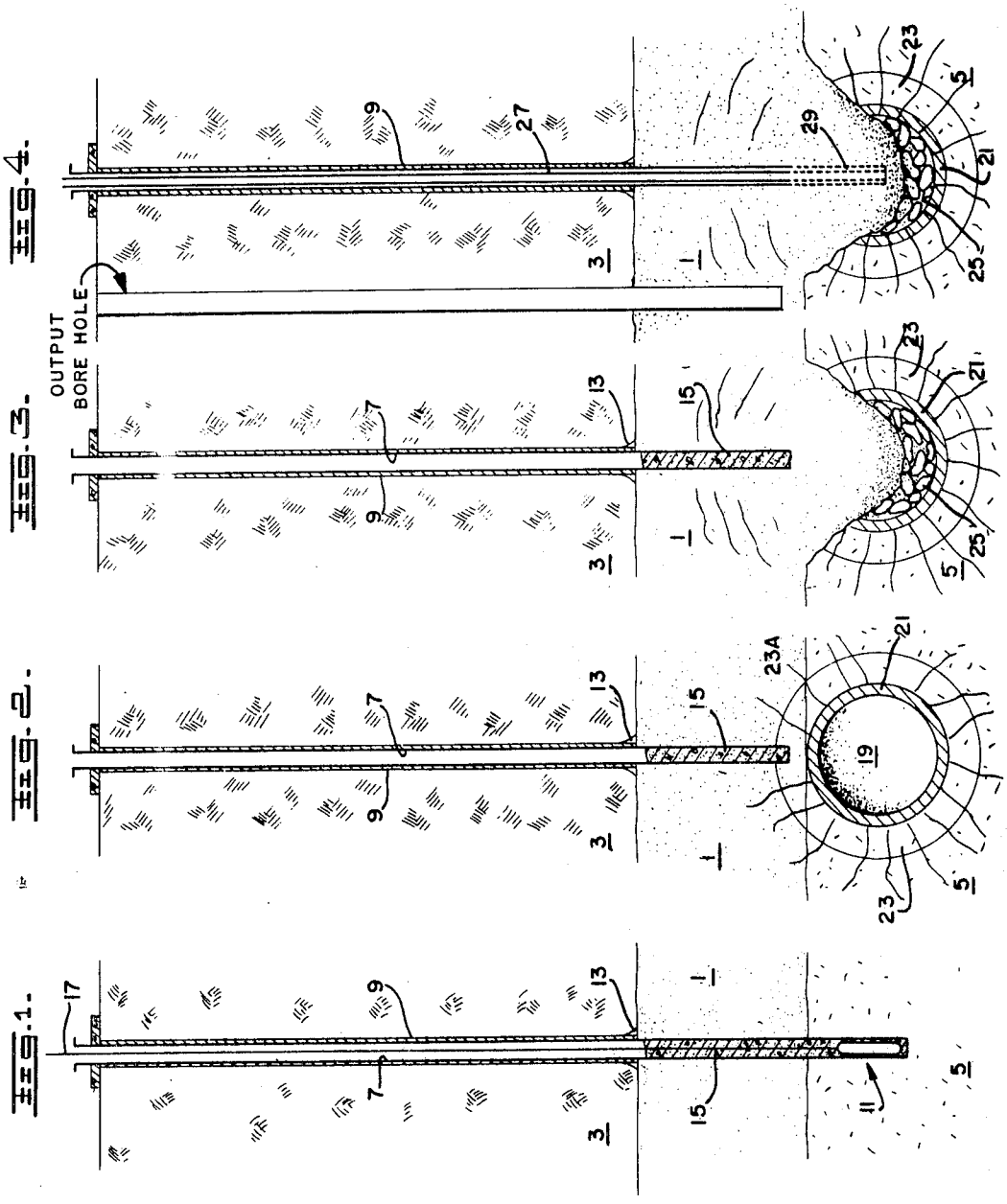
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PROCESS FOR RECOVERING PETROLEUM UTILIZING A NUCLEAR EXPLOSION

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PROCESS FOR RECOVERING PETROLEUM UTILIZING A NUCLEAR EXPLOSION

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The present application is a continuation-in-part of my U.S. patent application Ser. No. 752,282, filed July 31, 1958.

The present invention relates to an improved method for the recovery of petroleum and particularly so when the petroleum is contained in subsurface oil-bearing formations having an adjacent limestone stratum. One aspect of the present invention involves the setting off of a nuclear explosive device under the surface of the earth and in the limestone stratum and subsequently contacting the resultant decomposed limestone with water so as to release heat energy by their reaction.

It has been found that nuclear explosive devices, i.e. atomic and hydrogen bombs, can be detonated beneath the surface of the earth and that many of the heretofore undesirable effects of such an explosion can be avoided with little or no deleterious effects, such as underground water and oil contamination, rupturing of the earth's surface, earthquakes, etc. It has also been found that such a subterranean explosion results in a certain sequence of events which I employ as aids in the recoveries of petroleum contained in subsurface formations. In explosions of this type, i.e. subsurface, the force of the blast and the tremendous heat values released will cause the formation immediately surrounding the blast site to fuse and be compressed resulting in a cavity, the diameter of which will normally be directly proportional to the magnitude of the explosion. Subsequent to this cavitation and perhaps coextensive therewith the weight of the overburden will cause the collapse of the roof of the cavity with a downward displacement of the overlying formation into the cavity. This downward movement of the overburden can extend upwardly for several hundred feet or more resulting in a large area of loosened and more permeable formation. When this formation moves downward the heat values released by the blast move upward and through the downwardly moving formation, resulting in an increase in the temperature of the displaced formation. It is with these downwardly displaced formations that one aspect of the present invention is concerned and with the beneficial effects imparted to the formation by such shifting which is described in my copending application Ser. No. 739,273, filed June 2, 1958, and hereby incorporated by reference. For a more detailed explanation of the results achieved by such an explosion, further reference is made to the University of California Research Laboratories (UCRL) Report No. 5124, entitled "Ranier Operation Plumbob," Feb. 4, 1958.

Also results of such explosions are reported in: The Second Plowshare Symposium (UCRL 5675–5679); the U.S. government publication "The Effects of Atomic Weapons," revised September 1950; "Project Plowshare," by Ralph Sanders, Public Affairs Press, 1962; Life Magazine for Mar. 15, 1963, article entitled "Man's First Atomic Cave," U.S. Congressional Hearings conducted Mar. 22, 1960 and entitled "Frontiers in Atomic Energy Research." Indeed, as reported on page 120 and 133 of UCRL 5675 correlation between predicted results are generally in good agreement with experiment using well known principles of physics and properties of materials.

Thus it is believed that one may with a good degree of accuracy predict the effect of underground explosions such as cavity size and the nature of the cavity in formations of different materials which may or may not include an oil bearing limestone formation. Apart from the formation of a cavity the formations surrounding and extending outwardly from the cavity region are fractured to condition such formations for the flow of petroleum therethrough in subsequent secondary recovery methods wherein either heat or pressure or both are used to cause the petroleum to flow through such fractured formations from the general vicinity of an input bore hole to one or more output bore holes spaced from such input bore hole.

Now, in accordance with one aspect of the present invention I provide a new and improved method of recovering petroleum from subsurface oil-bearing formations having an underlying limestone stratum, the method including a nuclear explosion of the type referred to above. In general terms the present invention involves the setting off of a nuclear explosive device at such a point beneath the oil-bearing formation and in the limestone stratum that the cavity resulting from the explosion will extend towards the lower surface of the formation sufficient so that at least a substantial portion of the formation will fall into the cavity, and then recovering petroleum from the oil-bearing formation. The recovery of petroleum in this manner is advantageous in that a reservoir is provided into which the petroleum can fall or even drain as by gravity, the formation is heated to a considerable extent and thus the viscosity of the petroleum is accordingly reduced rendering it more flowable particularly when secondary recovery methods are used wherein the fractured formations results in greater permeability and paths of smaller resistance for oil flow to one or more output bore holes. The formation displaced downwardly is loosened and rendered more permeable to oil flow and the molecular structure of the petroleum can be favorably altered by contact with the gamma radiation retained in in the cavity. Not only will these results be attained but also the present method envisions imparting additional heat values to the petroleum contained in the formation by releasing the latent heat contained in the calcium oxide formed as a result of heating the limestone, i.e. calcium carbonate, the latent heat being released by contacting the calcium oxide with water to provide an exothermic reaction. The feasibility of conducting such an exothermic reaction is explained in pages 25–30 of the above mentioned publication "Frontiers in Atomic Energy Research."

The present method can be applied to any oil-bearing formation having an underlying stratum of limestone. For instance, the Athabasca tar sands of Canada can be treated with particular advantage by the present method since they are substantially water free and lie directly over a limestone stratum. The oil in these sands is heavy and is usually of a gravity of about 5 to 15 or 20 degrees API. Although I will refer most often to the preferred procedure for recovering oil by my method as described above, the process is also applicable to situations where the adjacent limestone overlies the oil-bearing formation and in this situation it is preferred that the cavity caused by the nuclear explosion extend at least somewhat into the oil-bearing formation. In addition, in other less advantageous operations the cavity produced above or below the oil-bearing formation need not extend to it nor need the collapse involve the falling of the oil-bearing formation; and yet the addition of water to the decomposed limestone will generate heat which will pass to the oil-bearing formation providing, of course, that the cavity is close enough or in proximity to it.

The type and magnitude of the explosive device utilized in the present method is controlled primarily by the depth of the oil-bearing formation to be treated beneath the sur-

face of the earth, with the greater depths permitting the use of devices of greater magnitudes. In some cases, depth permitting, a thermonuclear explosive device, i.e. hydrogen bomb, can be utilized if desired either in the vicinity of a limestone layer for reducing the limestone to calcium oxide or for fracturing the surrounding formations to make them more permeable for secondary recovery processes or for other purposes described in my applications Ser. No. 675,637, filed Aug. 1, 1957, Ser. No. 707,058, filed Jan. 3, 1958, both now abandoned and Ser. No. 739,273, filed June 2, 1958.

In general, the explosive device can be situated so that the magnitude of the device conforms to the relationship

$$D=450(W)^{1/3}$$

when D is equal to the minimum depth of positioning and W is equal to the magnitude in kilotons of the device. For instance, if the oil-bearing stratum to be treated is 1000 feet beneath the surface of the earth, a bomb having a magnitude of about 10 to 11 kilotons can be utilized with little danger of causing a surface eruption. The bomb is preferably placed at such a position beneath the lower level of the oil-bearing formation that the limestone melted by the explosion forms a sphere which is tangent to the limestone oil sand interface. The cavity growth beyond the point at which melting ceases extends into the oil sand zone which is pushed upwardly. When cavity growth is complete and its internal pressure drops below that capable of supporting the overburden it collapses and a large amount of oil sand will fall into the cavity, with the full radius of the cavity being defined by the relationship

$$R=50(W)^{1/3}$$

when W is the magnitude in kilotons of the device. Thus, if the formation is about 1000 feet beneath the earth's surface a device as indicated above, having a magnitude of about 10 kilotons can be selected and this device can be located about 25' beneath the lower interface of the formation. Of course, the above-indicated relationships will vary from formation to formation depending upon the density and compaction of the overburden but for general purposes these formulae offer a useful guide for calculating the depth of the placement.

In the accompanying drawings:

FIGURE 1 shows a bore hole traversing the oil-bearing formation and penetrating an underlying limestone stratum, the bore hole having positioned at its lower terminal end a nuclear explosive device;

FIGURE 2 shows in schematic form the spherical cavity produced in the limestone stratum as a result of the nuclear blast;

FIGURE 3 shows in schematic form the collapse of the roof of the cavity and the downward movement of the oil-bearing formation; and

FIGURE 4 shows the cavity of FIGURE 3 having perforated tubings in place for recovering petroleum and supplying water to the strata as desired.

Referring now to FIGURE 1, I have shown oil-bearing formation **1**, e.g. an Athabasca tar sand, having an overlying stratum **3** and an underlying limestone stratum **5**. Traversing the stratum **3**, tar sand formation **1** and penetrating into the underlying limestone stratum **5**, I have provided casing **7** cemented in bore hole **9**, casing **7** having positioned at its lower terminal end nuclear explosive device **11**. The cement retaining casing **7** in place terminates in base **13** at the top of formation **1**. The distance bore hole **9** and casing **7** extend into the strata **5** is, as indicated previously, primarily dependent upon the magnitude of the explosive device **11**, with this magnitude being a function of the distance to the earth's surface. For example, in the instant case if the formation **1** is about 300 feet deep or thick and if the upper level is located about 1000 feet beneath the surface of the earth, a bomb of a magnitude of about 10 kilotons can be utilized without danger of rupture of the earth's surface. Using a bomb of this magnitude, its placement below the lower interface of formation **1** can be defined by the relationship

$$R=50(W)^{1/3}$$

thus, the explosive device **11** would be positioned at a point approximately 100 feet beneath the lowermost interface of formation **1** and at a depth of about 1400 feet beneath the earth's surface. In order to prevent radioactive fission products from blowing back up the bore hole **9** and contaminating above surface equipment and personnel, I have provided a plug **15** made of cement or similar material completely covering the explosive device **11** and extending upwardly in bore hole **9** to a height sufficient to contain the force of the explosion, e.g. 300 to 600 feet. Extending from the earth's surface down the bore hole **9** and to the device **11** is provided means **17** for detonating the device at the desired time. Means **17** can take the form of a rod designed to be rapidly withdrawn upwardly or it can be an electrical cable or similar electrical detonating device for instance, for initiating a minor explosion to set off the nuclear device.

When properly positioned and secured, the device **11** can be triggered and the resultant explosion will form, as shown in FIGURE 2, a cavity **19**, the radius of which will be proportional to the magnitude of the explosion, in this case, about 100 feet. As here shown, the device **11** was positioned so that the upper perimeter of the cavity **19** will be substantially or approximately tangential to the lowermost edge of the oil-bearing formation. It is to be realized, of course, that the device can also be positioned at such a depth beneath the lower interface that this interface will define a cord through the cavity and above the mid-point of the cavity to avoid undue loss of oil, or in the other positions previously noted.

The temperature produced as a result of the explosion will, of course, be extremely high, e.g. 1,000,000 degrees F. approximately, the high temperatures resulting in the vaporization and sintering of the stratum immediately surrounding the blast site. As indicated previously the stratum underlying the oil-bearing formation and in which the nuclear explosion takes place is limestone, i.e. calcium carbonate. Due to the high temperatures, the calcium carbonates will be readily decomposed and vaporized to calcium oxide and carbon dioxide gases with vaporized gases diffusing upward into the tar sand formation. As the vapors cool in passing upward calcium oxide will precipitate in the bottom portion of the tar sand formation as generally shown at **23A**. Immediately surrounding the blast site there will be formed a shell **21** of calcium oxide glass or sinter which is substantially impermeable and of such a character that most, if not substantially all, the radioactivity from the nuclear blast will be absorbed thereby. Outwardly from the blast site the temperatures are rapidly dissipated and the temperature will be such that the carbon dioxide will be vaporized from the limestone leaving behind an area **23** of chalky unslaked lime, calcium oxide. The thickness of the two areas, i.e. **21** and **23** will, of course, depend primarily on the heat generated by the blast and thus proportional to the magnitude of the blast. In the instant case, using an explosive device of a magnitude of about 10 kilotons the shell **21** may have a thickness of about 1 to 3 feet whereas the area **23** may be about 100 to 500 feet in thickness.

Immediately subsequent and perhaps coextensive with the above-described cavitation, the weight of the overburdens **1** and **3** will cause the collapse of the roof of cavity **19** and the tar sand formation **1** immediately thereabove will be displaced vertically downward into cavity **19** as shown in FIGURE 3. That portion of the shell **21** forming the roof of the cavity **19** will be carried downward and disposed as shown at **25** in a layer of broken slag on the bottom of cavity **19**. This slag will, of course, be composed of material from shell **21** and calcium oxide

layer 23. The collapse of the roof and the downward movement of the formation 1 will proceed vertically until a structure is reached of sufficient strength to support the overlying formation. In a formation as presently described this vertical displacement may proceed through substantially the entire cross-section of the formation 1 and the formation 3 will be sufficiently strong to support its own weight. As the sands move downward and fill cavity 19 the heat contained in the cavity will pass upward serving to raise the temperature of the heavy viscous petroleum and thereby reduce its viscosity. Usually the tar sands will be elevated in temperatures, for instance to about 100 to 500 degrees C. Due to the proximity of the highly radioactive shell 21 and the radioactive gases contained in the cavity 19 the viscosity of the petroleum may also advantageously be affected by changes in its molecular structure due to bombardment with gamma radiation.

Thus, by establishing a nuclear blast as indicated above, a large area of the tar sand formation 1 is heated and bombarded with gamma radiation resulting in a pool or reservoir of less viscous petroleum contained in cavity 19. In order to effect the recovery of petroleum from this reservoir I can provide recovery tubing string 27 as shown in FIGURE 4 extending from the earth's surface down cased bore hole 9 and into the cavity area 19, through which the petroleum can be pumped or otherwise carried to the surface by conventional methods. The tubing string need not, of course, extend into the cavitation area but it can be moved upward into the area of the formation 1 wherein the effects of the nuclear explosion are felt and as the formation progressively cools the recovery means can be progressively lowered into the cavitation area.

As the heat resulting from the nuclear exposion dissipates throughout the formation the petroleum in the reservoir will gradually cool and may once again become viscous and heavy, thus decreasing the amount recoverable through tubing string 27. When this stage of cooling has been reached, or before if desired, and recoveries are no longer practical because of the increased viscosities of the petroleum, one aspect of the present invention further envisions the introduction of secondary heat values into the tar sand formation occasioned by the heat resulting from the reaction of water with the decomposed limestone. Thus, about ⅓ of the energy released by the nuclear blast may be consumed in the chemical reaction of decomposing the calcium carbonate and would normally be lost from the system. However, I utilize potential energy present in the calcium oxide surrounding the blast site and am thus able to again increase the temperature of the tar sands to such a point that further recoveries of petroleum are possible.

Thus, after the nuclear explosion or after petroleum recoveries are no longer possible or desirable through tubing string 27, I provide means at the earth's surface (not shown) to pump water down the bore hole 9 and spray the interior of and/or around the cavity and the calcium oxide present. The water upon contacting the calcium oxide will generate heat in the form of superheated steam and in about the same amount that was necessary to decompose the calcium carbonate, i.e. about ⅓ the heat released by the blast, and this heat will act in the same manner as the heat energy originally imparted to the tar sands except that the temperature may be somewhat lower. The water can be sprayed into the cavity 19 and on the bottom of the tar sand formation by means of the tubing string 27 if desired or an additional tubing string can be run down the bore hole 9 when it is desired to recover oil by tubing string 27 while adding water. In either case the lower terminal end of the tubing string should be perforated as shown at 29 in order to spray the water over all sides of the cavity 19 and area bounded by the calcium oxide lining. Also one or more separate output wells may be drilled so that the water added can be forced towards the output well to effect a hot water drive for secondary oil recovery with the water and oil flowing through formations previously fractured by the nuclear explosion.

The explosive device to be utilized in carrying out the method of the present invention can be constructed in accordance with principles and theories well known to those versed in the art.

Although in the instant drawings I have shown only one blast site located beneath the oil-bearing formation 1 and in the limestone stratum 5, a plurality thereof can be employed if desired, thus establishing across the entire horizon of the formation a multiplicity of heated areas, thereby stripping the petroleum from the entire formation. Thus, by the present invention I have provided a method whereby a substantial area of oil-bearing formation can be elevated in temperature, the viscosity of the petroleum contained therein reduced to such an extent that it becomes more fluid, the method providing in particular means to recover the heat values consumed in decomposing the limestone stratum to calcium oxide and utilizing them to impart to the petroleum higher temperature levels. It is, of course, to be realized that it is within the purview of the present invention to cause the release of the heat values from the calcium oxide prior to the recovery of oil from the formation. That is immediately after the collapse of the cavity and the downward movement of the formation water can be sprayed over the calcium oxide, and petroleum recoveries can thereafter be effected as described or by any conventional manner.

It is appreciated that the decomposition of limestone as described above is accompanied by the liberation of carbon dioxide and that such carbon dioxide is at a high temperature and under pressure. The carbon dioxide may, if desired, be removed from the cavity under its own pressure and being in a heated state can be used as an energy source for example by using it to drive a turbine or to apply it to a heat exchanger for heating the oil in a pipe line or tank to render it less viscous for its transmission to a remote location in which case the carbon dioxide flows upwardly under its own pressure through the cased hole 9 after drilling through the plug 15 and the material overlying the cavity to establish communication between the cavity and the surface where such turbine or heat exchanger is located. In such case the carbon dioxide may be communicated to such turbine or heat exchanger through conduit connected to the upper end of the cased hole 9 or through tubing such as exemplified by tubing 27.

Alternately, the heated carbon dioxide under pressure may be used as a drive for heating the oil and driving it through the fractured formation to one or more output bore holes which are formed either prior to or after the nuclear explosion with conventional pumping means connected with such output bore holes to pump the oil collected in such bore holes to the surface. On the other hand, the heated carbon dioxide may penetrate the formations surrounding the cavity to heat the petroleum to render it less viscous and promote its flow into the cavity from where it is recovered by surface pumps.

In some instances it may be desired to minimize the recombination of carbon dioxide with the calcium oxide so as to have more of such calcium oxide available for the above described exothermic reaction in which case communication is established between the cavity and the surface shortly after the nuclear explosion by having available drilling equipment for drilling through the plug 15 and any other material overlying the cavity and allowing the carbon dioxide to escape from the cavity under its own pressure as soon as practically possible after the explosion with or without the use of auxiliary pumps. By thus releasing the pressure in the cavity recombination of carbon dioxide with the calcium oxide is minimized. To minimize the time for relieving such pressure heat resistant tubing may be previously extended from the surface of the earth to a region within the expectant cavity and capped; then after the formation of the cavity such tub-

ing may be uncapped to allow immediate release of the carbon dioxide pressure either directly to the atmosphere or into a large vessel which prevents any radioactive products entering the atmosphere.

Any carbon dioxide which recombines with calcium oxide results in the formation of a thin crust that provides an inhibiting barrier for penetration of the carbon dioxide ad thus further recombination with the main mass of calcium oxide is inhibited; and should there be insufficient cracks in such crust to allow introduction of water into the main mass of calcium oxide the crust is mechanically disturbed as for example by introducing and detonating small charges of TNT in the cavity.

I claim:

1. In a method for the recovery of petroleum from a subsurface oil-bearing formation, having an adjacent limestone stratum, the steps which comprise establishing a nuclear explosion at a point in proximity to the oil-bearing formation to form a cavity in said limestone stratum and to form calcium oxide and carbon dioxide from said limestone stratum using the heat produced as a result of the nuclear explosion, removing the carbon dioxide, contacting the calcium oxide in the area of the cavity with water to produce heat as a result of the reaction between the water and calcium oxide for further heating the oil-bearing formation, and recovering oil from said oil-bearing formation.

2. The method as set forth in claim 1 including providing at least one output bore hole adjacent to and outside of the cavity either before or after production of said cavity, and recovering the oil from said output bore hole with said oil being driven to said output bore hole by said carbon dioxide under temperature and pressure which removes itself from said cavity by traveling through formations fractured by said explosion.

3. The method as set forth in claim 1 including the step of establishing a gas path between said cavity and the surface of the earth for removal of the carbon dioxide.

4. The method as set forth in claim 3 including the steps providing said gas path prior to said explosion.

5. The method as set forth in claim 3 including using the heat and pressure energy in said carbon dioxide removed through said gas path for recovering oil from said oil bearing formations.

6. The method as set forth in claim 1 including the steps of periodically injecting water into said cavity to produce additional heat as needed.

7. The method as set forth in claim 1 including introducing means into said cavity for disturbing any crust produced as a result of recombination of the carbon dioxide with the calcium oxide.

References Cited

UNITED STATES PATENTS

59,936	11/1886	Roberts.	
2,911,046	11/1959	Yahn	166—36
3,002,454	10/1961	Chesnut	166—36 X
3,113,620	12/1963	Hemminger	166—36 X

OTHER REFERENCES

Mascat: Physical Principals of Oil Production, 1st edition, McGraw-Hill Book Company Inc. (1949), page 105.

Rougeron, Camille: les Applications de l'Explosion Thermonucleaire, Paris editions, Berger-Levrault, 5 Rue Auguste-Compte VI, 1956, pages 162–168, 190–202.

Time Magazine, Mar. 24, 1958, page 64.

UCRL–5124: University of California Research Laboratory Report, "The Underground Nuclear Detonation of Sept. 19, 1957, Ranier Operations Plumbob," Feb. 4, 1958, pages 3, 10, 11, 14, 20, 21, 22, 26 and 27.

Uren: Petroleum Production Engineering (Oil Field Development) 4th edition, McGraw-Hill Book Co. (1956), pages 12–25.

STEPHEN J. NOVOSAD, Primary Examiner

U.S. Cl. X.R.

166—271, 272