Long Room Section Mining in Salt Domes

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ABSTRACT

Section mining in the true sense of the word is unique to salt domes because of the limited teral working area. Cargill's mine at Belle Isle, Louisiana, was laid out in sections primarily ecause of two problems -- ventilation and scales.

With the increased use and production of salt, more voids are opened which means more exosure. The long room method will eliminate some of the dangerous corners prevalent in the oom and pillar method. Pre-splitting prior to floor mining is another method we hope to use in rming a smoother wall. With the use of more diesel equipment and the use of ammonium nitrate an explosive, proper ventilation must be maintained. Each section as it is mined out will be aled off, thereby keeping air circulating through the working areas only. The incorporation of ese methods at the mine should help the overall efficiency.

DISCUSSION

Section mining is unique to salt domes because the lateral working area rarely covers over mile. Section mining, as referred to coal, has been practiced since underground mining started. is, along with room and pillar method of extraction, accounts for nearly all the coal production ing in beds or seams. There are many variations to this method and in any case those which ll yield a maximum recovery, at a minimum cost, with a good quality product, and with the ast danger to the miners, are the governing factors. Because of the presence of explosive dust d gas, thorough ventilation is most important in coal mining. The presence of gas in salt domes rare. Occasionally a pocket of hydrogen sulphide or carbon dioxide gas is encountered but not dangerous amounts. Then where does the advantage of section mining present itself in salt mes? Here the answer is twofold -- VENTILATION and SCALING. With the use of more diesel uipment and the use of ammonium nitrate as an explosive, ventilation now becomes a major oblem and one which must be recognized and dealt with immediately. With the extraction of salt benching to a depth of 58 feet, a scaling problem develops and again this must be dealt with. creased salt production over the past eight years magnifies the scaling problem because more ids mean more scales and more exposures.

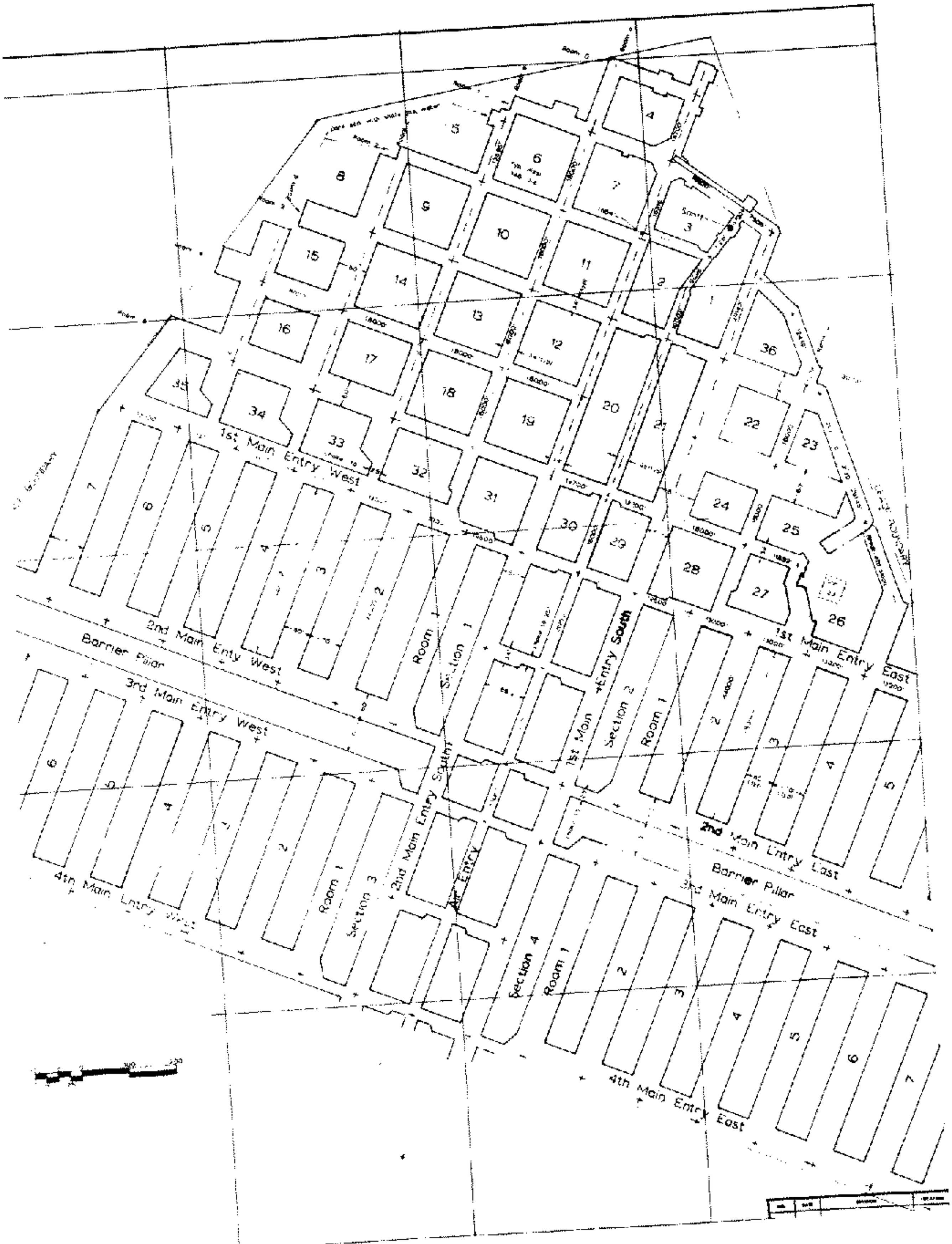
With these problems in mind Cargill's mine started operation in December 1962 -- to keep much fresh air to the working faces and to keep away from as many unnecessary corners as ssible. Pillars seem to have a tendency to become cylindrical and slough off at the corners. ese can be watched during low roof extraction and corrective action can be taken to overcome danger. However, with floor removal, the scales up 40 to 50 feet may not seem to be as danrous and may be overlooked temporarily before being pulled down.

Cargill's mine at Belle Isle covers a subsurface lease of approximately 235 acres with the aft located near the northeast corner. The mine was laid out in a three-main entry system with the center entry furnishing the air. See Mine Map. These entries run southwestwardly about 4,200 feet and divide the lease in half. Room and pillar method of mining was started so that the mine could operate with sufficient working faces. In order to protect the shaft, these pillars were left large -- the recovery, at a 38° draw from the shaft, was 34.2%, with a safety factor of 2.65 to 1. The recovery was based on compressive tests taken in the salt. Two-inch cubes were sawed from 16-inch core samples taken horizontally during the shaft sinking for timber sets. Of course, these tests are not conclusive but were a starting point, and as the mine develops, more samples will be tested to determine whether we can extract a greater percentage. As the mine developed beyond the 38° draw or approximately 800 feet from the shaft, extraction was increased to 52.8% with a safety factor of 2 to 1. It is hopeful that recovery will increase to 60-65% with further tests. The general section mining layout as developed and started is also shown on the Mine Map. You will note the room and pillar method used near the shaft and how these rooms were widened away from the shaft. The narrow necks shown at the start of the Main East and West entries were purposely mined that way so they could be filled easily with waste salt when these sections are completed. In these necked out areas the salt will not be removed the full 80 feet but will be mined 22 feet high in the low roof and at the final floor level with 36 feet remaining between openings -- see Fig. 1 and Photo 1. Each section will develop the low roof 22 feet high and the floor will be benched the remaining 58 feet for a total of 80 feet. Two sections will be mined simultaneously and with proper planning -- as low roof is completed in one section, the floor mining will also be completed in another section. With just two sections operating most of the time we hope to keep ventilation in the working areas at a maximum. In addition as one section is completed to 80 feet, the whole section will be sealed off, eliminating haulage through these high rooms where scales may form. With limited voids, it is hoped that smoke and fumes from blasting will be removed from the mine much quicker. With long rooms in the sections many of the hazards from pillar corners will be eliminated. Since the corners seem to take more pressure and start to spall, we have drilled and shot them at approximately a 45° angle. It takes time to mine these corners but with this long room method, we are eliminating three-fourths of the corners. See Map and Photo 2. Again observation of these corners over the years will tell if our thinking was justified. Ventilation along the air entry will be controlled by waste salt stoppings again at the necked out X-cuts shown toward each main entry. As new openings are made the old ones will be sealed off. Ventilation to the lower level will be pushed through holes five to six feet in diameter drilled between levels along the air entry -- see Fig. 1. Air will be split between the levels or can be channeled to one or the other depending on where the work group is mining. Along the entire three main entries there will be two levels with 36 feet of salt remaining between.

Photo 1

In conjunction with section mining, we have incorporated the use of presplitting along the ribs and pillar corners where the floor has been bench mined. With a well-defined smooth wall and a minimum of crushing around the holes, we hope to eliminate the majority of scales which form later after the fractures have had a chance to open up.

Presplitting or preshearing was developed from experimentation with line and cushion blasting as employed by the construction industry. Ordinary drilling and blasting caused backbreaks and dangerous and rugged walls for setting forms and, in turn, resulted in the removal of more burden and the use of additional concrete. Presplitting forms a smooth wall, to prescribed tolerances, easier to form and with less burden to move and less concrete to pour.



CARGILL INCORPORATED
Belle Isle Salt Mine

ENTRY LAYOUT FOR CONTROLLED VENTILATION

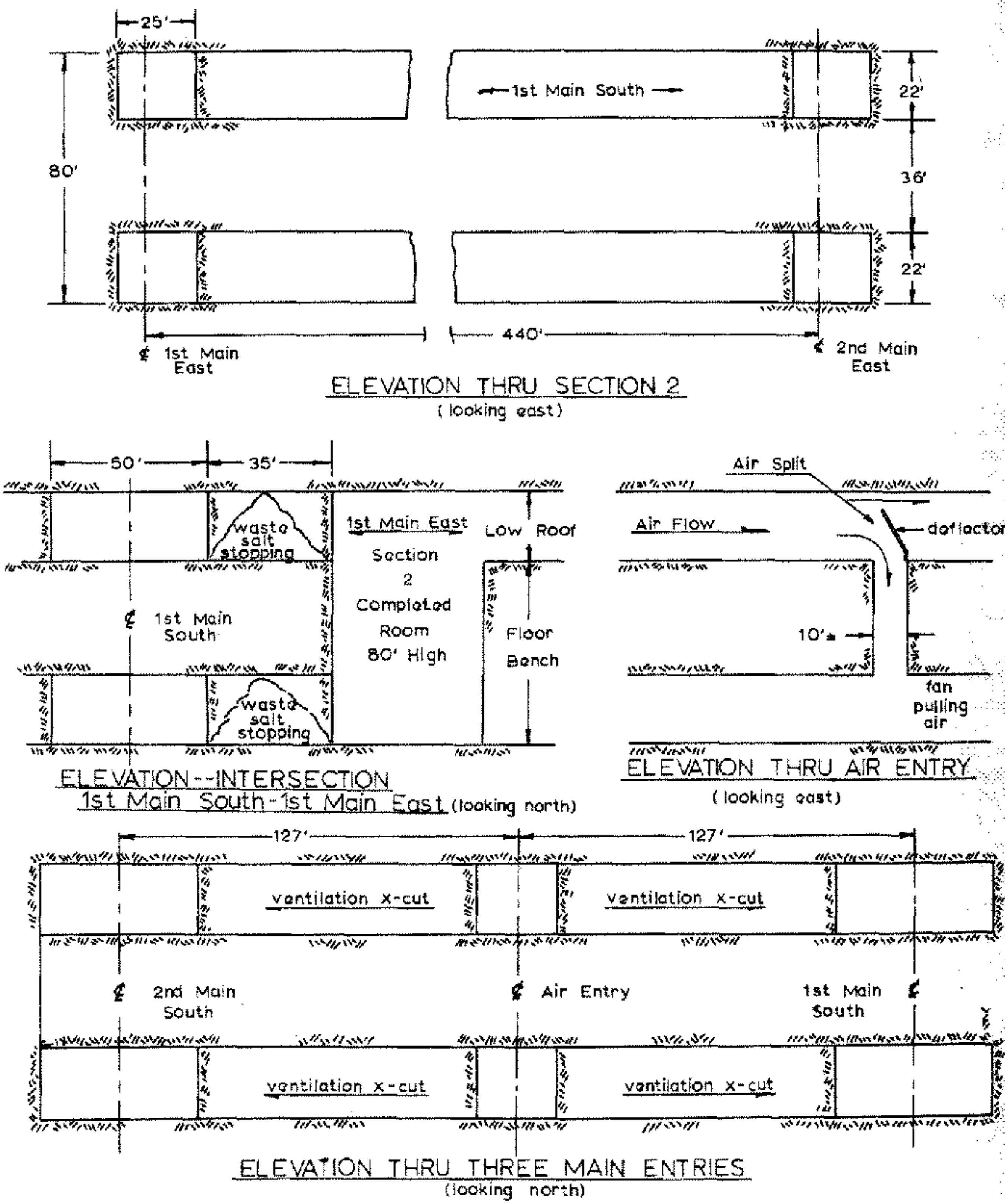


Figure 1

Presplitting in mining has been limited to presplitting along boundaries of massive ore bodies · minimize ore dilution and to presplitting the periphery of tunnel shots, for the purpose of stress ·lieving the rock to be blasted in the main advance rounds. Presplitting differs from smooth wall ıd perimeter blasting in that the detonation of the rib holes precedes the detonation of the re- ainder of the blast; whereas, in smooth wall blasting, the detonation is delayed until after the ain blast. With the advent of rock engineering and rock mechanics, blasting is now changing om an art to a science. This fact has made the application of engineering principles to blasting ·sign an important consideration in overall mine operations. Technically speaking, presplitting defined as the establishment of a free surface or shear plane within a solid media by controlled ıe of explosives and drilling techniques. The key to the ultimate results is the ability to drill ›les as vertically as possible and in the same plane or in angle drilling, to the desired angle and ;ain in the same plane. The theory of presplitting is based on the fact that for most materials e compressive strength is from 13 to 16 times greater than the tensile strength. It is evident, erefore, that rocks break more easily in tension than in compression -- ideally, then, it is pos- ble to eliminate crushing of rock around a drill hole and still produce tension cracks between two ljacent holes. As stated before, these results are obtained provided the spacing, hole diameter ıd loading factors are correctly matched to rock strength.

The method of presplitting consists of drilling small diameter holes along a carefully laid ıtline. These holes are then deck-loaded with an optimum explosive charge. See Figs. 2 and 3. st enough explosive is used to break the rock in tension without wasting energy crushing rock ımediately to the drill hole. Stemming is used the entire length of each hole. The individual ıarges are either secured to or placed in contact with the primacord downline in each hole. The ·imacord downline is attached to a trunk line that is detonated with an electric or cotton fuse cap. ·e Photo 3. The presplitting action is effected by the pressures resulting from the detonation. ıese pressures set up tensile stresses normal to the plane between adjacent drill holes, and re- .lt in a splitting of the rock along this plane, giving rise to a surface of discontinuity. See g. 4. Presplit test data and test results are shown in Tables I and II.

TEST RESULTS

Although tests are still being conducted, some preliminary conclusions are as follows:) optimum hole space appears to be close to 24 inches. Tests with holes on 26-inch centers elded fairly good results but the shear plane sometimes became indistinct if the holes drifted off ightly. (2) With holes on 24-inch centers, loading factors close to .33# /ft. gave best results.) Tests using holes drilled on centers less than 24 inches and leaving alternate holes unloaded elded good results. However, the results did not justify the additional drilling time. (4) It was cessary to use a spacing-to-burden ratio between 1.3 and .8 to insure that the burden would peel

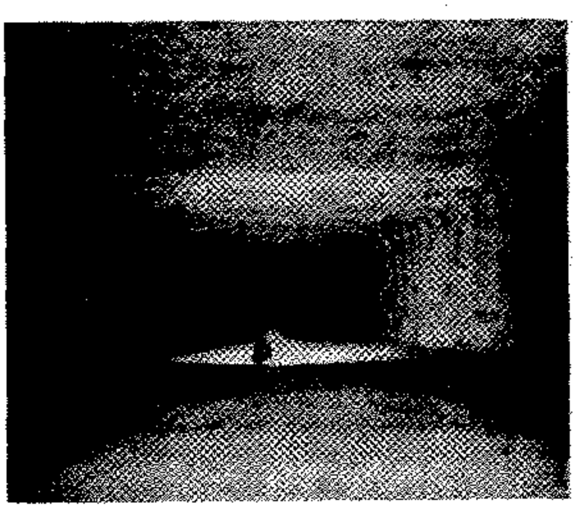
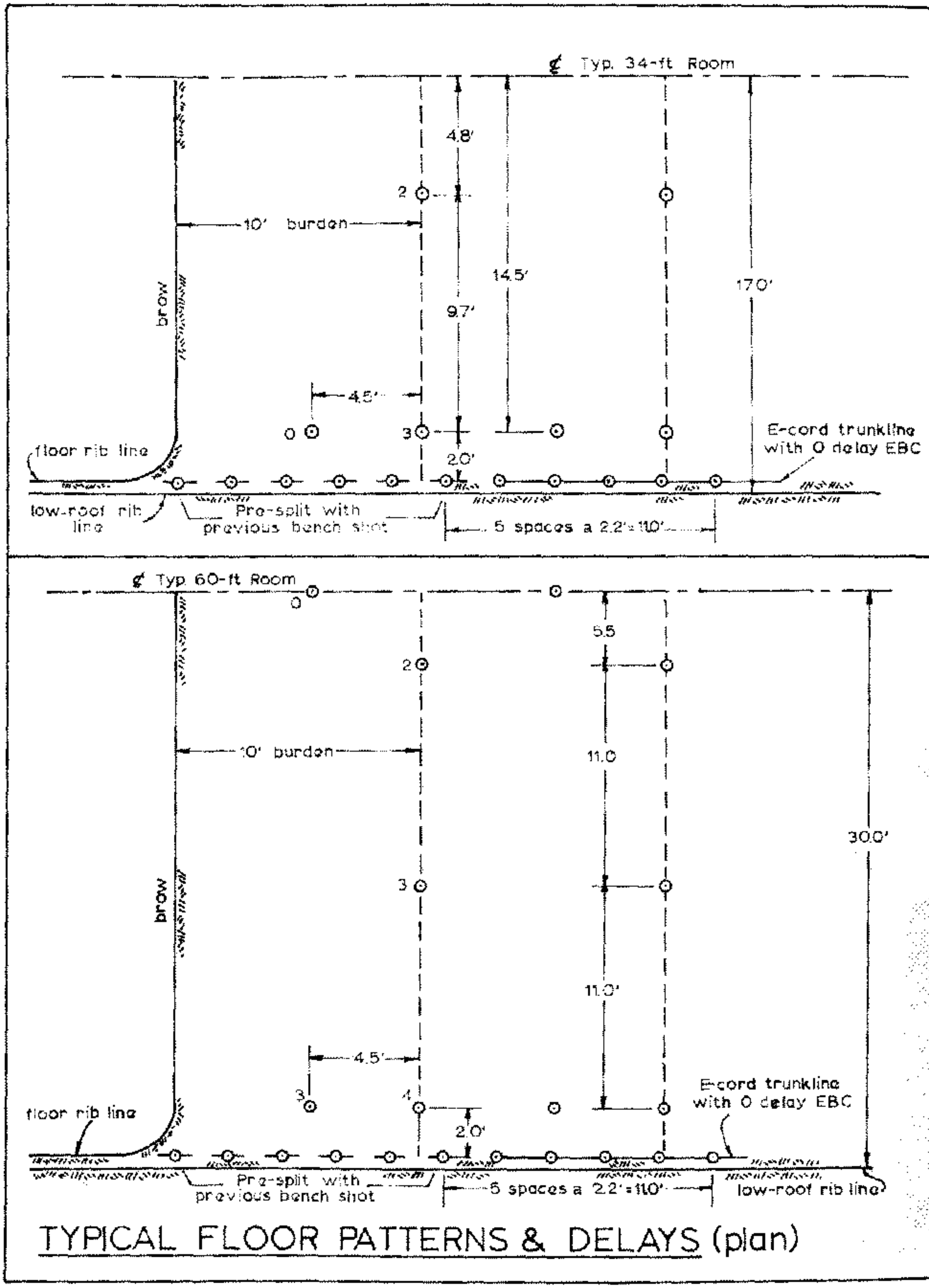


Photo 2

Photo 3



℄ Typ. 34-ft Room
4.8'
2
10' burden
brow
14.5'
17.0'
9.7'
4.5'
0
3
2.0'
floor rib line
E-cord trunkline
with 0 delay EBC
low-roof rib
line
Pre-split with
previous bench shot
5 spaces a 2.2'=11.0'
℄ Typ. 60-ft Room
0
5.5
2
10' burden
11.0
30.0'
brow
3
11.0'
4.5'
3
4
2.0'
floor rib line
E-cord trunkline
with 0 delay EBC
Pre-split with
previous bench shot
5 spaces a 2.2'=11.0'
low-roof rib line
TYPICAL FLOOR PATTERNS & DELAYS (plan)

Figure 2

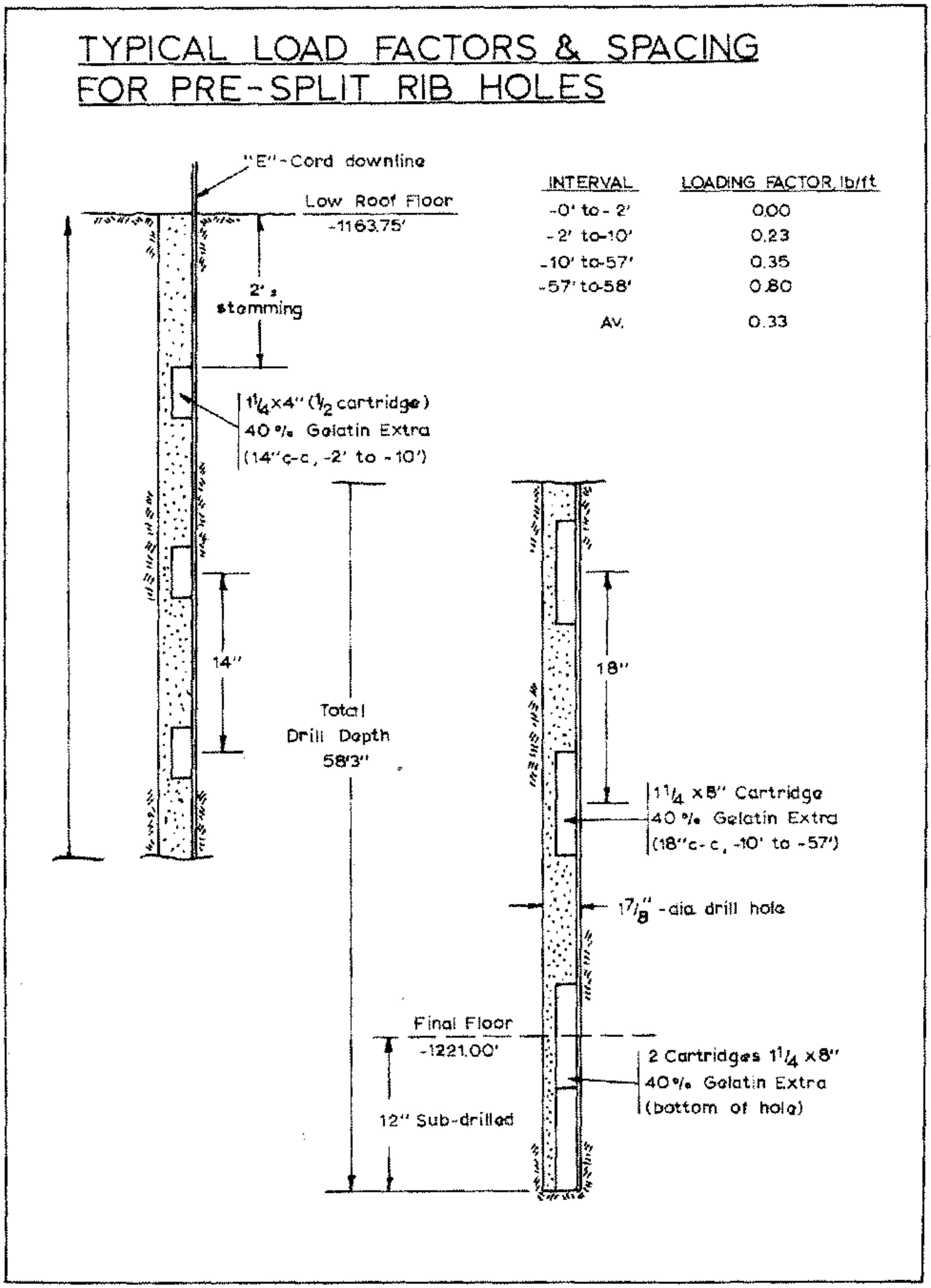

TYPICAL LOAD FACTORS & SPACING FOR PRE-SPLIT RIB HOLES
"E"-Cord downline
Low Roof Floor
-1163.75'
2' ± stemming
INTERVAL
LOADING FACTOR, lb/ft
-0' to -2'
0.00
-2' to -10'
0.23
-10' to -57'
0.35
-57' to -58'
0.80
AV.
0.33
1¼×4" (½ cartridge)
40% Gelatin Extra
(14" c-c, -2' to -10')
14"
Total
Drill Depth
58'3"
18"
1¼ ×8" Cartridge
40% Gelatin Extra
(18" c-c, -10' to -57')
1⅞" -dia. drill hole
Final Floor
-1221.00'
12" Sub-drilled
2 Cartridges 1¼ ×8"
40% Gelatin Extra
(bottom of hole)

Figure 8

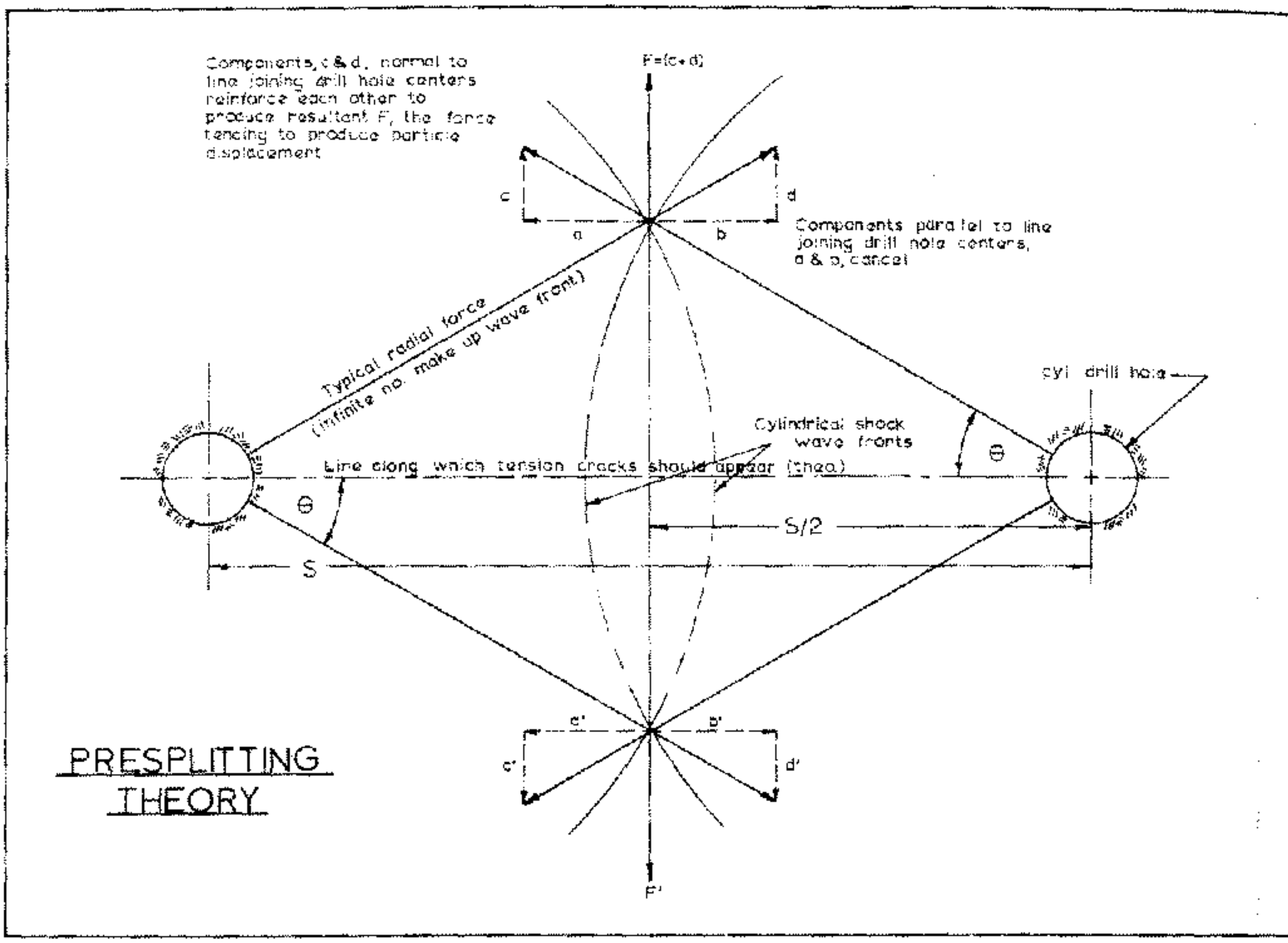


Figure 4

TABLE I

Presplit Test Data

April 1965

Test Shot -- Room	4-1[c]	4-2	4-3	4-4	4-8[d]	4-9	4-10[e]	5-1	5-2	5-4[e]
No. of Holes	5	5	5	5	10	10	16	16	5	10
Total Drill Hole Length	181'	180'	176'	179'	356'	360'	561'	612'	274'	562'
Lbs. Explosives[a]	43	45	92	61	73	101	158	201	88	174
Overall Loading Factor lb./ft.	0.23	0.25	0.52	0.34	0.41[d]	0.28	0.28	0.33	0.32	0.31
Charge Size[b]	1-1/4 × 4"	1-1/4 × 4"	1-1/4 × 8"	1-1/4 × 8"	1-1/4 × 8"	1-1/4 × 8"	1-1/4 × 8"	1-1/4 × 8"	1-1/4 × 8"	1-1/4 × 8"
Charge Spacing	12"	12"	12"	18"	16"	22"	20"	18"	18"	18"
Hole Spacing	24"	24"	24"	24"	15"	18"	24"	24"	26"	24"
Drill Hole Diameter	1-7/8"	1-7/8"	1-7/8"	1-7/8"	1-7/8"	1-7/8"	1-7/8"	1-7/8"	1-7/8"	1-7/8"
Stemming	3'	Full Length	Full Length	Full Length	Full Length	Full Length	Full Length	Full Length	Full Length	Full Length

a. Hercules' 40% Gelatin Extra.
b. Whole or fractional parts of 1-1/4" x 8" cartridges.
c. No stemming between charges.
d. Alternate holes unloaded; Loading Factor calculated only for the 5 loaded holes.
e. Cushion shot; was delayed behind main blast.

TABLE II

Presplit Test Results

April 1965

Test Shot	Results and Comments
Room 4-1	Only top three feet of hole stemmed; all holes rifled upon detonation; no evidence of shear plane; holes subsequently reloaded and shot.
Room 4-2	Holes stemmed full length; no evidence of a shear plane after detonation; holes subsequently reloaded and shot.
Room 4-3	Holes overloaded; floor badly fractured and dislocated; ribs showed evidence of communication between more than one set of tension cracks; tabular scales formed between holes.
Room 4-4	Good results; cracks between holes at the collar; shear plane well defined and smooth.
Room 4-8	Guide holes drilled between loaded holes; results excellent, but comparable to holes on 24-inch centers.
Room 4-9	Holes on 18-inch centers; lighter loading factor; results very good, but comparable to holes on 24-inch centers.
Room 4-10	Cushion shot at terminal end of floor removal in 4 West; results very good; smooth, clean wall; some backbreak at brow.
Room 5-1	First test in 5 West; North rib results -- excellent; West rib badly fractured and broken as a result of previous shot (not presplit) at corner of room 5 West and 2nd Main South.
Room 5-2	Holes on 26-inch centers; smooth, solid wall; results comparable to those obtained with holes on 24-inch centers.
Room 5-4	Cushion shot in 5 West; South rib -- fair, plane not well defined; North rib -- three holes failed to detonate; trunkline apparently ruptured when interior blast holes detonated.

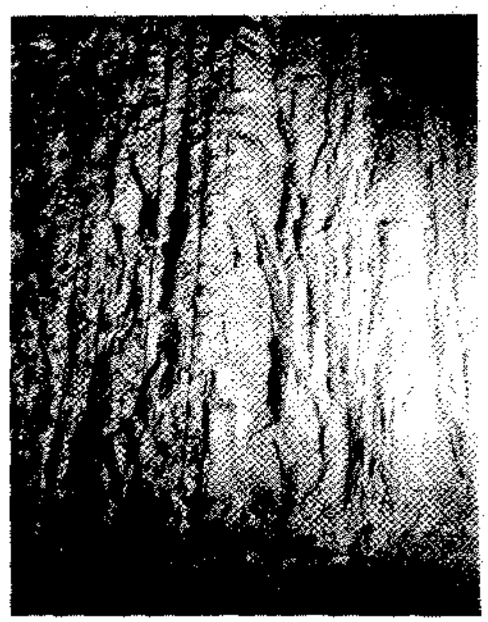
away from the presplit surface. A ratio S/B greater than 1.3 resulted in partial destruction of the presplit surface while a ratio less than .8 sometimes failed to peel the burden completely from the shear plane, leaving dangerous scales along the ribs. (5) The most efficient method of loading presplit holes involved placing the E-cord downline in the hole and alternately adding an explosive charge in a measured quantity of stemming. Each explosive charge is tamped lightly to insure contact with the E-cord. This tamping unfortunately increases the coupling between the explosive and the drill hole, causing local crushing of the rock adjacent to the drill hole. This effect, however, is minor and does not produce objectionable scales. This method permits simultaneous loading of two holes: one man charges one drill hole while the other man tamps the charge in the alternate hole. The following eight photos show the results of presplitting, the contrast of presplitting vs. ordinary shooting and the face of a brow presplit before tunnelling.

ADVANTAGES

Properly engineered, designed and executed, presplit blasts produce clean shear planes along the rib line to any given depth. Overbreak into the permanent walls behind the rib holes is almost completely eliminated. The shear plane greatly reduces hazardous and distracting scales. Consequently scaling time is sharply reduced and with the reduced exposure to scales, miners are able to focus their attention on their jobs because of improved morale. Drilling and loading of rib holes are carried out with a minimum exposure to the bench brow for the driller and powderman because rib holes for presplitting are drilled and shot ahead of the main advance round. Drill set up time is reduced because it isn't necessary to maneuver around any ragged backbreak that may occur during the previous bench shot. Because rib holes are shot ahead of the main advance round, it is practically impossible to lose rib holes in a predrilled pattern due to any backbreak from the previous bench shot.

DISADVANTAGES

Inherent stresses within the rock being blasted have a pronounced effect upon presplitting in certain directions. Most materials have a tendency to split in the direction of maximum compressive stress. The magnitude and orientation may in some cases be such that presplit plane may fail to materialize or be poorly defined. Loading presplit holes requires three to four times the man-hours required for loading regular blast holes and the requisite close loading tolerances involve more conscientious and continuous supervision than required under normal loading



circumstances. Since ANFO blasting agents are not readily applicable to presplitting, loading must be accomplished with more costly explosives, in addition to the use of primacord.

CONCLUSIONS

Presplitting has proved to be too expensive and time-consuming a proposition to be applied to bench mining generally. However, the resulting advantages are such that it is anticipated that the method will be employed in areas of personnel concentration, heavy traffic, and permanent equipment installations. Areas of abnormal stress concentration, such as pillar corners, would be areas where presplitting would be used.