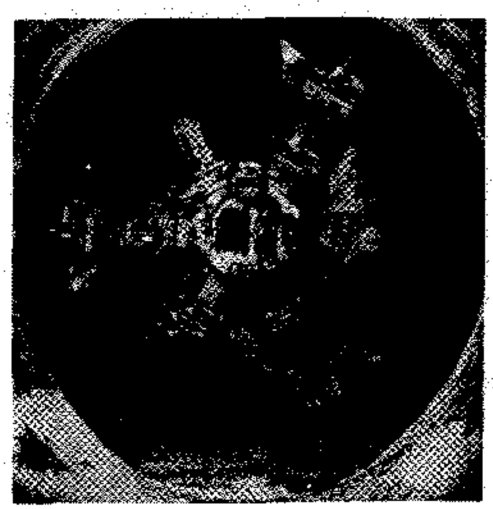


Figure 8.

these spokes. The whole machine was skid mounted and arranged to be bolted to the mine floor when operating. Advance of the cutting head was by hydraulic cylinders with 2' stroke. Two 2' long shaft sections could be bolted into the main drive shaft allowing a total advance from one setting of 6'. With this machine, we could accurately measure torque requirements, thrust required, penetration in inches per minute, etc. All data was tabulated and the most favorable bit and core breaker arrangement became easily discernable. Dynamometer pull tests were conducted, using a tractor on the salt floor, to furnish the data needed for most efficient tractor shoe caulk design.

The field test was carried on over a four month period. The results checked the laboratory tests much closer than we expected. To be sure that we were getting results that would be consistent with actual mining, we entered a pillar a total distance of 18' with three holes. No appreciable difference was noted in the mineability of the salt after penetration exceeded 2'.

The complete test program covered a period of almost six months. At its conclusion, we and the mining company felt that we were on safe enough ground to proceed with the design and construction of a full scale production machine. Eighteen months later, or May, 1959, this machine was shipped on a firm order and was almost immediately put to work (Figures 9 and 10).

The important general specifications are:

Size of single pass face cut	- - 7 1/2' high x 13' wide
Area of face cut, single pass	- - 90 sq. ft.
Retraction for tramming	- - 12" (6" all around)
Total horsepower	- - 500
Voltage	- - 440 - 3 ph., 60 cycle
Weight	- - 56 tons
Production rate at 9" per minute feed rate	- - 4.7 TPM

The company's decision to put the machine to work at their Detroit mine for a "de-bugging" process before putting it on full production in their new mine proved to be a good one. Modifications were expected to be needed and they were needed.

Time was available to make all changes permanent in nature. Operators could be trained and mechanics could become familiar with maintenance procedures. The major changes required were:

1. Cutter bit deterioration in the outer two kerfs was excessive, requiring slowing down the cutter bit speed by reducing rotor speed with gear changes. This greatly improved the bit life and did not reduce the productive rate of the machine.

2. Reducing the number of annular kerfs per rotor from six to four, to decrease the percentage of fines.

3. In order to break the wider cores resulting from the reduction in kerfs cut, core breaking wheels were substituted for core splitting wheels. This actually resulted in an increased penetration rate without increasing horsepower demand.

I am told that approximately 130,000 tons of salt were mined during this initial development period. The machine is ready to go to work in the company's new mine within a few weeks.

The performance of this No. 1 machine encouraged potash mining companies to install several similar machines in the Carlsbad, New Mexico, area. These machines are practically duplicates of the No. 1 salt machine except that they were modified to cut at 6' rather than 7 1/2' high. Since the physical characteristics of potash ore are very similar to salt ore, results gained at Carlsbad match up well with the best obtained in Michigan salt. The only significant difference is that potash ore is relatively homogenious and free from hard impurities, resulting in a cutter bit cost of under 4¢ per ton. Average production over a sustained period with a 6' machine in potash is sufficient to show a satisfactory saving over conventional mining costs (Figure 11).

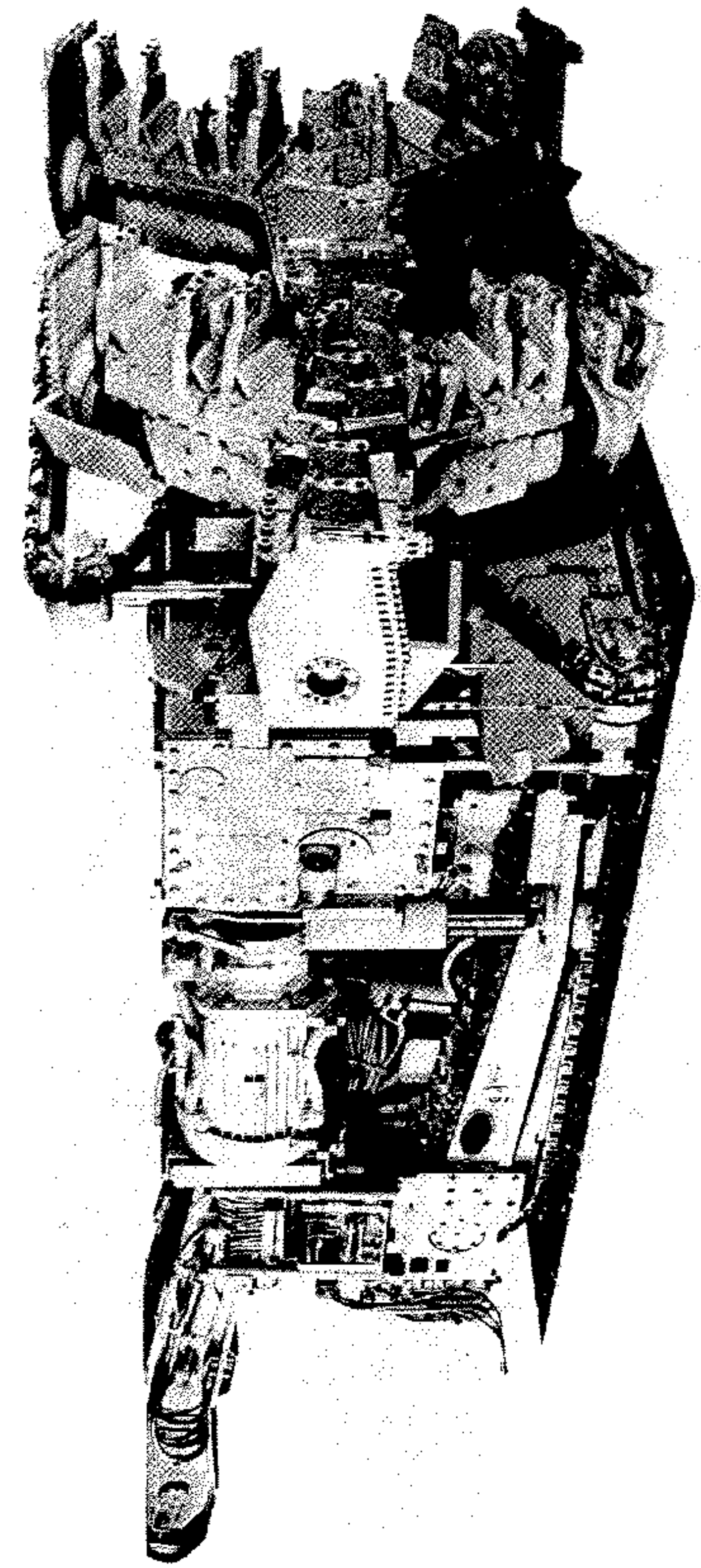


Figure 9.

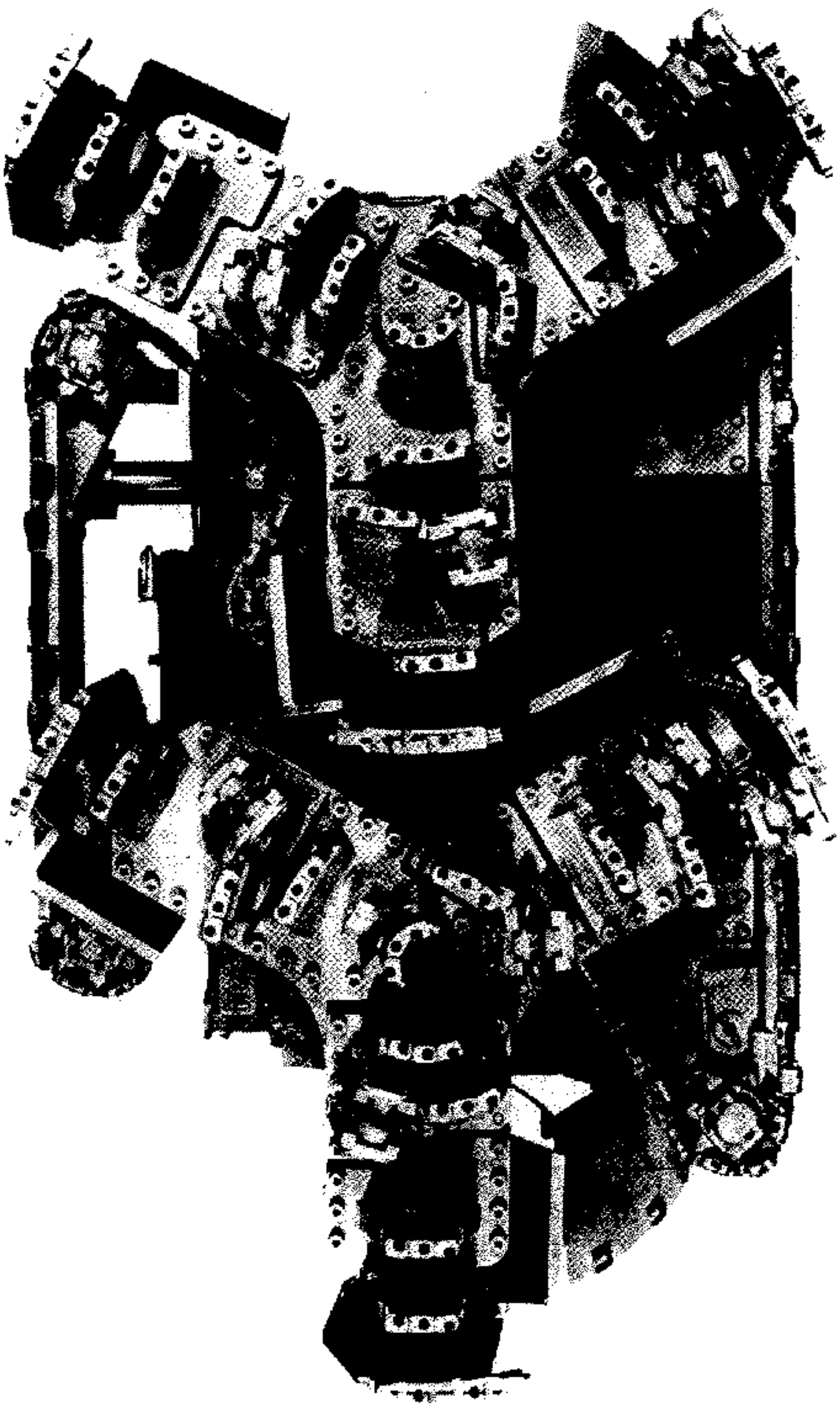


Figure 10.

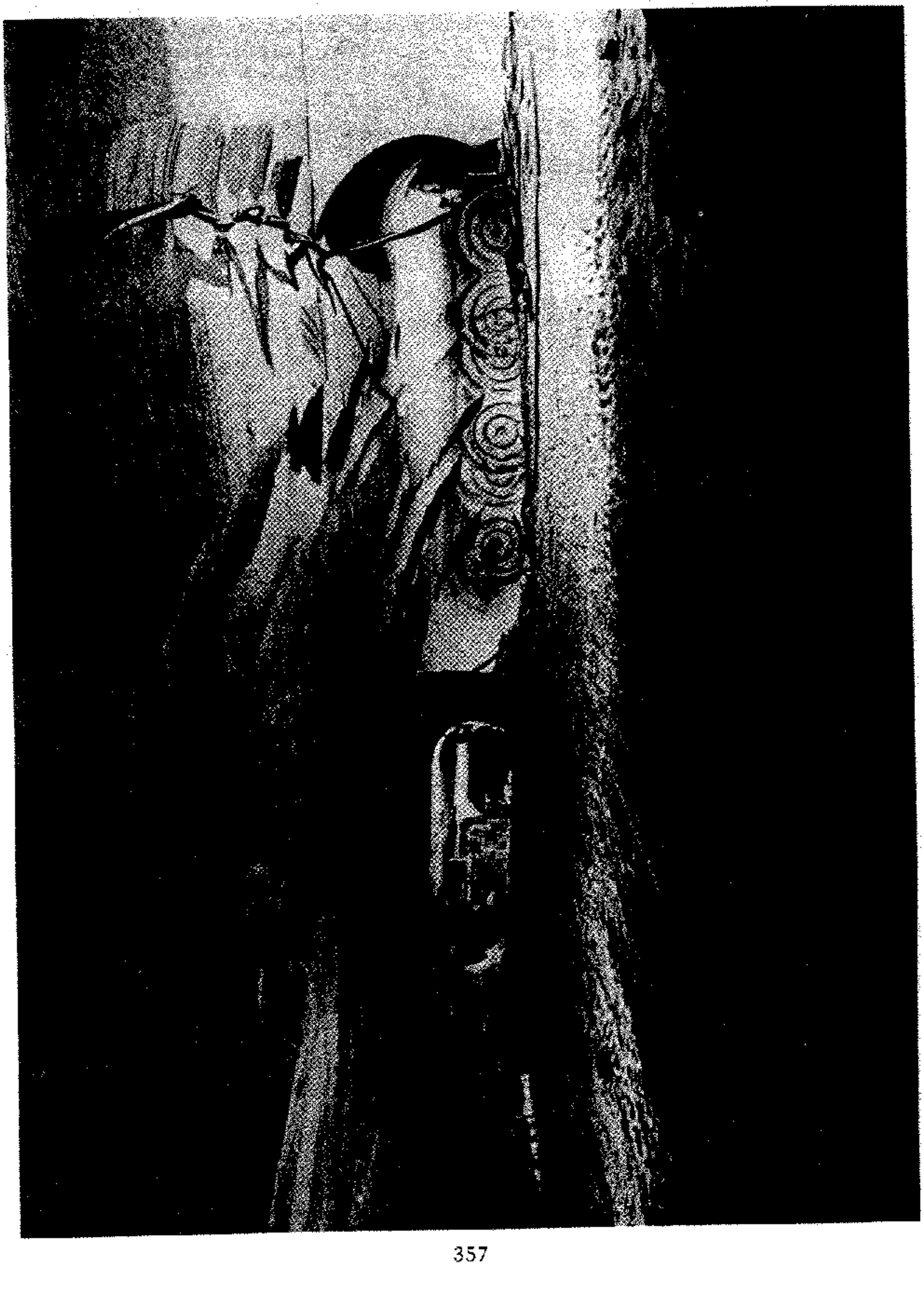


Figure 11.

Of probable interest is the fact that during last year we developed this machine for operation on 4160 volts, 3 phase, 60 cycle, A.C. power and are furnishing several of them to a Canadian potash producer. To my knowledge, these will be the first continuous mining machines to operate at over 550 volts. This high voltage allows the use of over 1,000' of small size #4 trailing cable. Control gear will be located at the power distribution center and not on the machine. Since the ambient temperature in this mine will be 90° F., it is necessary to provide for the highest possible electrical and hydraulic efficiency to prevent producing excess heat at the working faces (Figure 12).

A full measure of credit must be given to the management of the salt company who had the vision and courage to invest corporate capital and their energies into the development of a machine so revolutionary in character as this Boring Machine.

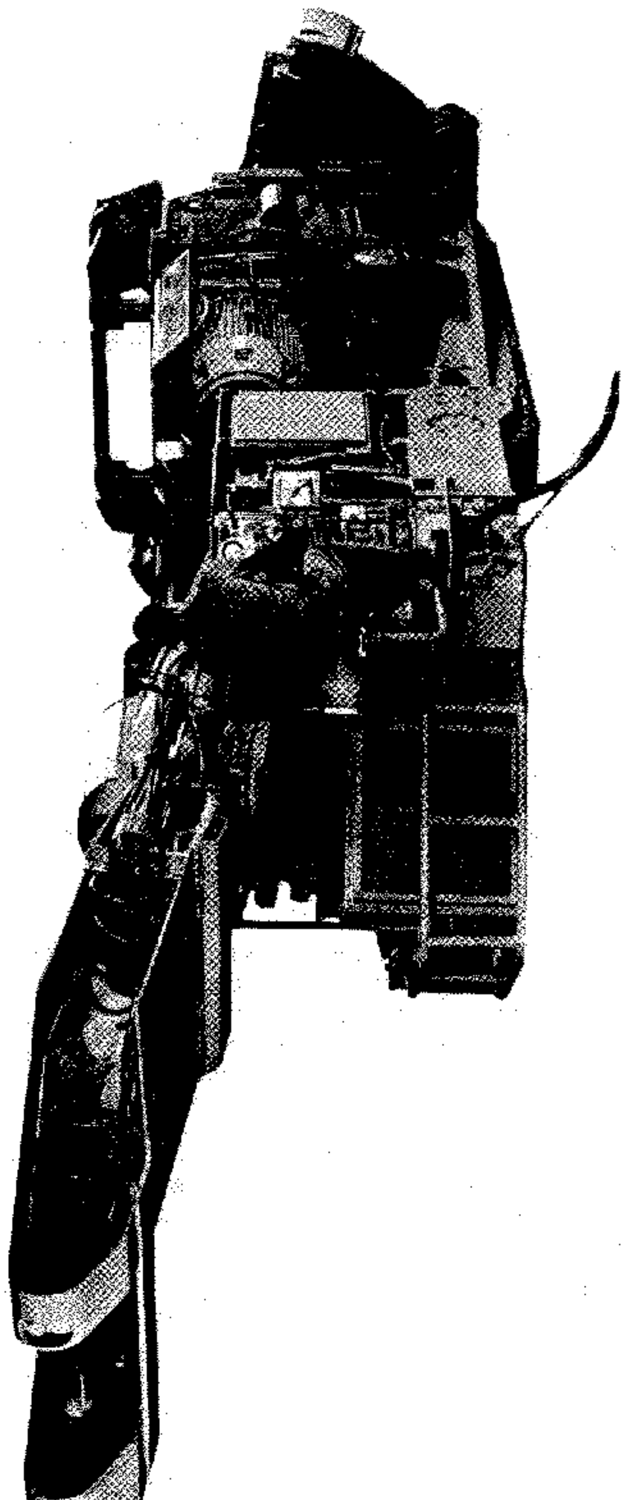


Figure 12.