

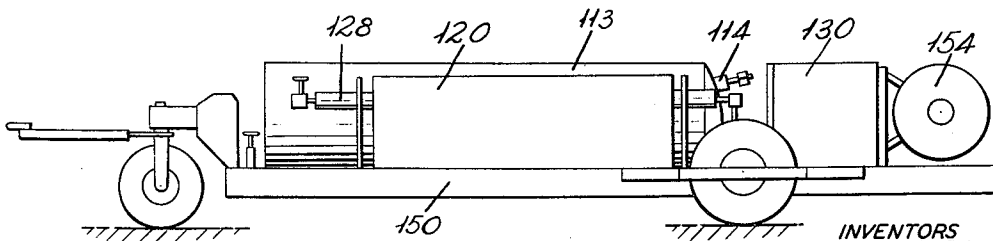
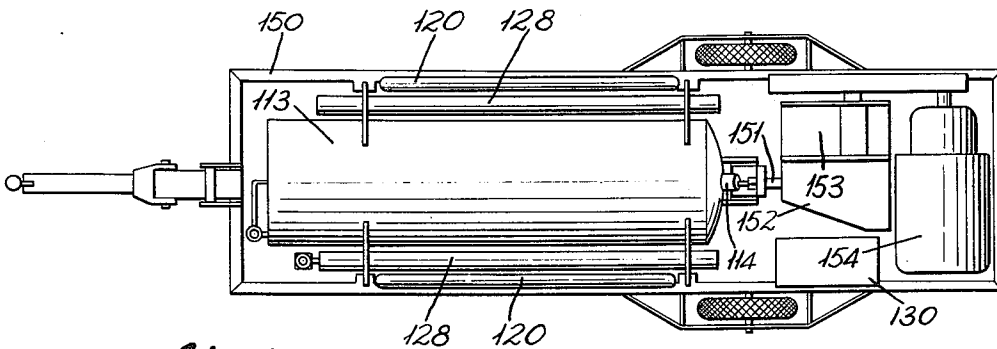
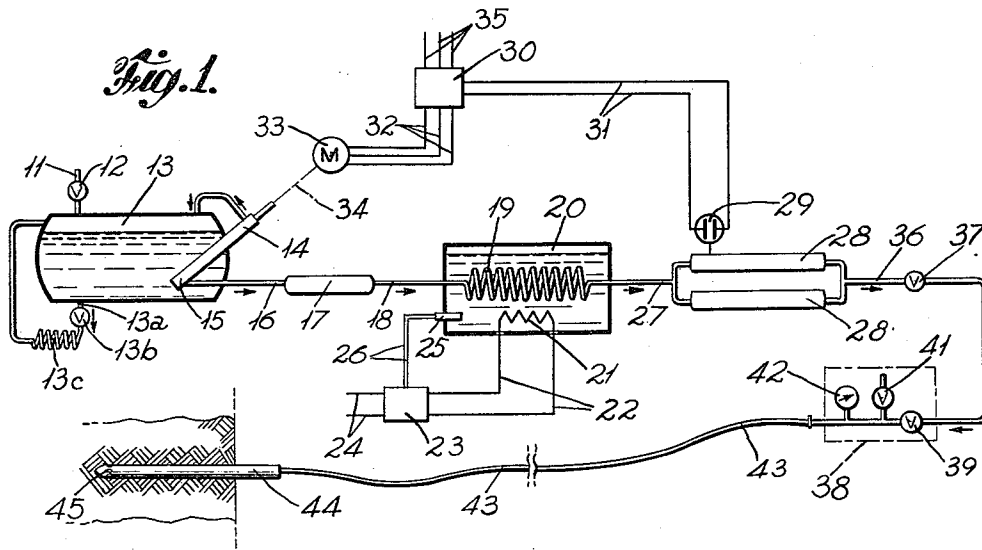
March 26, 1963

M. M. REYNOLDS ETAL

3,082,690

BLASTING METHOD AND APPARATUS

Filed March 28, 1958



INVENTORS
MARTIN M. REYNOLDS
ODD A. HANSEN
JAMES A. PROCTOR
PETER M. RIEDE
CHRISTIAN F. GOTTSMANN

BY *William F. Mesinger*
ATTORNEY

1

3,082,690

BLASTING METHOD AND APPARATUS

Martin M. Reynolds, Denver, Colo., and Christian F. Gottzmann, Buffalo, Odd A. Hansen, Kenmore, James A. Proctor, Tonawanda, and Peter M. Riede, Kenmore, N.Y., assignors to Union Carbide Corporation, a corporation of New York

Filed Mar. 28, 1958, Ser. No. 724,682

14 Claims. (Cl. 102—25)

This invention relates to an improved method and apparatus for blasting, particularly for the blasting or breaking down of coal.

In coal mining operations and the like, the blasting step is probably the most important phase from the standpoint of safety and economy. Improper blasting may produce a dirty-finely divided coal with a relatively high percentage of unsaleable material and a product having excessive ash content. Also, the commonly used explosive type of blasting is a source of danger and delay to the mine operations since the workers must withdraw from the working area for a sufficient time after the blast to permit purging out the dangerous fumes and dust produced by the explosion.

Because of these disadvantages, strenuous efforts have been made to develop new blasting methods. Perhaps the most successful of these is pressure blasting, in which a gas is charged into a closed cartridge inserted in a drill hole in the material to be blasted, the cartridge containing pressure release means. The gas under high pressure is discharged from the cartridge through the pressure release means so as to generate a sudden blasting pressure in the drill hole. In general, pressure blasting as described above has proven far preferable to explosive blasting from the safety standpoint, as for example, minimizing damage to the mine roof structure from the blasting operation. This method also has many economic advantages. For example, pressure blasting devices crack and dislodge coal with a slow heaving action that avoids shattering while explosives are so violent and hammerlike in action that they shatter and tend to pulverize coal without heaving it well out from the face. A major advantage of pressure blasting is therefore a general upgrading in the quality of the coal produced by virtue of its larger lump size and lower percentage fines. Other advantages over explosive blasting include cleaner coal, increased loading efficiency, and lower investment cost per ton of coal produced.

The high pressure gas for pressure blasting has heretofore been provided by a number of methods. For example, in one proposed method a cartridge is charged with a predetermined amount of liquid carbon dioxide and is fitted with a chemical-type heater. The charged cartridge is placed into the drill hole and set off with a small electrical charge, thus initiating a chemical reaction which vaporizes the liquid carbon dioxide to provide high pressure gas. Unfortunately, this pressure blasting method has been found unsafe, probably because of exposed electrical firing systems. Furthermore, a large number of cartridges are needed for loading above ground and transportation into the mine.

The required high pressure gas has also been provided in the form of compressed air. In this pressure blasting method, large stationary air compressors may be located at the surface with an extensive high pressure piping system to distribute the compressed air. As might be expected, the system requires a large investment, and the pressure drop through the lengthy piping is a severe problem, necessitating high power costs. Also, if the atmosphere surrounding the compressor contains small quantities of inflammable gases or other materials, explosions within the compressed air system may result.

2

This is a particularly acute problem if the air compressor is placed within the mine.

Principal objects of the present invention are to provide a method of and apparatus for blasting material by high pressure gas which is substantially safer, lower in investment costs, and more economical to operate than the heretofore proposed blasting systems.

Another object is to provide a method of and apparatus for blasting material by high pressure gas which economically employs a gas other than the mine atmosphere.

Still another object is to provide a method of and apparatus for blasting material by high pressure gas in which a low temperature liquefied gas is warmed and pressurized prior to introduction into the blasting device.

These and other objects and advantages of this invention will be apparent from the following description and accompanying drawings in which:

FIGURE 1 is a schematic flow diagram of an exemplary system for blasting earth material, according to the present invention;

FIGURE 2 is a top plan view of a portable liquefied gas pressure blasting assembly including the components of FIGURE 1; and

FIGURE 3 is a vertical longitudinal view of the same portable assembly of FIGURE 2.

In these drawings, similar items of apparatus in the several figures are designated by similar reference characters with the addition of 100 to the reference characters of FIG. 1.

According to the present invention, a low-temperature liquefied gas having a boiling point below -100° C. at atmospheric pressure is provided at the mine and transferred to a storage container, which is preferably thermally insulated. The low pressure liquefied gas is completely transformed into a high pressure gas suitable for the blasting operation before introducing such gas into the cartridge. No means are provided within the cartridge for adding energy to the gas. Consequently, a liquefied gas must be selected which after vaporization will remain a superheated gas at ambient temperature and the maximum pressure to be employed in blasting. This maximum pressure may be as high as 20,000 p.s.i. The liquefied gas is preferably chemically inert, non-toxic and odorless and may, for example, be liquid nitrogen which is transported to the mine site from an air separation plant, or produced in an on-site plant.

In preparing the gas for blasting the low pressure liquefied gas is pressurized to a high pressure such as 5,000 p.s.i., warmed to about atmospheric temperature, and passed to a closed cartridge which has previously been inserted in a drill hole in the mine working face. The cartridge has pressure release means so that the high pressure gas is emitted through such means to generate a sudden blasting pressure in the drill hole and obtain the desired material breaking. In the specification and ensuing claims, the expression "pressure release means" refers generally to both the bursting disk type of cartridge one of which is described in U.S.P. 2,145,366 to L. D. Myers, and the quick-opening valve type of cartridge an example of which is described in U.S.P. 2,720,167 to J. C. Hesson.

The liquefied gas pressurizing means is preferably a pump which has its suction or working end immersed in the liquefied gas storage container. For example, the immersion pump described and claimed in C. F. Gottzmann's co-pending application S.N. 692,311 filed October 25, 1957 now U.S. Patent 3,016,717 would be suitable as the pressurizing means of the present invention. The high pressure fluid from the pump is warmed to provide

a high pressure gas which is passed to the cartridge for subsequent blasting.

The aforementioned high pressure fluid is preferably warmed in a heat exchanger which operates with such heat or utilities as are normally available in the mine. For example, a preferred form of heat exchanger employs a water ballast compartment and may contain an electric immersion heater for rapid heat transfer to the high pressure fluid. High pressure gas storage means may be provided between the discharge end of the heat exchanger and the piping and/or hoses leading to the blasting cartridges, the gas storage means acting as ballast so that the pump may operate less frequently while charging a series of blasting cartridges.

Another feature of the present invention is an automatic system for controlling the operation of the pump. This system is actuated by the pressure in the high pressure gas storage means, and is connected to control the pump motor. Means responsive to a lower pressure, e.g. 4,000-8,000 p.s.i. in the gas storage means are provided to start the pump, and means responsive to a higher pressure, e.g. 12,500 p.s.i. serve to stop the pump. These pressure responsive means may, for example, be of the pressure switch type and may be incorporated in a single device. This automatic system in combination with the above mentioned high pressure gas storage means serves at least three functions: (1) It assures an immediate source of high pressure gas for passage to the blasting cartridges. This reduces the time interval between pressurizing the cartridge and blasting. Such time interval should be minimized in the interests of safety and efficiency. (2) It minimizes without inconvenience the number of pump starts and stops which in turn reduces the wear and maintenance on the mechanical components such as the motor starter and the pump driving mechanism. Furthermore the pump efficiency is lower immediately after startup and until temperature and flow equilibrium is reached within the pump. Reducing the frequency of pump operation therefore reduces the heat introduced into the stored low pressure liquid resulting from pump inefficiency. This is a significant factor because excessive pressure buildup will necessitate venting and consequent loss of gas through the over-pressure release means connected to the low pressure container. (3) This combination permits charging cartridges in rapid succession notwithstanding the fact that the instantaneous charging rate may greatly exceed the pump capacity.

The material blasting process and apparatus of the present invention provides important advantages over the previously proposed pressure blasting systems. For example, one cubic foot of liquid nitrogen stored at -192°C . will produce about 697 cubic feet of gaseous nitrogen at 20°C ., so that handling the pressurizing fluid in the liquid phase permits substantial savings in weight and investment. Instead of using heavy and bulky high pressure gas compressors, the fluid may be pressurized by a relatively small liquid pump. Also, the liquefied gas storage and pressurizing apparatus of the present invention has much greater portability than blasting apparatus using gas compressor. For example, the liquefied gas storage container, the pump, the heat exchanger, the high pressure gas receivers, and the automatic pump control system of the present invention may all be mounted on a cart provided either with flanged wheels to fit the mine track system or with rubber tired wheels. The cart may be pulled to a point within the mine near the working face as by means of a mine locomotive, and a relatively short length of high pressure piping or hose may be run from the portable unit to the cartridges in the working face. A self-powered cart of this type filled with 12,500 cubic feet (NTP) liquid nitrogen will weigh only about 6,500 lb. This amount of nitrogen is sufficient to supply two 8-hour shifts at the average working face. By comparison, an air compressor-type unit on wheels weighs about three times as much, costs about

twice as much, and is so difficult to move that it is not generally regarded as being truly portable. The greater portability and lower investment of the liquefied gas unit will generally make it unnecessary to use a stationary assembly requiring long, expensive high pressure conduit systems for distributing the gas from the gas compressors to the mine working faces.

Another advantage of the liquefied gas system is that liquid pumping requires considerably less power than gas compression. For example, a 10 H.P. motor is suitable for a liquid nitrogen pressure blasting system which provides more high pressure gas than an air compression system requiring a 50 H.P. compressor motor. As a general rule, gas compression to 10,000 p.s.i. at 75% adiabatic compression efficiency will require about 5.6 times more power than pumping an equal mass of liquid to the same pressure with 55% overall pump efficiency. Additional savings can be realized from the use of lighter power lines, switchgear and control equipment.

It is also advantageous to employ a low temperature liquefied gas such as nitrogen as a large temperature difference is thus available for transferring most of the heat energy to the fluid in the form of atmospheric heat. With a relatively high boiling liquid such as carbon dioxide, insufficient heat is available from the atmosphere to provide the required energy.

Referring now to the drawings and particularly to FIGURE 1, liquefied gas, preferably nitrogen, is supplied at a low pressure e.g. 0 to 5 p.s.i.g. through inlet conduit 11 and control valve 12 therein, to thermally insulated storage container 13. The liquid is then preferably subcooled to perhaps 12°C . below saturation by withdrawing liquid through conduit 13a and control valve 13b. The withdrawn liquid is passed to pressure building coil 13c and returned to the top of container 13 so as to additionally pressurize the liquefied gas in such container. The barrel of high-pressure pump 14 passes through a hole in the wall of storage container 13, the annulus between the pump barrel and the container wall being sealed from the atmosphere. The suction or working end 15 of pump 14 is immersed in the stored liquefied gas, and the warm or driving end of the pump is exposed to the atmosphere. The liquid nitrogen is pressurized in the pump to a high pressure, for example 3,500 to 20,000 p.s.i., and discharged through conduit 16 which passes through the walls of liquefied gas storage container 13, and preferably leads to surge cylinder 17. This cylinder is a small uninsulated high pressure vessel provided to dampen or smooth out the pressure fluctuations at the pump discharge. Cylinder 17 is preferably oriented vertically with the inlet and outlet at the lower end. A warm, compressible gas phase exists in the warm upper end of the cylinder 17 and acts as a cushion to dampen the pressure fluctuations. The high pressure nitrogen is led from the surge cylinder 17 through conduit 18 to passageway 19 in heat exchanger 20, the aforementioned passageway being exposed to a source of heat. Passageway 19 is installed in heat conductive relation with shell 20 which is filled with water or other heat storage fluid. An electrical heater 21 may be immersed in the fluid bath to provide additional heat. In this event, electrical leads 22 are provided to connect the heater 21 with the heater controller 23, and electric power is supplied to the controller by leads 24. Thermostat 25 in the shell 20 is also connected to heater controller 23 by means of electrical leads 26. The fluid temperature is not particularly critical, although it should not be so high as to cause excessive fluid evaporation. When the heat storage fluid is water, a suitable temperature setting for the thermostat 24 is about 38°C . Alternatively, passageway 19 may be provided with greatly extended surfaces exposed only to the atmosphere, in which case the instantaneous rate of heat transfer from the atmosphere must be sufficient to warm the fluid as rapidly as it is delivered from the pump. The first described

heat exchanger employing a fluid heat storage bath is preferred for several reasons which are important in a portable pumping unit where space, weight and cost are major considerations. More specifically, the heat transfer coefficient between the heat storage fluid and passageways 19 is much higher than between the atmosphere and passageways 19. The fluid thus comprises a reservoir of readily available heat, enabling the gas to be warmed at high rates of flow in a small compact heat exchanger. Another advantage of this heat exchanger is that the heat storage fluid permits the system to absorb heat from the atmosphere continuously and at a relatively low rate, and to release the heat rapidly to passageways 19 during the intermittent pumping periods. This results in a further reduction in the size, weight and expense of the heat exchanger. Another advantage is that the fluid provides a medium for transferring heat efficiently from an electrical immersion heater to passageways 19, if desired. Also, by storing the electrical heat in the fluid a desired amount of heat can be obtained from a relatively small electric heater operating continuously or for extended periods of time. Adding an efficient electric heater to the system supplements the heat absorbed from the atmosphere and permits a still further reduction in the size, weight and cost of the heat exchanger.

The high pressure nitrogen gas is discharged from heat exchanger passageway 19 at about 0° C. to 20° C. into conduit 27, and passed into high pressure gas storage receivers 28 which act as ballast so that the pump 14 operates at infrequent intervals. Gas receivers 28 are connected to the high pressure pump 14 by an automatic system for controlling the operation of the pump. This system includes pressure switch 29 which closes when the gas receiver pressure drops to a pre-set lower pressure, e.g. 4,000-8,000 p.s.i., and opens when the gas receiver pressure rises to a pre-set higher pressure, e.g. 12,500 p.s.i. Pressure switch 29 is connected to motor controller 30 by electrical conduits 31, and the controller is in turn connected by electrical leads 32 to pump prime mover motor 33. The pump 14 is operated by driving means 34 communicating with the motor 33. Power is supplied to the motor controller 30 through conduits 35. Thus, when the gas receiver pressure falls to the pre-set lower pressure, switch 29 is closed, pump 14 is automatically started and operates until sufficient additional high pressure gaseous nitrogen has been passed to the gas receivers 28 for the pressure therein to rise to the higher pre-set pressure, at which point switch 29 opens and the pump operation is terminated. The high pressure nitrogen gas in receivers 28 is discharged through conduit 36 and main valve 37 therein to the operating panel control system 38, which for safety reasons is preferably located around at least one corner from the mine working face.

The operating panel control system 38 includes regulating valve 39, blowdown valve 41, and pressure gauge 42. The high pressure gas flow to the control system is regulated by valve 39, and blowdown valve 41 is provided as an emergency pressure release device to depressurize partially charged blasting cartridges. Pressure gauge 42 facilitates visual determination of the pressure imposed on the cartridge, as well as the pressure at which the gas is released from the blasting cartridge into the breaking material, such as coal. The high pressure nitrogen gas is discharged from the operating panel control system 38 into flexible conduit 43, and hence to the blasting cartridge 44 which is inserted in a drill hole in the mine working face. As previously discussed, each blasting cartridge 44 contains pressure release means communicating with discharge openings 45 for passage of high pressure gas therethrough and generation of a sudden blasting pressure in the drill hole. For example, the pressure release means may be a bursting disk designed to rupture at the desired high pressure, e.g. 3,500-20,000 p.s.i. It is to be noted that although the control panel system 38 of FIGURE 1 provides for pressurizing

only a single blasting cartridge, multiple control panels may be used instead, with each panel receiving high pressure gas from receivers 28 and connecting to separate flexible conduits 43 and blasting cartridges 44.

It can be seen from the foregoing description that the entire operation of the blasting system of the present invention may be safely conducted from the control panel which may, if desired, be located at a remote point from the high pressure pumping and storage equipment. The latter is automatically controlled and maintains the required system pressure without attendance. The coal is blasted by opening regulating valve 39 at the operating panel to release high pressure nitrogen gas from the high pressure gas receivers 28 into the blasting cartridge 44 through the interconnecting tubing. In a few seconds, the pressure release means opens and the high pressure nitrogen gas is released behind the coal face at a depth of perhaps 50 to 100 inches. The coal is thus cracked into large lumps and is pushed out from the face of the mine onto the floor where it is readily accessible to loading devices. The regulating valve 39 is closed immediately after the pressure is released, and after a drill hole is "shot," the blasting cartridge is retrieved from the loose coal, reset or fitted with a new bursting disk, and inserted in the next drill hole to be "shot."

FIGURES 2 and 3 illustrate the flexibility and portability of the blasting apparatus of the present invention, whereby the liquid storage, pressurizing, heating, and high pressure gas storage components are all mounted on portable cart 150, which may be self-propelled or may be pulled to a point within the mine near the working face as by means of a mine locomotive. The high pressure gas discharge connection from the portable cart may then be joined to high pressure tubing which is run between the cart and the previously described operating panel control system 38 (see FIGURE 1). Referring more specifically to FIGURES 2 and 3, liquefied gas storage container 113 and pump 114 are mounted along the longitudinal axis of the portable cart 150, with pump drive shaft 151 connected to cross head 152, which in turn communicates with gear drive 153. The latter drive is connected to motor 154 at the rear end of the cart, the motor being powered through motor controller 130. A high pressure gas receiver 128 is longitudinally positioned on either side of liquefied gas storage container 113, and a heat exchanger 120 is longitudinally mounted on the outer side of each high pressure gas receiver 128. The various components are interconnected as previously described and illustrated in FIGURE 1.

The terms and expressions which have been employed are used as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding any equivalents of the features described. It should be recognized that various modifications are possible. For example, liquid air or liquid argon could be used to provide the high pressure gas instead of liquid nitrogen, although nitrogen is preferred. Nitrogen has the advantages over air of being inert and of being a pure substance. Liquid air contains two major components, and as a consequence of evaporation occurring during normal storage and repeated handling, the liquid would become enriched in oxygen. Oxygen enrichment would be hazardous and would be difficult and expensive to avoid. Compared with argon and the other rare gases, nitrogen is much less expensive and is readily available in large quantities.

As another alternative, the liquefied gas could be pressurized in several stages instead of a single stage.

What is claimed is:

1. A method for blasting material in which a closed cartridge having pressure release means is inserted in a drill hole in said material, comprising the steps of providing a source of low-temperature liquefied gas at a low pressure, said liquefied gas having a boiling point be-

low -100°C. ; pressurizing the liquefied gas to a high pressure of from about 3500 to about 20,000 p.s.i.; warming the high pressure liquefied gas to provide a high pressure gas, storing said high pressure gas in a gas receiver; sensing the pressure of said high pressure gas in said receiver to control the pressurizing of said liquefied gas; continuously maintaining a supply of said high pressure gas; controllably passing such gas to said closed cartridge and expanding the high pressure gas through said pressure release means to generate a sudden blasting pressure in said drill hole.

2. A method according to claim 1 for blasting material in which said low-temperature liquefied gas is inert.

3. A method according to claim 1 for blasting material in which said low-temperature liquefied gas is nitrogen.

4. A method according to claim 1 for blasting material in which said high pressure liquefied gas is warmed by heat exchange contact with a heat-storing liquid.

5. A method for blasting material in which a closed cartridge having pressure release means is inserted in a drill hole in said material, comprising the steps of providing a storage body of low-temperature liquefied gas at a low pressure and having a boiling point below -100°C. ; maintaining such storage body in a subcooled state by withdrawing liquid therefrom, evaporating such withdrawn liquid, and returning the resulting higher pressure gas to the gas phase of said storage body so as to increase the pressure of such body; pumping subcooled low pressure liquefied gas within said storage body to a high pressure of from about 3500 to 20,000 p.s.i.; discharging the resulting high pressure fluid from said storage body and warming such subcooled fluid sufficiently to provide a high pressure gas; storing said high pressure gas in a gas receiver; sensing the pressure of said high pressure gas in said gas receiver to control the pumping of said subcooled low pressure liquefied gas to a high pressure sufficient to actuate the cartridge release means; controllably passing such gas to said closed cartridge and expanding the high pressure gas through said pressure release means to generate a sudden blasting pressure in said drill hole.

6. In apparatus for blasting material including a closed cartridge adapted to fit in a drill hole and having pressure release means, and means for passing high pressure gas to said closed cartridge for expansion through said pressure release means for generation of a sudden blasting pressure in said drill hole, the improvement of gas supply means comprising means for providing a low-temperature liquefied gas at a low pressure, said liquefied gas having a boiling point below -100°C. ; means for storing the low pressure liquefied gas; means for pressurizing the liquefied gas to a high pressure of at least about 3500 to about 20,000 p.s.i.; means for warming the high pressure liquefied gas to provide said high pressure gas at a point upstream from said cartridge, high pressure gas storage means communicating with said warming means; automatic means for controlling the operation of said pressurizing means, said automatic means communicating between said high pressure gas storage means and said pressurizing means and flow control means provided in said means for passing a high pressure gas to said closed cartridge for controllably bringing the pressure in said cartridge up to rupture pressure.

7. Apparatus according to claim 6 for blasting material in which a thermally insulated container comprises said means for storing the low pressure liquefied gas.

8. Apparatus according to claim 6 for blasting material in which a thermally insulated container comprises said means for storing the low pressure liquefied gas; and a pump having its suction end immersed in the liquefied

gas in said thermally insulated container comprises said means for pressurizing the liquefied gas to a high pressure.

9. Apparatus according to claim 6 for blasting material in which said means for warming the high pressure liquefied gas comprises a heat exchange passage in thermal contact with a heat-storing liquid, said heat exchange passage being connected in flow relationship intermediate the discharge end of said liquefied gas pressurizing means and said closed cartridge.

10. Apparatus according to claim 9 for blasting material in which electric heating means are provided to supply a part of the heat for said heat storage liquid, the remaining part of said heat being supplied by the atmosphere.

11. Apparatus according to claim 6 for blasting material in which a heat exchange passageway exposed to the atmosphere comprises said means for warming the high pressure liquefied gas, said heat exchange passageway being connected in flow relationship intermediate the discharge end of said liquefied gas pressurizing means and said closed cartridge.

12. Apparatus according to claim 6 for blasting material in which high pressure gas storage means are provided between the liquefied gas warming means and said means for passing such high pressure gas to said closed cartridge.

13. In apparatus for blasting material including a closed cartridge adapted to fit in a drill hole and having pressure release means, and means for passing high pressure gas to said closed cartridge for expansion through said pressure release means for generation of a sudden blasting pressure in said drill hole, the improvement of gas supply means comprising means for providing a low-temperature liquefied gas at a low pressure, said liquefied gas having a boiling point below -100°C. ; a thermally insulated container for storing the low pressure liquefied gas; a pump for pressurizing the liquefied gas to a high pressure, the suction end of said pump being immersed in the liquefied gas in said thermally insulated container; heat exchange means communicating with the discharge end of said pump for warming the high pressure fluid to provide said high pressure gas; high pressure gas storage means communicating with said heat exchange means and with said means for passing said high pressure gas to said closed cartridge; automatic means for controlling the operation of said pump, said automatic means communicating between said high pressure gas storage means and the pump, and including means responsive to a lower pressure in the gas storage means for starting said pump, and means responsive to a higher pressure in said gas storage means for stopping said pump.

14. Apparatus according to claim 13 for blasting material in which said thermally insulated container, said pump, said heat exchange means, said high pressure gas storage means, and said automatic means for controlling the operation of said pump are mounted on portable means.

References Cited in the file of this patent

UNITED STATES PATENTS

497,513	Bechler	May 16, 1893
1,569,222	Ferrell et al.	Jan. 12, 1926
2,058,097	Noble	Oct. 20, 1936
2,058,099	Osgood	Oct. 20, 1936
2,098,529	Armstrong	Nov. 9, 1937
2,552,518	Churchman	May 15, 1951
2,580,710	Wildhack	Jan. 1, 1952
2,748,249	Collerati	May 29, 1956
2,964,917	Webster	Dec. 20, 1960