

May 8, 1962

A. G. BODINE
SONIC METHOD AND APPARATUS FOR SURFACE
MINING MINERAL BEDS OR THE LIKE

3,033,543

Filed Nov. 15, 1961

2 Sheets-Sheet 1

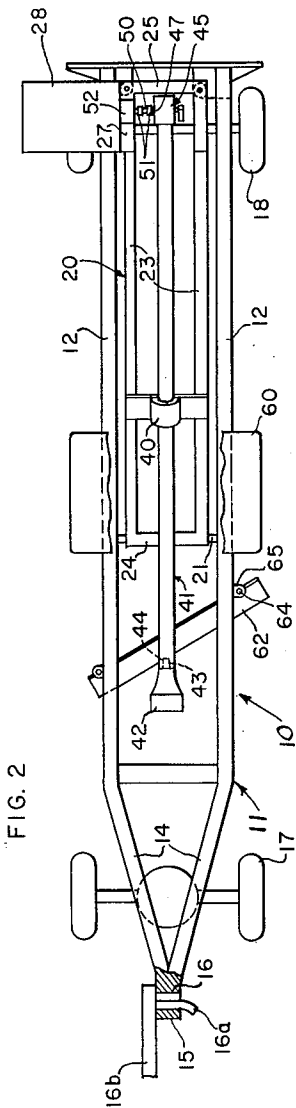


FIG. 2

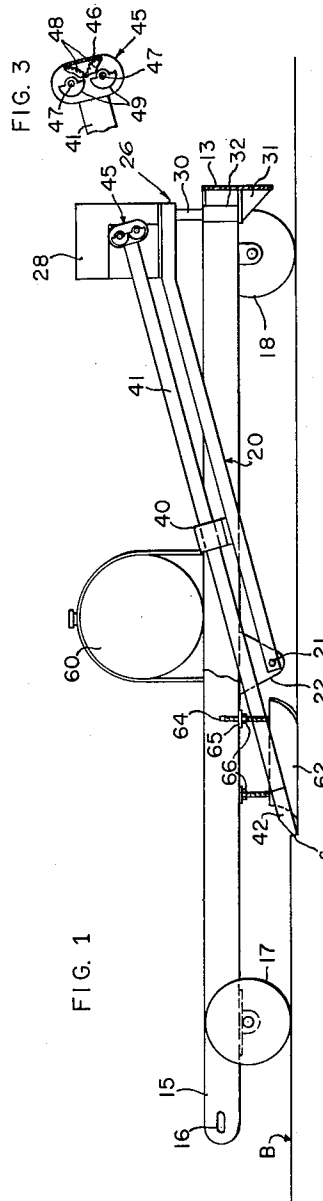


FIG. 3

INVENTOR.
ALBERT G. BODINE
BY *Tilly and Nykogen*
ATTORNEYS

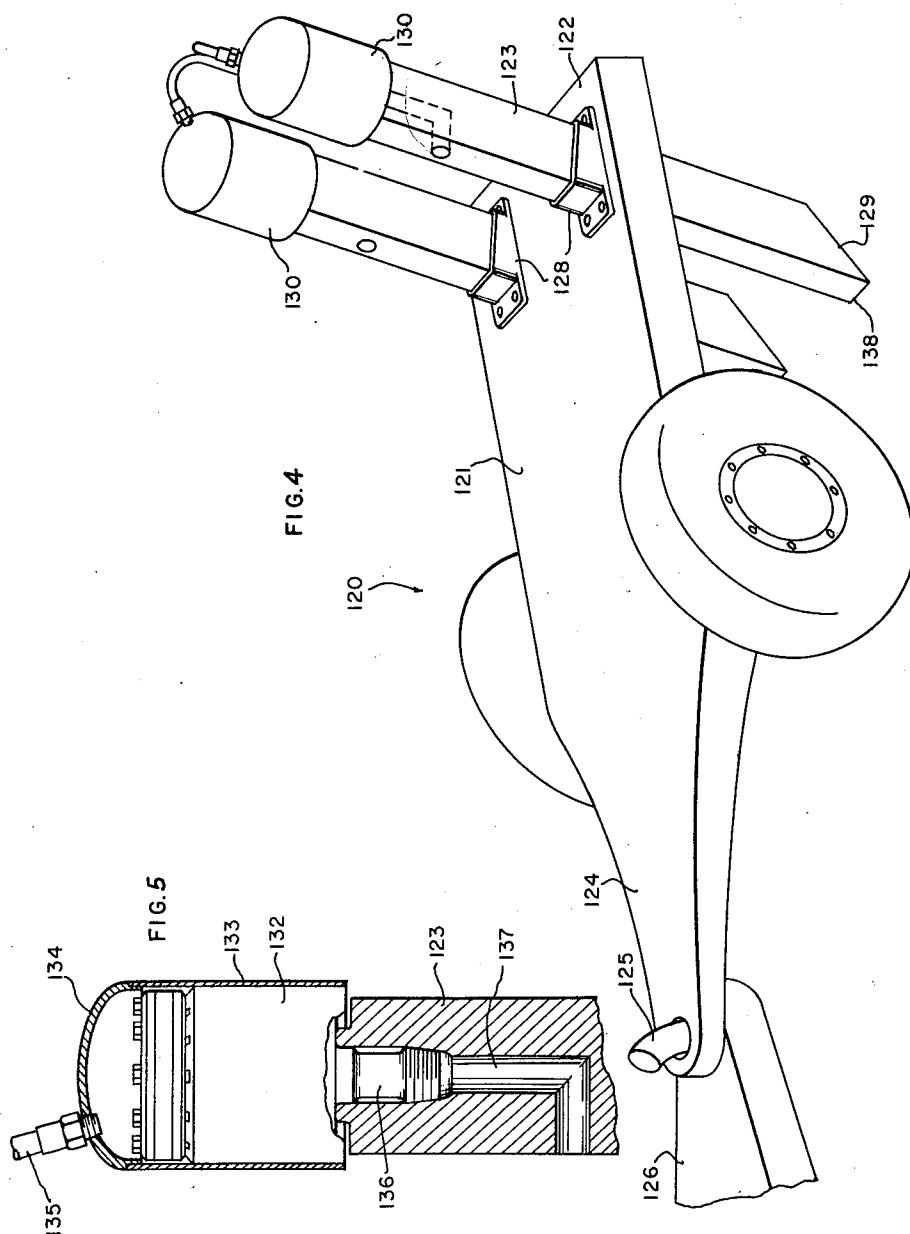
May 8, 1962

A. G. BODINE
SONIC METHOD AND APPARATUS FOR SURFACE
MINING MINERAL BEDS OR THE LIKE

3,033,543

Filed Nov. 15, 1961

2 Sheets-Sheet 2



INVENTOR.

ALBERT G. BODINE

BY *Levy and Kephart*

ATTORNEYS

1

SONIC METHOD AND APPARATUS FOR SURFACE MINING MINERAL BEDS OR THE LIKE

Albert G. Bodine, 13120 Moorpark St.,

Sherman Oaks, Calif.

Filed Nov. 15, 1961, Ser. No. 152,601

7 Claims. (Cl. 262-13)

This invention relates generally to sonic wave processes and apparatus for surface mining of minerals or the like, and deals more particularly with application to a bed of mineral of a sonically vibratory bit in such a manner as to break away particles of the mineral in predetermined size ranges.

This application is a continuation-in-part of my earlier application entitled Sonic Wave Earth Digging and Moving Machines, Serial No. 839,196, filed September 10, 1959, and allowed September 7, 1961.

The general object of the invention is the provision of a method and apparatus, of sonic wave character, for "planing" the surface of a bed of mineral surface in such manner as to rapidly take a cut of the order of several inches in depth, yielding mineral fragments within a predetermined size range, which may be of sufficiently small grading as to dispense with the necessity of a rock crusher at the site of the operation.

Many mineral deposits, such as limestone, dolomite, borax, perlite, coal, etc., occur naturally in beds which can be "planed," so to speak, by a properly manipulated sonically vibrating tool. The process of the invention employs a bit on a resonant elastically sonically vibratory member, such as an elongated steel bar. The vibration pattern is preferably longitudinal of the bar, such as a half-wavelength longitudinal standing wave mode. The bar and the bit are preferably oriented at a fairly sharp acute angle to the surface of the mineral to be mined, and the bit is guided so as to make a cut of predetermined depth, such as of the order of two or three inches, for example. The sonically vibratory bit is applied to the mineral, in such attitude, and pressure is exerted to force the bit against the deposit. Substantial sonic wave energy is thereby expended upon the mineral deposit, and the mineral breaks into fragments by elastic fatigue. By reason of attitude of the guided bit, a step-cut or shoulder is formed as the bit is moved against the formation, yielding fragments within a predetermined size range depending upon the depth at which the bit is guided.

The bit is vibrated against the shoulder of the formation by a sonic elastic vibration pattern set up in the bar that carries the bit. The bar is composed of a good grade of alloy steel, and the vibration pattern is preferably a longitudinal mode of standing wave vibration.

This sonic pattern is thus acoustically coupled to the mineral in a particular way which results in a surprising rate of elastic fatigue failure, apparently due to the acute angle which engenders cyclic tension waves in the mineral. These tension waves are equally spaced between very high amplitude compression waves, and the resulting asymmetrical wave form gives rapid fatigue.

In a preferred form, the bar is mounted on a suitable transport vehicle at or near its midpoint, and is set into half-wavelength standing wave vibration, the wave generator most conveniently and effectively being mounted on the rearward ends of the bar. If the generator delivers alternating forces to the rearward end of the bar in a direction longitudinally thereof and at a frequency f equal to $S/2L$, where S is the speed of sound in the material of the bar, and L is its length, the bar will undergo resonant longitudinal half-wavelength standing wave vibration. Such a bar is known in the science of acoustics as a half-wavelength bar. The theory of longitudinal waves in bars is well understood in the science of acous-

2

tics, and it will suffice here to explain that in half-wavelength standing wave vibration, each half-length of the bar alternately elastically elongates and contracts at the frequency of operation of the wave generator. It will be understood that the two half-lengths elastically elongate simultaneously with one another and elastically contract simultaneously with one another. The extent of elastic elongation or contraction is minimized at the midpoint of the bar, and progressively increases, for successive increments of length of the bar, from its midpoint to its two extremities. In standing wave vibration of the type in question, the point of minimized vibration amplitude, at the midpoint of the bar, is termed a velocity node, and the two points of maximized vibration amplitude, at the extremities of the bar, are termed velocity antinodes. It will be clear that the bar does not vibrate bodily or as a whole.

Half-wavelength vibration must also be understood as a resonant phenomenon, occurring when the frequency of generator operation is such that the inertia reactance of the bar is equal to the elastic stiffness reactance thereof. In the region of this resonance frequency, maximized amplitude of vibration is attained at the extremities of the bar for a wave generator of given power.

In operation, the bit on the forward end of the bar, engaged with the mineral bed, and pressed thereagainst by the effort exerted by the transport vehicle, act to radiate into the mineral body sonic waves which may, depending upon their length, be for example of the order of 400 to 1000 cycles per second, or thereabouts. Using a generator of adequate power, and operating safely within the maximum stress to which the bar should be subjected, a vibration amplitude may be attained at the bit of the order of 0.06". The bar, after contraction, elongates with an acceleration many times the acceleration of gravity, and it should be evident that great vibratory force is delivered to or applied against the mineral bed.

The sonic wave radiation into the mineral bed is responsible for fracturing the bed material ahead of the bit. The wave stress is of comparatively large amplitude, and the repeated cyclic tension or rarefaction phase of the wave causes the mineral to fail or disintegrate as a result of elastic fatigue. With a comparatively sharp acute angle between the bar and the surface of the mineral bed, and with the bit guided to take a shallow cut, such as two or three inches, or thereabouts, the material fractures and breaks away primarily above the edge of the bit, so as to form a shoulder against which the bit may then work, and which is progressively broken back.

It should be mentioned that the effectiveness of sonic wave radiation into the mineral body, and therefore the rate of disintegration in the shoulder, depends directly upon the mean pressure with which the bit is engaged with the shoulder. In other words, the sonic "coupling" efficiency, and the actual wave form in the mineral, depends upon mean bit pressure against the shoulder. This in turn depends, of course, upon the effort exerted upon the transport vehicle. That is to say, when the transport vehicle is pushed or propelled ahead, the bit is forced into pressural engagement with the shoulder.

The invention will be better understood from the following detailed description of typical means for carrying it into effect, reference being had to the accompanying drawings, in which:

FIG. 1 is a side elevational view of an illustrated embodiment of the invention;

FIG. 2 is a plan view of the embodiment shown in FIG. 1;

FIG. 3 is an enlarged fragmentary view taken from a portion of FIG. 1 with parts broken away;

FIG. 4 is a perspective view of another embodiment of the invention; and

FIG. 5 is a longitudinal sectional view through the upper rearward extremity of a bar of the machine of FIG. 4, showing the generator in elevation and the generator casing in section.

Reference being first directed to the embodiment of the invention somewhat diagrammatically shown in FIGS. 1-3, numeral 10 designates generally a transport vehicle having a main frame 11 comprised of two parallel longitudinal members 12, convergent at their forward ends, and including at their rearward ends a transverse member 13 by which the vehicle may be pushed by another vehicle, not shown. The convergent forward end portions 14 of members 12 merge into a tongue 15 formed with an eye 16 which may receive a drag element or prong 16a projecting from the draw bar 16b of a towing vehicle, not shown.

Frame 11 is provided with steerable front wheels 17 and with rearward wheels 18.

A rectangular sub-frame 20 is pivotally mounted on pivot pins 21 mounted in brackets 22 secured underneath frame members 12 at about the midpoints of said members, and is adjustably swingable between the members 12. This sub-frame may comprise longitudinal members 23 and front and rearward end members 24 and 25, respectively. The main portion of the frame 20, from its pivoted forward end to a point a little short of its rearward end, is normally in an inclined position, making a relatively sharp acute angle with horizontal, such as shown. The rearward end portion 26 of the sub-frame, in the position of inclination illustrated, is substantially horizontal. Extending laterally from this horizontal rearward portion 26 is a platform or suitable supporting framework 27 for an internal combustion engine 28.

The rearward end of the sub-frame rests upon struts 30 supported by brackets 31 on frame member 13. These struts are adjustable in length for adjustment of the angle of inclination of the sub-frame by means of jacks 32, which may be, for example, conventional piston and cylinder hydraulic jacks, equipped with hand pumps, not shown.

Supported at its midpoint in a fixture 40 carried by sub-frame 20, and extending generally parallel to the sub-frame, is an elastic bar 41, composed preferably of a good grade of alloy steel. This bar carries at its forward end a bevelled bit 42. The coupling between the bit and the bar 41 may comprise a threaded pin 43 on the bit screwed into a threaded box in the end of the bar. The bit preferably flares from its coupling end to a bevelled blade, as illustrated.

Mounted on the rearward end of bar 41 is a vibration generator 45 for setting up a longitudinal vibration pattern in the bar 41. It may be of a conventional type having a housing 46 mounting parallel shafts 47 carrying, inside the housing, a pair of meshing spur gears 48, and outside the housing, a pair of unbalanced weights 49. One of the shafts 47 is coupled, through a shaft 50, universal joints 51, and a gear box 52, with the drive shaft of engine 28. The unbalanced weights 49, which turn in opposite directions, are so phased as to move toward and from one another in unison, and longitudinally of bar 41 in unison. The lateral components of vibratory force developed thereby therefore cancel out, while the vibratory forces longitudinal of the bar are additive, and are applied through the generator housing to the end of the bar 41.

In accordance with principles discussed fully in the introductory portion of the specification, the vibration generator is driven by engine 28 through gear box 52 at a resonant frequency of the bar 41, so as to establish a longitudinal standing wave pattern in the bar, preferably of substantially half-wavelength.

The bit 42 is thereby set into vibration in a direction longitudinally of the bar, moving through a short stroke,

amounting to a small fraction of an inch, but with high force.

To add weight to the transport vehicle, near its middle, so as to assure that the bit will be held down against the mineral bed to be "planed," I prefer to equip the vehicle, near its midpoint, with a large tank 60, which can be filled with water.

A further desirable feature is the provision, rearwardly of the bit, of an angularly disposed scraper blade 62, adapted to catch the material fragmented by the bit and move it to one side. The blade may be hung from the frame members 12, with capability for vertical adjustment, by hanger screws 64 threaded in frame lugs 65, and tightened by jamb nuts 66. The lower ends of these screws will be understood to be swivelled to the blade.

When the vehicle 10 is being transported from place to place, the scraper blade is elevated, and the sub-frame 20 tilted so as to raise the bit 42 out of ground engagement, this latter being accomplished, of course, by proper manipulation of the jacks 32.

To initiate operation, the sub-frame is tilted toward the position of FIG. 1, at first, so to take a relatively shallow cut, or so as just to engage firmly against the surface of the mineral bed B to be planed. The engine is then started and driven at a speed to set up a standing wave in the bar 41. The bit begins to work on the mineral, generating positive elastic waves therein, working through an amplitude of a small fraction of an inch. As the bit begins to penetrate, or to cut a notch, the angle of tilt can be somewhat increased, so as to deepen the cut; and at this time, forward effort is exerted on the vehicle to force the bit against the mineral. The resultant line of pressure is thus at an acute angle to the surface of the mineral bed. This forward effort on the vehicle can be supplied through a towing vehicle, or a pushing vehicle; or, of course, the vehicle 10 could be self-propelled. The forward effort against the vehicle 10, and therefore the increased pressure of the bit against the mineral bed, increases the acoustic coupling between the bar and bit and the mineral bed, and increases the fragmenting action of the bit against the mineral bed. The angle of tilt of the sub-frame and bar 41 can then be increased relative to the surface of the bed to take the desired cut, to a depth of say two to three inches, for example, while at the same time, the forward effort on the transport vehicle is increased. With this increased pressure, and under these described conditions, acoustic coupling is improved, and a shoulder *s* is cut into the mineral bed, and the bit works against this shoulder along a pressure line having the same acute angle as the bar. The material of the bed in the general region in back of this shoulder is set into sonic wave activity, or sonic vibration, and the bit then maintains contact with the shoulder throughout a large part, if not the entirety, of its vibratory cycle. Under these conditions an asymmetrical wave pattern is generated in the mineral, having a predominance of positive phase, but also a desirable answer of negative phase.

The material of the bed in back of the shoulder, under the stress concentration exerted by the edge of the bit, and also because of elastic fatigue due to the vibratory cycle set up therein, rapidly breaks in fragments, the plane of severance being, in general, parallel to the surface of the bed, and at the depth of the forward edge of the bit. There is of course substantial irregularity in this break-away plane; but the shoulder *s* gradually recedes as the bit works against it, and the material breaks away, in general, on a rough plane at the bottom of the shoulder.

The great advantage is gained that the fragmented mineral tends to break away in fragments of somewhat uniform size range, small enough that the usual rock crusher at the site can be dispensed with.

A further embodiment is shown in FIGS. 4 and 5 employing a different means for regulating the depth of cut, showing a larger acute angle between the vibratory bars

and the horizontal, and showing a form in which the bits comprise integral end portions of the vibratory bars. Here again the asymmetrical wave action is accomplished, particularly with materials more adaptable to a larger acute angle.

A two-wheeled vehicle 120 has a fairly heavy platform 121 which includes a rearward portion 122 mounting a pair of longitudinally vibratory steel bars 123, and a forward portion 124 coupled as at 125 to the drag element 126 of a tractor machine, not shown. It will be understood that the element 126 is designed for vertical adjustment to accomplish proper depth engagement of the lower extremities or bit ends of bars 123 with the mineral bed, or to elevate the bars 123 sufficiently for adequate road clearance during towing when not in service.

The bars 123 are again half-wavelength standing wave vibration members, being tightly mounted at or near their midpoints in fittings 128 secured to platform 121 in positions inclined at acute angles to horizontal, as shown. The bit elements integrally formed with the forward extremities of the bars 123 are beveled, as indicated at 129, and the rearward or upper extremities of the bars carry vibration generators 130, which may be of the same type shown in FIGS. 7 and 8 of my aforementioned application Serial No. 839,196. Referring to FIG. 5, generator casing 132 is snugly embraced by pressure tight casing 133, including dome 134 into which is coupled air supply conduit 135 leading from a suitable compressor plant, not shown. The tubular air discharge and mounting stem 136 of the generator is fitted tightly in the upper end of bar 123, and air is exhausted via passage 137 leading outwardly to one edge of bar 123.

The generators 130 will be understood to be operated to set up half-wavelength standing wave vibration of the bars 123. In operation, platform 121 is manipulated to engage the relatively sharp edges 138 on the forward and lower extremities of the bars with the mineral bed at a controlled depth, causing disintegration of a layer of the mineral bed ahead of the bars in accordance with principles heretofore explained.

Vibration generators of the type shown in FIGS. 1-3 may be used on the ends of the bars 123, if desired. In such case, the driving engine can be mounted on platform 21, and can be belt-connected with pulleys on the generator drive shafts, as will be fully understood without the necessity of illustration.

It will of course be understood that the embodiments of the invention illustrated and described herein are for illustrative purposes only, and that various changes in design, structure and arrangement may be made without departing from the scope of the appended claims.

I claim:

1. The method of surface mining of minerals and the like comprising, generating a resonant vibration pattern in an elastic member which is coupled to a bit, forcing said bit against said surface of said mineral with an oblique angle whereby the resultant of said force bears an acute angle relative to said surface so as to form a stepped shoulder in said surface, directing said resonant vibration pattern so as to transmit acoustic vibrations into said shoulder whereby acoustic fatigue of said mineral is concentrated within said shoulder so as to form broken particles of said mineral having a predetermined size range.

2. The subject matter of claim 1, wherein the acute angle between the line of pressure exerted by the bit and the surface of the mineral is relatively sharp.

3. The subject matter of claim 1, wherein the acute angle between the line of pressure exerted by the bit and the surface of the mineral then does not exceed substantially 30°.

4. The subject matter of claim 1, wherein said elastic member comprises an elastic bar, and the resonant vibration generated in said bar is a longitudinal standing wave.

5. Apparatus for surface mining of minerals and the like comprising, a resonant elastic member, a vibratory bit, having a transversely disposed working edge coupled to said elastic member, a sonic oscillator coupled to said resonant elastic member and operable at a resonant sound wave frequency of said elastic member so as to generate a resonant vibration pattern therein, which applies a vibration to said bit, guiding means connected to said resonant member in supporting relationship so as to guide said bit along the exposed surface of said mineral at a predetermined depth setting and with the vibration path of said bit vibration bearing an acute angle with said surface of said mineral, and means for forcing said bit into acoustic coupling relationship with the progressively formed shoulder in said mineral surface, whereby said mineral is removed in a particle size of predetermined size range.

6. Apparatus for surface mining of a mineral bed or the like comprising, a transport vehicle adapted for forward travel over the surface of the mineral bed, a vibratory bar disposed generally longitudinally of the vehicle and mounted on said vehicle with a downward inclination in a direction forwardly of the vehicle, a bit on the forward end of said bar having a transverse working edge engageable with the mineral bed, means for varying the angle of inclination of the bar to vary the acute angle made by the bar with the surface of the mineral bed, and thereby the line of pressure application from the bit to the mineral bed, and a sonic oscillator coupled to said bar so as to set up a longitudinal resonant vibration pattern therein.

7. Apparatus for surface mining of a mineral bed or the like comprising, a transport vehicle adapted for forward travel over the surface of the mineral bed, a frame pivotally mounted on said vehicle on a horizontal pivot axis transverse of the vehicle, a vibratory bar disposed generally longitudinally of the vehicle and mounted on said frame with a downward inclination in a direction forwardly of the vehicle, a bit on the forward end of said bar having a transverse working edge engageable with the mineral bed, means for adjustably raising and lowering said frame about said pivot axis, whereby to vary the angle of inclination of said bar relative to the surface of the mineral bed, a sonic vibration oscillator mounted on and acoustically coupled to said bar, so as to set up a longitudinal vibration pattern therein, drive means on said frame drivingly coupled to said oscillator.

References Cited in the file of this patent

UNITED STATES PATENTS

2,422,490	Le Tourneau	June 17, 1947
2,554,005	Bodine	May 22, 1951
2,748,298	Calosi et al.	May 29, 1956