Sept. 9, 1969 G. R. HAWORTH ET AL 3,466,094

BLASTING ARRANGEMENT FOR OIL SHALE MINING

Filed Feb. 5, 1968 2 Sheets-Sheet 1

FIG. 2

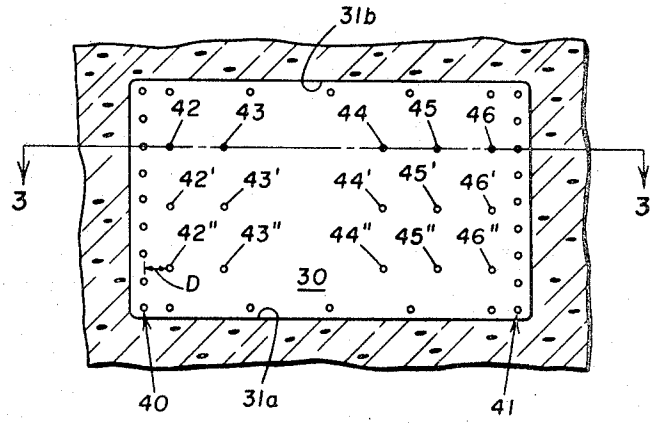
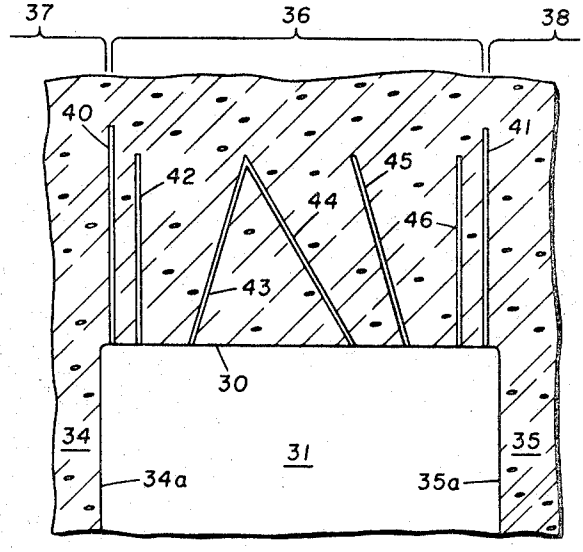


FIG. 3



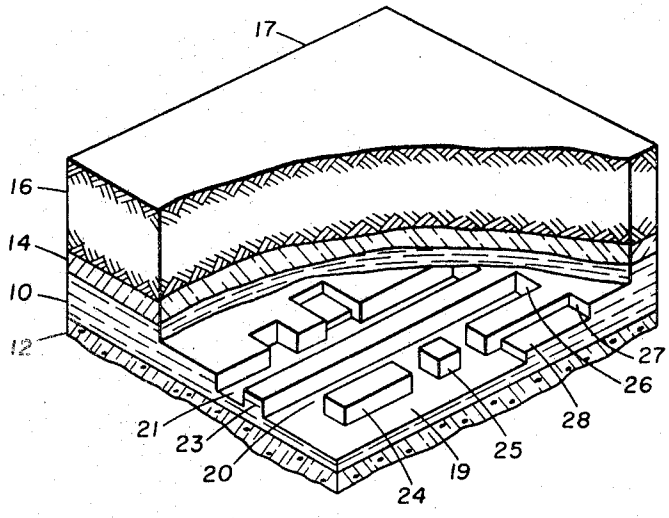


FIG. 1

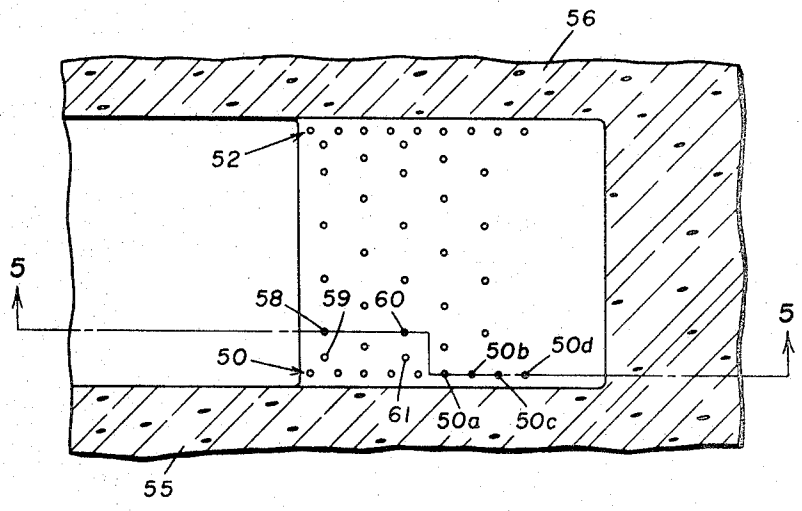
GORDON R. HAWORTH
PETER G. ZAMBAS
INVENTORS

BY William R. Jackson
ATTORNEY

BLASTING ARRANGEMENT FOR OIL SHALE MINING

Filed Feb. 5, 1968 2 Sheets-Sheet 2

FIG. 4



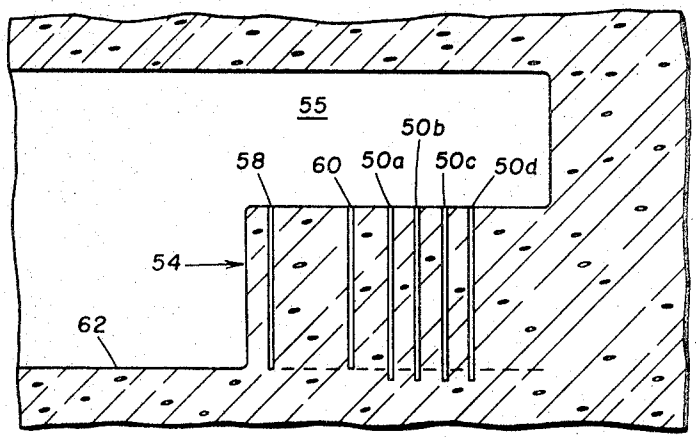


FIG. 5

GORDON R. HAWORTH
PETER G. ZAMBAS
INVENTORS

BY William R. Jackson
ATTORNEY

United States Patent Office

3,466,094

Patented Sept. 9, 1969

3,466,094

BLASTING ARRANGEMENT FOR OIL SHALE MINING

Gordon R. Haworth, Ponca City, Okla., and Peter G. Zambas, Woodside, N.Y., assignors, by mesne assignments, to the United States of America as represented by the Secretary of the Interior

Filed Feb. 5, 1968, Ser. No. 702,965
Int. Cl. E21c 41/10; F42d 3/04
U.S. Cl. 299—13 14 Claims

ABSTRACT OF THE DISCLOSURE

This specification discloses a blasting technique for use in excavation of an oil shale deposit during the subterranean mining thereof. Primary blasting holes are provided in a working zone such as a heading or bench within the mine. In addition, a row of explosive-loaded secondary blasting holes is provided along a line between the working zone and a support zone adjacent the working zone. Thus, in a benching round, secondary holes extend downwardly through the bench from the top thereof and in a heating round the secondary holes extend into the heading from the heading face. The secondary and primary blasting holes are detonated in a desired sequence. Preferably, the secondary blasting holes are detonated first although this sequence of operation may be reversed. The secondary blasting holes carry a lower explosive charge than the primary holes and also are spaced closer together than the primary holes.

BACKGROUND OF THE INVENTION

This invention relates to the subterranean mining of oil shale and more particularly to the blasting of oil shale deposits in carrying out mining operations.

Large deposits of oil shale are located beneath the earth's surface in flat-lying subterranean formations. One technique for recovering the oil from such deposits involves the application of underground mining procedures by which the oil shale is removed from its natural subterranean location to the surface of the earth. At the surface the oil shale is crushed as necessary and then subjected to retorting. The "shale oil" recovered during such retorting operations then may be subjected to further refining operations in order to produce desirable hydrocarbon products such as gasoline.

In the underground mining procedures used, the extraction of the oil shale from its subterranean location requires, as a practical matter, the excavation of large stopes in order to accommodate the mechanical equipment used. For example, in the "room and pillar" mining technique for oil shale, it is desirable to provide open stopes or "rooms" which exhibit at least horizontal dimension on the order of sixty feet and height of about forty to one hundred feet. In forming stopes of such size the blasting of large quantities of shale in single rounds is an economic necessity. The large blasting rounds involved induce high magnitude vibrations in the mine, particularly in the pillars adjacent the working zones of the mine in which blasting operations are carried out.

Oil shale normally has a laminated structure which exhibits a large number of joints and incipient planes of weakness. These characteristics of the oil shale, in combination with the high magnitude of vibrations encountered during blasting operations, often result in a general weakening of the pillar structures adjacent the blasting areas and also in the excessive amounts of spallation in the sides or "ribs" of the pillars. These conditions create severe safety hazards. For example, the pillars may become so weakened that they fail to support

adequately the roof of the mine with the attendant result that cave-ins may occur. In addition, the vibrations transmitted to the pillars are in turn transmitted to the roof of the mine, and this may result in weakening of the portion itself. Thus, even though the pillars may be of sufficient strength to support the mine, portions of oil shale may become parted from the roof and fall into the open stopes with the attendant hazard to personnel working in the mine.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a new and improved blasting technique for use in the subterranean mining of an oil shale deposit. In carring out the invention a plurality of explosive-loaded primary blasting holes are provided in a working zone of the oil shale deposit within the mine. In addition, a plurality of explosive-loaded secondary blasting holes are provided along a line between the working zone and a support zone adjacent the working zone. The secondary blasting holes have a lower average explosive charge than the primary holes and function to control the effect of the primary blasts in order to minimize damage to the support zone. The primary and secondary blasting holes then are detonated in the desired sequence. The secondary blasting holes preferably are detonated prior to detonation of the primary blasting holes. In a preferred embodiment of the invention, the average spacing of the secondary blasting holes is less than the average spacing of the primary blasting holes.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is an isometric view, with parts broken away of a subterranean oil shale mine being developed by the room and pillar method;

FIGURE 2 is an illustration, partly in section, showing the application of the present invention in blasting a heading round;

FIGURE 3 is a sectional view taken along line 3—3 of FIGURE 2;

FIGURE 4 is an illustration, partly in section, showing the application of the invention in the blasting of a benching round; and

FIGURE 5 is a sectional view taken along line 5—5 FIGURE 4.

DESCRIPTION OF SPECIFIC EMBODIMENTS

With reference to FIGURE 1 of the drawing, there is illustrated a subterranean oil shale deposit **10** which is being mined by the room and pillar procedure. The oil shale deposit lies between formations **12** and **14**, and above formation **14** additional overburden **16** extends to the surface **17** of the earth. As illustrated, the mine comprises a number of stopes such as those indicated by reference numerals **19**, **20**, and **21**. The stopes are formed in the oil shale deposit by suitable excavation procedures and leave support structures, commonly termed "pillars," which extend between the floor of the mine and the roof thereof in order to support the overburden above the mine. The pillars may be substantially continuous, such as the pillar indicated by reference numeral **23**, although more typically they will be in block form such as those indicated by reference numerals **24** and **25**.

Excavation of the stopes within the mine typically is accomplished through the application of "heading" and "benching" blasting techniques. By way of example, the stope **20** shown in FIGURE 1 may be extended by full heading blasting in which a number of blasting holes are drilled into the face **26** of the heading and then loaded with explosives and detonated. Further excavation of the stope **19** may be effected by heading blasting through the similar utilization of blasting holes in face **27** or by a

bench blasting procedure in which a plurality of substantially vertical holes are drilled into the bench **28** from the top thereof, loaded, and then detonated.

The invention will now be described in detail with reference to its application in the blasting of a heading round. With reference to FIGURES 2 and 3, there is illustrated a heading face **30** at the end of a stope **31**. For example, the face **30** may be considered to correspond to the heading face **26** shown in FIGURE 1. The stope **31** is defined by the ribs **34***a* and **35***a* of pillars **34** and **35**, the heading floor **31***a*, and the roof **31***b*. The portion of the unworked oil shale which is to be excavated by the blasting procedure to provide an extension of stope **31** is termed the "working zone" and is indicated generally by bracket **36**. The portions adjacent the working zone which are to be left in place to become extensions of pillars **34** and **35** are designated by brackets **37** and **38**, respectively, and are termed the "support zones."

In carrying out the invention, rows **40** and **41** of secondary blasting holes are drilled into the heading from the face **30**. The holes desirably are located as close to the lines of the ribs **34***a* and **35***a* as possible and lie in a common plane. The secondary blasting holes may be drilled to any suitable diameter and spacing. Typically, the holes will be on the order of about four inches in diameter and will be spaced approximately four feet apart. In addition to the secondary blasting holes which provide for blasting control, the heading also is provided with a plurality of primary blasting holes such as those indicated by reference numerals **42–46**. As is best shown in FIGURE 3, the primary holes in the heading round are drilled in accordance with a V-cut procedure in order to notch the heading face to provide for an adequate free face for the blasting procedure.

The primary and secondary holes are loaded such that the primary holes have a greater average explosive charge than the secondary holes. By way of example, each of the primary holes may be loaded with five pounds per foot of a suitable explosive agent such as semi-gelatin powder, with the first ten feet of hole either vacant or filled with stemming. Thus, a primary hole drilled to a depth of twenty-five feet may be loaded with approximately seventy-five pounds of explosive. The secondary holes normally will be loaded with an explosive charge of approximately one-fifth or less of the power of the primary loads. For example, where the primary holes are loaded as described above, each of the secondary holes may be loaded with strings of powder made from 100-grain primacord and one and one-half-inch by eight inch sticks of semi-gelatin powder. The semi-gelatin powder is taped to the primacord with twenty-inch gaps between adjacent sticks.

After loading the respective blasting holes they are detonated in the desired sequence. Preferably, the secondary blasting holes are detonated first in order to effect a "pre-splitting" function with regard to the primary blasting round. The effect of this is to form fractures along the planes in which the secondary holes lie which tend to de-couple the support zones **37** and **38** of the oil shale deposit from the working zone **36**. Thus, the vibrations induced by the blasting of the primary rounds are transmitted to the support zones at greatly reduced intensity. In addition, the resulting walls or "ribs" of the pillars resulting from the heading round are relatively smooth and resistant to spalling.

After detonation of the secondary holes the primary blasting holes are detonated in order to remove oil shale from the working zone **36**. By way of illustration, the primary and secondary blasting holes shown in FIGURE 2 can be detonated in the following sequence. The secondary holes preferably are detonated in groups of three or more. For example, the holes in rows **40** and **41** may be detonated in groups of three at intervals of 25 milliseconds. Thus, the three lower holes in row **40** may be detonated at zero milliseconds and the progression repeated until the upper three holes in row **41** are detonated at 125 milliseconds. Thereafter, the primary holes **43–43″** and **44–44″** are detonated at 200 milliseconds, holes **42–42″** and **45–45″** at 250 milliseconds, and holes **46–46″** at 300 milliseconds. The holes along the top and bottom of the heading face are detonated at 350 to 400 milliseconds.

While it usually will be desirable to detonate the primary and secondary blasting holes in a common round through the use of electrical detonating equipment, it will be recognized that the secondary holes may be drilled, loaded, and detonated before drilling of the primary holes.

It is preferred in carrying out the invention that the spacing between the secondary blasting holes be less on an average than the spacing between the primary blasting holes. In this regard, the nature of oil shale is such that blasting can be carried out most economically and expeditiously by utilizing heavily loaded, widely spaced, primary holes. The secondary holes on the other hand should be located in a relatively closely spaced pattern in order to obtain effective de-coupling. It usually will be desirable to provide an average spacing between secondary holes of less than one-half of the average spacing between primary holes. It also is preferred that the outer perimeter primary holes, e.g., holes **42**, **42′**, **46**, etc., be located relatively close to the adjacent row of secondary holes. More particularly, the distance between the outer perimeter primary holes and the line along which the adjacent secondary holes lie normally should be less than the average distance between primary blasting holes and also less than twice the spacing of the secondary holes. Thus, the dimension of D in FIGURE 2 should be less than the average spacing of the primary blasting holes and less than twice the spacing of the secondary blasting holes in row **40**.

In addition to the above criteria, it is preferred that the secondary blasting holes extend further into the oil shale deposit from the face **30** than the primary holes. This relationship should be observed in order to clearly delineate the working and support zones and produce the desired de-coupling action.

Turning now to FIGURES 4 and 5, there is illustrated the use of the invention in blasting benching rounds. This procedure is similar to that described above with reference to the blasting of heading rounds except that in this case the secondary holes are drilled downwardly through a bench. More particularly, and with reference to FIGURES 4 and 5, there are provided rows **50** and **52** of secondary blasting holes located along each side of a bench **54** and as close as possible to the ribs of adjacent pillars **55** and **56**. The secondary holes extend downwardly through the bench **54** and may be drilled vertically as shown in FIGURE 5 or inclined. A plurality of primary blasting holes, such as those indicated by reference numerals **58**, **59**, **60**, and **61** are drilled into the bench **54** between the rows **50** and **52** of secondary holes. The secondary and primary blasting holes are loaded with explosives similarly as described above with reference to FIGURES 3 and 4. Thus, the average explosive charge of the secondary holes is less than the average explosive charge of the primary holes, preferably by a factor of at least one-fifth. After drilling and loading of the blasting holes they are detonated in the desired sequence with the secondary holes being detonated first in groups of three or more. After detonation of the secondary holes, the primary holes are detonated in a desired sequence with those next to the free face normally being detonated first.

The relationships between the primary and secondary blasting holes preferably are the same as those described above with reference to FIGURES 3 and 4. Thus, the average spacing between the primary blasting holes located between rows **50** and **52** preferably is greater than the average spacing between the secondary blasting holes. In addition, the outer perimeter primary blasting holes, such as those indicated by reference numerals **59** and **61**, preferably are located from rows **50** and **52** by a distance less

than the average distance between the primary blasting holes and also less than twice the spacing between the secondary blasting holes. It also is desirable that the secondary blasting holes in rows **50** and **52** extend into the oil shale deposit from the top of bench **54** by a distance greater than the primary blasting holes. Thus, as is shown in FIGURE 5, the primary blasting holes **58** and **60** extend from the top of the bench and terminate in the bench at approximately the level of the bench floor **62**. The secondary blasting holes **50***a*–**50***d* extend further into the oil shale deposit and terminate at a level below the floor of the bench.

In the procedures heretofore described, the secondary blasting holes are fired prior to detonation of the primary blasting holes. While this sequence of operation normally will be preferred in order to provide for effective decoupling as described above, it sometimes may be desirable to reverse this order of operation. Thus, in either benching or heading blasting operations, the primary blasting holes may be drilled, loaded, and fired, after which the secondary blasting holes may be detonated. In this case the primary blasting holes should be located such that the width of the burden left in place after firing of the primary round is less than the spacing between the secondary blasting holes. Stated otherwise, the distance between the face exposed by the primary blasting round and the row of secondary blasting holes should be less than the distance between such holes.

What is claimed is:

1. In the working of an oil shale deposit by means of a subterranean mine therein having stopes in said deposit and pillars which support the overburden over said mine, the method of blasting within said mine comprising:

(a) providing a plurality of explosive-loaded primary blasting holes within a working zone of said oil shale deposit;

(b) providing a plurality of explosive-loaded secondary blasting holes along a line between said working zone and a support zone of said deposit adjacent said working zone, said secondary holes having a lower average explosive charge than said primary holes; and

(c) detonating said blasting holes.

2. The method of claim **1** wherein the average explosive charge of said secondary holes is less than one-fifth the average explosive charge of said primary holes.

3. The method of claim **1** wherein the average spacing of said secondary blasting holes is less than the average spacing of said primary holes.

4. The method of claim **1** wherein the average spacing of said secondary blasting holes is less than one-half the average spacing of said primary holes.

5. The method of claim **1** wherein said primary blasting holes are detonated prior to said secondary blasting holes to leave a burden of a width less than the average spacing between said secondary holes, and thereafter detonating said secondary holes.

6. The method of claim **1** wherein said primary blasting holes are detonated subsequent to said secondary blasting holes.

7. The method of claim **6** wherein said secondary holes extend into said deposit to a depth greater than said primary holes.

8. The method of claim **6** wherein the primary blasting holes next adjacent said line of secondary blasting holes are spaced from said line by a distance less than the average spacing of said primary holes and less than twice the average spacing of said secondary holes.

9. In the working of an oil shale deposit by means of a subterranean mine therein having stopes in said deposit and pillars which support the overburden over said mine, the method of blasting a heading within said mine comprising:

(a) a long each side of the face of said heading providing a row of explosive-loaded secondary blasting holes extending into said heading from the face thereof;

(b) providing a plurality of explosive-loaded primary blasting holes in said heading located between said rows of secondary holes, said primary holes having a greater average explosive charge and a greater average spacing than said secondary holes;

(c) detonating said secondary blasting holes; and

(d) subsequent to step (c) detonating said primary blasting holes.

10. The method of claim **9** wherein the average explosive charge of said secondary holes is less than one-fifth the average explosive charge of said primary holes.

11. The method of claim **10** wherein said secondary holes extend into said heading from the face thereof by a distance greater than said primary holes.

12. In the working of an oil shale deposit by means of a subterranean mine therein having stopes in said deposit and pillars which support the overburden over said mine, the method of blasting a bench within said mine comprising:

(a) along each side of said bench providing a row of explosive-loaded secondary blasting holes extending downwardly into said bench from the top thereof;

(b) providing a plurality of explosive-loaded primary blasting holes in said bench located between said rows of secondary blasting holes, said primary holes having a greater average explosive charge and a greater average spacing than said secondary holes;

(c) detonating said secondary blasting holes; and

(d) subsequent to step (c) detonating said primary blasting holes.

13. The method of claim **12** wherein the average explosive charge of said secondary holes is less than one-fifth the average explosive charge of said primary holes.

14. The method of claim **13** wherein said secondary holes extend downwardly through said bench by a distance greater than said primary holes.

References Cited

UNITED STATES PATENTS

1,269,747	6/1918	Rogers	299—2
1,833,368	11/1931	O'Rourke	299—13
1,919,636	7/1933	Karrick	299—2

FOREIGN PATENTS

163,027	9/1948	Austria.

OTHER REFERENCES

"How & Why Mines Go To Smoothwall," Engineering & Mining Journal, vol. 166, No. 10 October 1965, pp. 92–95.

Culver, Dr. R. S., "Pre-Split Blasting," The Mines Magazine, March 1966, pp. 20–24.

E. I. du Pont de Nemours & Co., "Four Major Methods of Controlled Blasting," Pamphlet No. Ex-1179-A, rev. 4–64.

ERNEST R. PURSER, Primary Examiner

U.S. Cl. X.R.

102—23; 299—11