March 31, 1953 J. J. MURPHY ET AL 2,633,332

FLAME PROCESS

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Fig. 1.

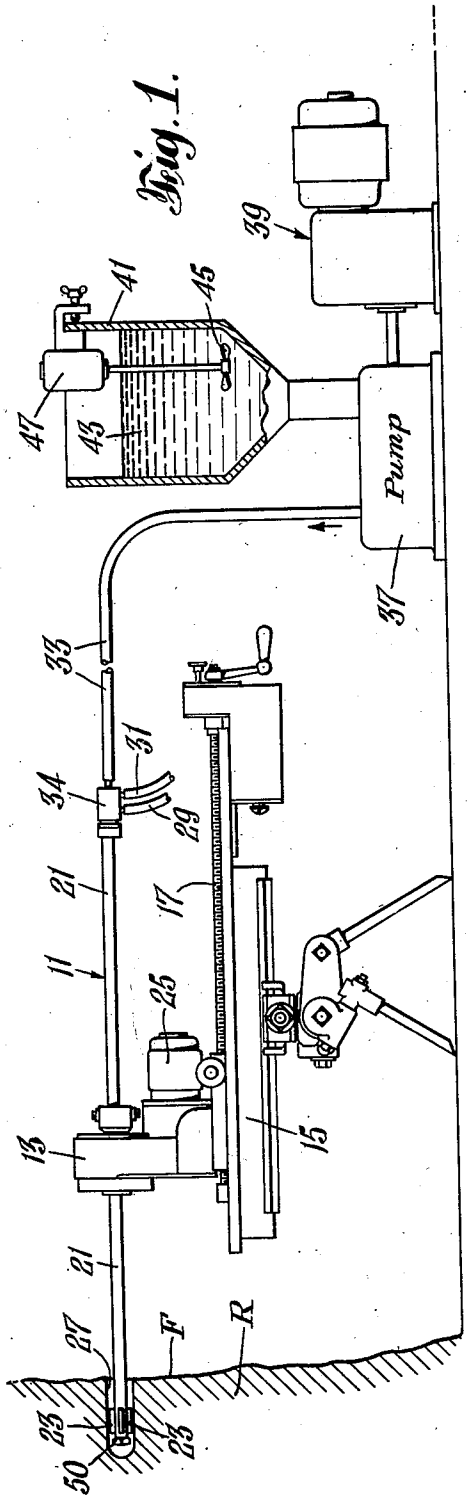
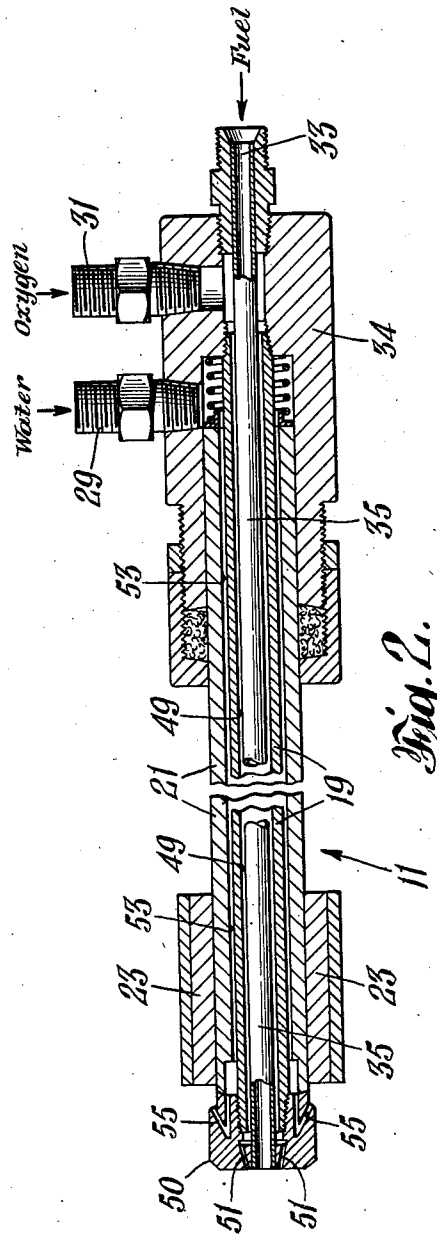


Fig. 2.



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FLAME PROCESS

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8 Claims. (Cl. 255—1.8)

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This invention relates particularly to improved means and components for generating and controlling high-temperature flame and its localized effective application for predetermined removal of material from solid hard and refractory masses such as rock or rock-like bodies, with or without metal reinforcement, or such as metal bodies. Exemplary, but not limiting, purposes of such predetermined removal are for making holes in or through, for gouging, severing, or desurfacing of, such bodies.

An object of the invention is to increase the economic advantage of such removal thermally as against any presently known alternative removal mechanically. The invention will be described in greater detail as it may be applied for working rock and mineral-like masses as by piercing deep holes therein to be charged with explosives.

Rock has been thermally worked heretofore with an oxyacetylene flame cooperating with burning particles of free metallic material. However, while such a gas flame has been satisfactory for some operations, it is not equally suitable to meet the requirements under other conditions. For example, safety codes do not permit acetylene to be used at very high pressures, and the combustion of low pressure acetylene does not produce gaseous products of combustion at pressures sufficiently high to remove detritus from a very deep hole without supplemental ejection fluid. Also, when employing an oxy-acetylene flame for piercing a hole by the process of melting, quenching with water, and disintegrating rock, disclosed in Patent 2,327,496, the depth of hole pierced in a downward direction is limited because water tends to accumulate in the bottom of the hole and extinguish the oxy-acetylene flame. When metal powder is used with an oxy-acetylene flame, as has been proposed, the combustion of metal powder does not increase the gas pressures available for the removal of detritus or water because it burns to a solid oxide rather than to a gas.

Among the objects of the present invention are: to produce a flame for heating a body and simultaneously apply thereto more effectively particles of material, such as powder; and to provide for carrying powdered material positively, continuously, and uniformly to a locality where it is to be used in conjunction with a flame. Other objects are to provide a novel method for thermally working rock whereby there is produced a large volume of gas for ejecting detritus; whereby deep holes can be successfully pierced in a downward

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direction; whereby water will be prevented from extinguishing a flame in a hole; whereby fuel can be delivered to the bottom of a hole positively at a relatively constant delivery pressure regardless of pressure variations in the hole and whereby thermal rock working will proceed safely, rapidly, and economically. Another object is to reduce the cost and eliminate some of the difficulties of shipping to relatively inaccessible localities the fuel required for thermal rock piercing.

Other objects are to provide novel mixtures of liquid fuel with powdered materials; to provide such mixtures which have improved stability of powder suspension, yet can be easily pumped; and to provide such a mixture whereby flame stability is assured even when water accumulates in the vicinity of the flame.

How the above and other objects are attained will become apparent from the following description, having reference to the accompanying drawing, wherein:

Fig. 1 is a side elevational view, parts being in section, showing schematically an arrangement of apparatus for piercing a hole in rock by the method of the invention; and

Fig. 2 is a longitudinal sectional view of a blowtorch suitable for piercing a hole in rock by the method of the invention.

In one specific embodiment of the method of the present invention a rock is thermally pierced, cut, or otherwise thermally worked by applying thereto a localized high temperature flame resulting from the combustion of a flowable non-gaseous fuel in an oxygen rich atmosphere, thereby separating material from the body of rock by the heating effect of the flame. The process is operable on many kinds of rocks and mineral masses, for example hematite iron ore, taconite iron ore, and concrete. Many flowable non-gaseous fuels can be used satisfactorily, but combustible liquid hydrocarbons such as various petroleum fractions are preferred. It is also preferred that the liquid fuel contain a jellying or pasting agent. Among the suitable fuels are jellied kerosene, jellied gasoline, kerosene, fuel oil, crude oil, petroleum tars and coal tars and semi-fluid asphalts, used crank case oil, and solutions of polymers such as polystyrene or polyisobutylene in an aliphatic hydrocarbon such as kerosene or an aromatic hydrocarbon such as xylene.

Jellied fuels can be prepared in ways well known in the grease art, using a small amount of one or more jellying agents such as the common soaps comprising alkali or alkaline earth

metal salts of fatty acids, for example sodium stearate, calcium stearate, or calcium oleate. Heavy fuels such as tars and semi-fluid asphalts may require dilution with light oils to make them easier to pump, and this is particularly true if a jellying agent is used.

Instead of a jellying agent, other thickening means may be used. For instance, a creamy emulsion with a small amount of water, or a grease containing some water, may be used in those situations where no water-reactive material is to be mixed with the fuel.

Such liquid fuels provide important advantages not provided by acetylene at customary pressures. They burn to form much larger volumes of gaseous products of combustion which act toward ejecting the detritus loosened from the rock mass by the flame because liquid fuels can be supplied at such high pressures that many more pounds of fuel can be pumped through a given flame port with a given head pressure per unit of time than is possible with relatively low pressure acetylene. They can be pumped to a combustion zone at a constant rate of flow because they are not affected by pressure variations in a hole. They are relatively inexpensive, and they can be transported to a remote locality in drums or tank cars at a relatively low cost for the quantity of heat available.

Although it is especially advantageous to burn the flowable non-gaseous fuel in substantially pure oxygen, which gives a flame of high temperature and heating intensity, the method can be operated using oxygen mixed with other gases as long as the proportion of oxidizing gas is high enough to give a flame having sufficient heating intensity to cause material to separate from the rock body.

An additional important feature of the present invention is that particles of solid powdered material adapted to aid the separation of rock can be incorporated in and dependably carried by a stream of liquid fuel to the locality where an oxy-fuel flame is being applied to the rock. In some instances the solid powder can be a preformed flux active to modify the composition of the removed rock. In other instances it can be a combustible powder which augments the heat of the burning liquid fuel, and additionally may be of such a character as to change composition and form a flux upon combustion, or as to form a large volume of gaseous products of combustion to assist in blowing detritus from the locality of flame application. Whatever the powder, it advantageously should be fine enough to pass an 80 mesh screen (U. S. Standard).

Such preformed powdered fluxes as calcium oxide, calcium carbonate, borax, and sodium carbonate can be suspended in liquid fuel and applied against a body of rock concurrently with a flame to combine with melted rock and assist in the formation of a highly fluid slag which is friable after quenching. Such combustible flux-forming fuel powders as ferromanganese and aluminum also can be suspended in liquid fuel and burned to oxides which combine with melted rock and form a fluid slag. Such solid fuels as powdered coal, carbon black, or other forms of carbon can be suspended in liquid fuel and burned to provide both intense heat and large volumes of gas to assist in removing detritus. Sometimes the best results are obtained by mixing together in the liquid fuel two or more powders from the three categories described above. Some powdered materials may melt in the flame and be in the liquid condition when they strike a body of rock, but generally the hot particles are solid.

Jellied combustible hydrocarbon liquids such as jellied gasoline and kerosene are superior to many other liquids for suspending and conveying powders. Jellied fuels provide the optimum combination of powder suspending ability and good pumping characteristics. In such jellied fuels, for example, powder settles out of suspension only very slowly, and even when it has finally settled the cake in the bottom of the container is loose and easily stirred back into suspension. Furthermore, the viscosity of a jellied hydrocarbon does not change greatly with changes in temperature. If the proportions of powder and liquid fuel are such as to give a stable paste, no jellying agent need be added but pumping is somewhat harder.

Although the fuel stream has certain advantages for carrying the powdered flux or flux-forming fuel, it is apparent that the powder also can be introduced to the reaction zone in other ways, as in the oxygen stream or independently of both the oxygen and fuel streams.

In the following description, all pressures mentioned are gage pressures.

The method of the invention will be described more specifically with reference to Figs. 1 and 2 of the drawing, by way of example, as applied to the piercing of a deep horizontal hole in a body of rock by a rock melting, quenching, and disintegrating procedure. Fig. 1 shows a long blowtorch 11 on a carriage 13 which is moved along a support 15 lengthwise of the torch by a lead screw 17. Blowtorch 11 comprises a non-rotating internal flame-producing unit 19 upon which is rotatably mounted a long sleeve 21 having reamer teeth 23 adjacent its forward end. Carriage 13 has a motor 25 acting through a suitable drive to rotate the sleeve 21 and reamer teeth 23 in a hole 27 being pierced in a body of rock R. Internal flame-producing unit 19 is restrained from rotation by flexible supply conduits 29, 31, and 33 for water, oxygen, and liquid fuel, respectively, coupled to the rear body 34 of the blowtorch. The apparatus outlined above is described in greater detail in United States Patent 2,327,496 granted in the name of Charles J. Burch on August 24, 1943.

A stream of liquid fuel is supplied to a central tube 35 in the blowtorch 11 by conduit 33 which is connected to a liquid reservoir or container 41 through a liquid pump 37 of any suitable type, such as a three-stage screw type pump driven by a motor and gear reducer unit 39 and building up a pressure of 25–50 lbs./sq. in. Forcing of the liquid also can be effected by other pumping devices, such as an hydraulic displacement chamber or a piston type pump. When powdered material is to be suspended in the liquid fuel in proportions other than those forming a stable paste or jelly, the mixture or slurry of powder and liquid fuel in the reservoir 41 is agitated continuously in the reservoir to keep the powder particles in suspension. Agitation of the liquid fuel can be accomplished in any suitable way, as by a propeller type agitator 45 driven by a small motor 47 clamped upon the top edge of the reservoir 41.

When piercing a hole 27 in a rock body R by a melting, quenching, and mechanical disintegrating procedure, the pump 37 is operated continuously to force liquid fuel from the container 41 to and through the central tube 35 of the blowtorch 11. Oxygen is supplied to the conduit 31 from any suitable source, passes through an

annular passage 49 surrounding tube 35, and is discharged from a tip 50 at the front of the blowtorch through a plurality of forwardly and inwardly converging discharge ducts 51 arranged in a circle around the central tube 35 in such a way that a plurality of oxygen jets impinge outside of the blowtorch against the central stream of liquid fuel from the tube 35 to form, upon ignition, a large bushy intensely hot flame.

Upon applying the flame to the face F of the rock body R, material is separated from the rock either by melting off, by spalling off in an unmelted condition, or by a combination of melting and spalling, and passes from the vicinity of the flame under the influence of gravity and/or the action of the gaseous products of combustion to leave a shallow cavity as the initial portion of hole 27. The tip of the blowtorch 11 is advanced progressively into the cavity and into successively formed portions thereof as it becomes deeper.

Water is supplied by conduit 29 from any suitable source to a second annular passage 53 in the blowtorch surrounding the annular passage 49. The water cools the blowtorch by passing forwardly through passage 53, and is then discharged laterally from the tip 50 into hole 27 through a plurality of annularly arranged ports 55 in front of the reamer teeth 23. Only a small flow of water is required initially, but the flow is increased after the hole is sufficiently deep to form an enclosed combustion zone for the flame. When the water flow is increased the water quenches and solidifies any molten slag separated from the rock by the flame, and the quenched slag is mechanically disintegrated in the hole by physical impact with the rotating reamer teeth 23. The pieces of disintegrated slag then are blown from the hole 27 by the gaseous products of combustion of the liquid fuel and of any solid carbonaceous fuel particles which may have been suspended in the liquid fuel, as well as by the large volumes of steam formed by evaporation of water in the hole.

Sufficiently large volumes of gaseous products of combustion are formed in the procedure described above to blow water out of even a deep downwardly directed hole, thus preventing accumulation of enough water to extinguish the flame. It has heretofore been possible to pierce such downwardly directed holes only to a limited depth by the melting, quenching, and disintegrating technique because water would accumulate in the hole and extinguish the flame.

Ordinarily it is considered hazardous for substantially pure oxygen to contact oil or other liquid fuels in commercial operations, but the method of this invention is such that the hazard is substantially eliminated by keeping the liquid fuel and oxygen separate from one another until they are actually discharged from the tip of the blowpipe. Thus, the mixture of oil with oxygen occurs outside of the blowpipe in the zone where combustion is desired.

In the rock melting, quenching, and disintegrating procedure described above it is important that the slag be very fluid when molten so as to flow freely from the vicinity of the flame, and that it be very friable when quenched and solidified so as to be readily disintegrated by the reamer teeth 23. Some rocks inherently possess these characteristics, but with other rocks it is important to introduce with the flame fluxing powder which will unite with the melted rock to form a fluid slag which is friable when quenched.

Holes have been successively pierced by the method described above in large bodies of concrete, Sudan iron ore (predominately hematite), and taconite iron ore. Taconite comprises alternate layers, in some of which magnetite predominates and in others of which silica predominates, and is to some extent self-fluxing. In a typical taconite iron ore the average composition was 40% Fe_3O_4 and 54% SiO_2, but the alternate layers varied from about 75% Fe_3O_4 to about 15% Fe_3O_4. Therefore, when piercing a hole in taconite iron ore transversely of the layers, any flux or flux-forming composition used must be designed to give the best compromise results between piercing in Fe_3O_4 and piercing in SiO_2. Due to the high silica content of taconite iron ore the oxy-fuel flame is maintained hot enough and of sufficient heating intensity to cause a substantial portion of the rock, estimated as 20–60% to be spalled off from the rock body and blown from the hole without ever fusing in the hole. Such spalled particles may be as large as one inch across.

Many liquid fuels can be used in performing the method, and they may be quite pasty in consistency or relatively free-flowing. When a liquid fuel is augmented by the addition of powdered material thereto, the constitution of the particular rock to be thermally worked will determine the character of the powder used, especially when a composition modifier such as a preformed flux, or a substance such as combustible flux-forming material which burns to form a composition modifier, is employed. Examples of typical powder-laden liquid fuels, which have been used successfully for piercing holes in taconite are as follows, proportions being expressed as percentages by weight:

1. 73% Al powder, 8% grease, 19% diesel oil.
2. 50% jellied kerosene, 50% CaO or $CaCO_3$ powder.
3. 27% mineral oil, 73% FeMn powder.
4. 80% mineral oil, 20% coal powder.
5. 40% jellied kerosene, 20% coal powder, 40% FeMn powder.
6. 70% jellied kerosene, 30% borax powder.
7. 29% mineral oil, 35.5% Al powder, 35.5% Mg powder.
8. 43% jellied kerosene, 9% coal powder, 48% Na_2CO_3 powder.
9. 50% jellied kerosene, 50% CaC_2 powder.

Commercially pure calcium carbide powder (CaC_2) carried in the fuel is surprisingly effective because it has several important properties not possessed by most powders. First, calcium carbide very effectively prevents extinction of the flame because it reacts with water to produce acetylene gas which burns in the hole. Further, the solid end products have a fluxing action on some melted rocks to form a fluid slag which is friable after quenching. Additionally, at least part of the calcium carbide is believed to burn in oxygen and liberate a large quantity of heat while forming a flux as a product of combustion. The calcium carbide powder is effective in any amount but desirably should constitute between 5% and 50% by weight of the fuel-powder mixture; and it can be used alone in the liquid fuel, or can be used in conjunction with other powders to give the optimum results. For example, when large quantities of calcium oxide are required to flux the rock it is economical to suspend in the liquid fuel a mixture of particles of relatively inexpensive calcium oxide with just enough of the rela-

tively expensive calcium carbide particles to prevent extinction of the flame by water.

Other powders which are the equivalent of calcium carbide are sodium acetylide, aluminum carbide, sodium, potassium, lithium, and hydrides of the alkali and alkaline earth metals. All of these except aluminum carbide and sodium acetylide generate hydrogen upon reaction with water. Aluminum carbide generates methane, sodium acetylide acetylene.

Liquid fuels such as kerosene, fuel oil, and the others named herein are especially advantageous for conveying the above-mentioned water-reactive powders because they protect the powders from contact with water, thus preventing premature deterioration. If such powders were carried in a moist gas stream, they would be prematurely slaked to some extent by the water vapor in the gas.

In a specific example of rock piercing by the improved method, a blowtorch six inches in diameter (including the reamer teeth) pierced a hole thirty feet deep vertically downward in taconite iron ore at a rate of 2.5 in./min., using a flame resulting from the combustion in oxygen of a slurry consisting 60% of jellied kerosene and 40% of calcium carbide dust fed to the blowtorch at a rate of 150 lbs./hr. The pressure in the combustion zone adjacent the bottom of the hole was greater than 15 lbs./sq. in., whereas the pressure would have been only 2 to 5 lbs./sq. in. if acetylene were used from a generator limited to 15 lbs./sq. in. acetylene pressure. In this hole, the actual hole diameter in the ore body was between 6½ and 9 inches, but a heavy hardened slag lining reduced the effective diameter to slightly more than 6 inches.

From the foregoing detailed description it is evident that there are several fundamental features of our novel process whereby deep holes can be pierced in a downward direction in mineral materials such as iron ore. One is the positive and uniform delivery of fuel to the reaction zone at a very high rate and at a relatively constant delivery pressure high enough to give rapid and efficient ejection of detritus regardless of variations of the pressure within the hole. Preferably the fuel pressure and flow rate should be high enough to produce a combustion pressure greater than 15 lbs./sq. in. at the bottom of a hole, so that the fuel pressure must exceed the combustion pressure to insure continuous flow into the progressing reaction zone. Another essential is the use of a high pressure ejection fluid, preferably steam generated by discharging cooling water from the blowpipe onto the molten slag in the hole. Another important feature where a very high rate of heat transfer to the rock is desired is the use of a metal powder as an auxiliary fuel. Where the rock is not self-fluxing, it is also imperative to use vigorous fluxing agents, either delivered to the piercing zone as preformed fluxes, or as the combustion products of appropriate combustible metal powders. Such fluxes should be selected to give a highly fluid slag which is easily friable after quenching.

The method of the invention has been described specifically above, by way of example only, as applied to the thermal piercing of holes in rock. It is to be understood that the principles of the invention can be applied quite generally where a body of material is to be heated and hot particles of material are to be applied simultaneously thereto, and especially where the composition of such a body of material is to be modified by contacting it with hot particles of a composition modifier while heating the body.

Although specific embodiments of the present invention have been described in detail, it is apparent that changes in the method and changes in the construction and relative arrangement of parts of the apparatus can be made within the spirit of the invention and within the scope of the claims appended hereto.

We claim:

1. In the method of working rock by progressively applying thereto flame from the combustion of a liquid fuel discharged from a blowtorch to separate material from said rock while water concurrently enters the vicinity of said flame, the improvement which comprises: directing into the water in the vicinity of said flame a flowing stream of particles of calcium carbide to generate acetylene, whereby such acetylene is generated, burns, and improves the stability of said flame.

2. In the method according to claim 1, said calcium carbide being carried into the vicinity of said flame by said liquid fuel.

3. A fuel mixture comprising a liquid hydrocarbon fuel having mixed therewith and suspended therein particles of commercially pure calcium carbide in an amount between 5 and 50% of said mixture by weight.

4. A fuel mixture comprising a liquid hydrocarbon fuel having mixed therewith and suspended therein particles of commercially pure calcium carbide and particles of calcium oxide, said carbide and oxide together amounting to between 5% and 50% by weight of said mixture, and said carbide being at least 5% of said mixture.

5. In a method for working rock by applying thereto flame, and separating material from said rock by the heating effect of said flame, the improvement which comprises: forming said flame by separately conveying to a combustion zone streams of water, oxygen, and a liquid fuel mixture comprising a liquid hydrocarbon fuel having mixed therewith and suspended therein particles of commercially pure calcium carbide in an amount between 5% and 50% of said mixture by weight, impinging said oxygen against said liquid fuel in said combustion zone to form a combustible mixture, igniting and burning said combustible mixture, and directing said water into said combustion zone to react with said calcium carbide particles and form combustible acetylene gas.

6. In a method for working rock by applying thereto flame, and separating material from said rock by the heating effect of said flame, the improvement which comprises: forming said flame by separately conveying to a combustion zone streams of water, oxygen, and a liquid fuel mixture comprising a liquid hydrocarbon fuel having mixed therewith and suspended therein particles of commercially pure calcium carbide and particles of calcium oxide, said carbide and oxide together amounting to between 5% and 50% by weight of said mixture, and said carbide being at least 5% of said mixture, impinging said oxygen against said liquid fuel in said combustion zone to form a combustible mixture, igniting and burning said combustible mixture, and directing said water into said combustion zone to react with said calcium carbide particles and form combustible acetylene gas.

7. A method in accordance with claim 5 wherein said oxygen and liquid fuel are delivered to

said combustion zone at pressures greater than 15 pounds per square inch.

8. A method in accordance with claim 6 wherein said oxygen and liquid fuel are delivered to said combustion zone at pressures greater than 15 pounds per square inch.

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