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OIL WELL CEMENTING PROCESS AND APPARATUS THEREFOR

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FIG. 1

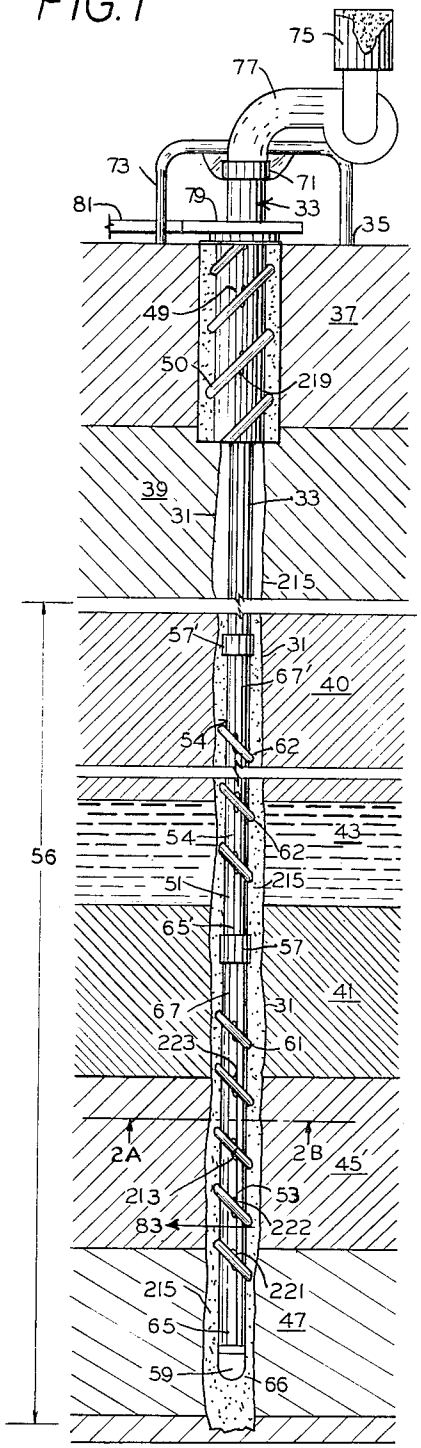
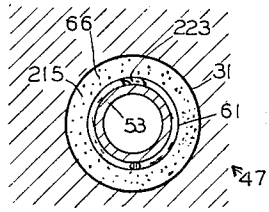



FIG. 2




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# OIL WELL CEMENTING PROCESS AND APPARATUS THEREFOR

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This invention relates to an oil well cementing process and apparatus therefor. In the normal procedure of cementing oil wells the casing is left within the cemented zone; accordingly, the expense of the apparatus in the cemented zone is an important economic factor for the operator to consider, especially where zones of extensive depth are to be cemented. However, as the cementing about the casing in a well hole is a critical and important part of the oil well completion proceeding it must be well and reliably done. While conventional methods and apparatus presently do not perform this operation with entirely satisfactory economy and reliability, according to the process and apparatus of this invention a cementing operation is performed with exceptionally good and reliable results and the apparatus therefor is inexpensively yet reliably made.

It is, therefore, one object of this invention to provide an improved process for cementing oil wells.

Yet another object of this invention is to provide an improved apparatus for the cementing of oil wells.

Still other objects will be apparent to those skilled in the art from a study of the below disclosure, of which disclosure the drawings attached hereto form a part and wherein;

FIGURE 1 is a diagrammatic overall view of the apparatus used in a process of this invention;

FIGURE 2 is a cross-sectional view along the plane indicated by 2A–2B of FIGURE 1.

Generally, the process of this invention is directed to cementing of a well bore as **31** within which is to be located a string **33** of casing or tubing. The string extends from the surface, **35** through a surface earth zone **37**, various earth strata as **39**, **40**, **41**, water layers as **43**, and gas producing zones as **45**, to the producing zone **47**. The casing string is composed of surface pipe **49** and a production string generally shown as **51**. The string **51** is composed of a series of lengths of casing as **53**, **54**, joined in sequence by intermediate collars, as **57**, and provided with a shoe, as float shoe **59** at its bottom. In the preferred embodiment the bore of the well **31** below the surface zone **37** is 7⅞ inches in outside diameter and the casing string **51** is made of 5½ inch outside diameter steel casing of a normal weight (e.g. 14 to 17 pounds per linear foot with coupling).

The process of this invention comprises firmly locating and attaching on the outside of each length, as **53** and **54**, of the string **33** in the zone or length thereof, as **56**, throughout which cementing is desired a hot-rolled steel rod, as **61** and **62**, in the form of a pre-formed spiral. In the preferred embodiment with a 5½ inch outside diameter casing the rods **61** are of ⅝ inch outside diameter and have a pitch of 26 inches and the spiral is a left-hand spiral. The spiral firmly fits and contacts the casing and is attached thereto at each 180° of the spiral by a weld of 3 inches length between the spiral and the casing. The spiral rod thus has an outer diameter of 6¾ inches which is substantially greater than the standard 6.05 inch outside diameter of the standard collar, as **57**, for such casing or tubing, while being substantially less than the internal diameter of the well hole, which is 7⅞ inches in the preferred embodiment.



On each length of casing or piping, as **53** and **54**, a length of spiral rod, as **61** and **62** respectively, extends, in the preferred embodiment from about 30 inches from the lower end of the length to about 42 inches from the top of that length of casing or piping. This leaves a lower space **65** on the bottom end of length **53** (and **65'** on length **54**) and an upper space **67** on the top end of lengths **53** (and space **67'** on length **54**). These spaces on the surface of the casing, as **53**, are available for attachment thereto of other tools such as centralizers and attachment of slips and elevators.

The spirals are attached to each length of casing prior to assembling of the string. The attachment of the spirals to the tubing is of sufficient strength so that the spirals cannot be pulled off the pipe; when a tension strength test is applied to them the pipe is pulled in two before the spiral is separated from the pipe. The spirals are pre-formed to fit the pipe and provide no mechanical stress for deformation of that pipe but actually serve to strengthen it; the spirals do not interfere with the pipes' elasticity because of the location of the points of the attachment of said spirals with said pipes. The pipe lengths with the spirals thereon as above described are assembled and run to the bottom of the well **31** with a bottom float or guide shoe **59** at the bottom of said string. The well is then circulated to clean it. The tubing string **33** is reciprocated with a 10-foot stroke at a frequency of two cycles per minute prior to putting the cement into the casing. This reciprocation is of sufficient length to cover the length of well surface opposite spaces as **65**, **67**, **65'** and **67'** not covered by the spirals **61** on the usual 28 to 32 foot length of pipe as **53**, **54** used on strings as **33**. The well may be again circulated with mud and/or water to clean it out.

The casing is then located vertically in the formation to be cemented, the bottom plug is introduced in the casing, a conventional rotary head **71** provided with supports **73** is rotatably connected to string **33** and rotatably connects a source of cement **75** to the string **33**. A slow setting cement, below described, is mixed and passed under pressure to feed pipe **77**. A rotary table **79** supporting string **33** is driven by a conventional controllable driving means **81**. The cement slurry is initially at 600 pounds per sq. in. pressure at the surface. The rotation applied by table **79** to string **33** is a right-hand rotation as shown by the arrow **83**. More particularly, the left-hand spiral of rods as **61** provides a counter-clockwise (as seen from above) or left-hand spiral on traveling downwards along the edge of such spiral; the direction of rotation impressed by the table **79** is, as shown by the arrow **83**, as seen from above, clockwise.

Conventionally, and according to this process, it takes about 45 to 60 minutes between the time the addition of cement to the casing string **33** and hole **31** begins and the time when substantially all the cement is in place, as usually indicated by "bumping" of the top plug usually added at the top of the to-be-added cement. According to the process of this invention the rotation of string **33** is continued while the cement is being moved to its intended position and is continued until the cement stiffens; a 300 H.P. motor is used as a drive for a 3,000 foot string: there is a usual draw of 15 to 20 H.P. as the cement stiffens the draw rises to 50 H.P. In the exemplary embodiment of this invention, for a 3,000 foot hole from 4 to 7 barrels per minute of a mixture, composed of 37 pounds Pozmix "A" Cement (product of Halliburton Oil Well Cementing Company) having an analysis as in Table I below and described in "Pozmix Cement Information," October, 1954, by Chemical Research Laboratory of Halliburton Oil Well Cementing Company, Duncan, Oklahoma) with 47 pounds type A (A.P.I.) Portland

cement, and 1.86 pounds of gel and 17 pounds of salt per sack of dry mix, is admixed with 5.75 gallons of water per sack for a slurry weight of 14.15 pounds per gallon or 1.26 cubic feet per sack. This provides a thickening time (as measured by Stanolind high pressure thickening time tester) of about 4 hours and 17 minutes.

The time of thickening is chosen so that there will be a sufficiently long time after the conventional cement top plug "bumps" or otherwise indicating that the cement is in place, for the kneading and other actions of the rotating spiral rods, as **61** and **62**, on each of the casing lengths as **53**, **54** of the string **33** in the to-be-cemented zone, as **56**, to take place before the cement sets. The cement characteristics are also chosen, notwithstanding such relatively slow setting, to reduce the time of waiting for the cement to set to a sufficiently short period to not economically interfere with any subsequent operations to be performed on the set cement.

TABLE I

*Properties of Pozmix "A"*

| | |
|---|---|
| Physical properties: | |
| Specific gravity | 2.46 |
| Weight per cubic foot absolute—pounds | 153.00 |
| Weight equivalent in absolute volume to 1 sack (94 lbs.) cement—do | 74.00 |
| Amount retained on 200 mesh sieve—percent | 5.27 |
| Amount retained on 325 mesh sieve—do | 11.74 |
| Chemical analysis: | |
| Silicon dioxide—percent | 43.20 |
| Iron and aluminum oxides—do | 42.96 |
| Calcium oxide—do | 5.92 |
| Magnesium oxide—do | 1.03 |
| Sulphur trioxide—do | 1.70 |
| Carbon dioxide—do | 0.03 |
| Loss on ignition—do | 2.98 |
| Undetermined—do | 2.21 |

According to this process the cement contacted by the rotating spirals is densified as demonstrated by that the same volume of cement required by normal cementing procedures using conventional cementing procedures as in "Oil Well Cementing Principles and Practices," 1959, B. J. Service, Long Beach, California, page 9) to fill a 650 foot height of annulus between 5½ inch outside diameter casing and a 7⅞ inch diameter hole, by the process of this invention will fill only from 525 to 570 feet of such annulus. Also, a cement log of a 3,100 foot deep well cemented to a total height of 2,550 feet with spirals according to this invention for the bottom 200 feet of such well showed excellent impermeability for the entire 200 foot zone—i.e., from 3,100 foot depth to 2,900 foot depth—throughout the depth whereat the spirals extended. Although the same cement was used and the same period of setting was provided for, not as good cement was provided up to 2,750 feet and the cementing results were only erratic from 2,750 feet to 2,550 feet of depth.

It is a desirable feature of this invention that the spirals as **61** attached to the casing sections as **53** are preformed reliably and economically. The tail end of each spiral may be cut off or the tail end may be turned in toward the axis of the spiral and tacked down to the pipe as **53**. The lengths of such spirals as needed to cover the length of the casing (less 30 inches at one end and 42 inches at the other end) are butted to each other as at 213 to form a continuous length of spiral along the usual approximately 30 feet length of each casing as **53**.

In the embodiment of the precess above described, with 200 feet of 5½ inch outside diameter casing working in a 7⅞ inch internal diameter hole to knead 200 feet of cement in the annulus as above described, the fifteen horsepower enregy output of the drive engine as **81** is absorbed substantially entirely in the kneading of the



cement in the vicinity of the spiral as **61** because less than one horsepower is required to rotate the same string in the same cement at 50 to 60 r.p.m. when no spirals are thereon. This energy absorption provides a measure of the energy of kneading. As above described, this energy rises to about three times such total energy input before the rotation of the casing and the kneading of the cement is usually stopped according to this process.

In the preferred embodiment a 26" pitch on a 5½" outside diameter casing (a pitch of 56 degrees to the horizontal) provides about 8'4" of spiral for each 10' length of feed rod. This pitch is found most preferable for providing a sufficient downward component of the kneading while providing a sufficient upward component for permitting and encouraging escape of air and gases from the kneaded cement.

By the apparatus and process herein a complete cement layer is provided around casing pipe, and slurry and cement are kept uniformly mixed prior to setting. Further, there is also obtained by this process and apparatus a strong bonding between the cement and the pipe due at least in part to the reentrant angle between the bottom edge of the spiral as **61** and the outer surface of the pipe casing as **53**. There is also a minimizing of any shrinkage effect due to this kneading action and a low permeability in the set product. Furthermore, the pressures otherwise usually needed for high turbulent flow to provide a good mixing of the cement in the annulus as **215** which might rupture a weak formation are avoided according to this process. Also according to this process and apparatus of this invention the turbulence of slurry obtained during cement setting is obtained for the full length of the desired cementing zone as determined by the length of the spiral and is not limited to the vicinity of the casing shoe alone, and, according to this invention, such spirals are sufficiently inexpensive and reliably made that they may be applied over the very extensive length of well hole to be cemented. Further according to the process and apparatus of this invention air and gases which are drawn into the pipe during the cementing operation or gas which enters the cement as by contamination from well hole liquids and gases is reliably released; thereby this process avoids channeling due to gas absorption below the surface as well as from gas absorption at the relatively low surface temperatures and release of that gas at the higher sub-surface and cement setting temperatures.

While not limiting my invention to the explanation hereinbelow the following is given to set out what I currently believe to be the theory of operation of the device as provided by the structure apparatus operation hereinabove recited. The substantial improvement in the cementing product appears due to a tamping and trowelling action. This action is obtained notwithstanding the limited volume available between the outer diameter of the tubing and the inner diameter of the well hole (e.g. only 0.17 cubic feet per linear foot between a 5½ inch O.D. casing and a 7⅞ inch I.D. hole). The pressure exerted on the concrete being set and used as a cementing material in annulus **215** is due to that a substantial proportion of the very high weight of the casing—about 50,000 pounds in a conventional 5½ inch seventeen pound tubing—bears on the spirals when they rotate. Because these spirals are firmly attached to the casing the weight of the casing is transmitted through those spirals to the cement. This very heavy pressure and motion of the spirals kneads the cement and thereby expresses therefrom the air which otherwise causes channeling on setting of said cement. For the purpose of accomplishing this kneading action which removes the air the spirals should be sufficiently firmly attached to the casing and rigid, as herein, to bear the weight of the casing in order to transfer such weight to the cement. The fastening of the spiral to the casing according to this invention does not interfere with the strength of the

tubing. As above described the strength of attachment of the spirals to the tubing is as great as the strength of the tubing itself. Accordingly, there is provided an apparatus to accomplish this forceful kneading. This transfer of pressure through the tubing which is conventionally worked very close to its limit of strength is accomplished in such a manner—inasmuch as the spirals are preformed—that there is not additional mechanical strain put on the tubing.

As shown in FIGURE 1 the surface pipe **49** is provided with a right hand spiral **50** thereabout. This also made of ⅝ inch rod as above described and firmly attached each 180° to the pipe by a 3 inch weld, as **219**. This right hand spiral **50** serves to draw the section downward through the earth on right hand rotation and facilitate its location. Such right hand spirals are readily made by the apparatus and process above described and are readily attached to surface string pipe welding as at **221, 222, 223** as described herein for attachment of the tubing **61** to the production string pipe length **51**.

The composition of cement **66** in annulus **215** is controlled by use of conventional retarders, such as starch, borox, and sugar to permit kneading until all the gases in the cement slurry are kneaded or otherwise expressed from that slurry. In an exemplary and preferred embodiment above described a 200 foot length of 5½ inch outside diameter tubing with spirals thereabout in a 7⅞ inch internal diameter hole draws 15 horsepower when the height of fresh cement slurry, as **66**, as shown in FIG. 1, is as high as the top of the highest spiral, as **62**, on the string during the kneading operation. This corresponds to an energy input rate of about 0.45 horsepower per cubic foot of annulus. A substantial rate of energy input, such as ¼ horsepower per cubic foot of annulus appears required to effect an energy of kneading adequate to express the air from fresh cement slurry under the conditions of a two to three thousand foot depth of well. The duration of such energy input should be about two hours with a minimum rate of energy input of one-quarter horsepower per cubic foot. The rate of about .45 horsepower per cubic foot of annulus is applied for about one hour at the end of which the viscosity of the cement slurry is doubled over its initial viscosity.

The pitch of the spiral **61** is about 30 degrees for the 5½ inch outside diameter pipe **53** with the spiral **61** thereabout as above described. Such a pitch is adequate to provide effective kneading and also sufficiently sloped to permit the rapid escape of gas which has been expressed from the cement by such kneading.

Although, in accordance with the provision of the patent statutes, particular preferred embodiments of this invention have been described in detail and the principles of the invention have been described in the best mode in which it is now contemplated applying such principles, it will be understood that the constructions shown and described are merely illustrative and that the invention is not limited thereto and, accordingly, alterations and modifications which readily suggest themselves to persons skilled in the art without departing from the true spirit of the disclosure hereinabove are intended to be included in the scope of the annexed claims.

I claim:

**1.** In a process for cementing a well comprising a string of well casing in a well hole in a gas producing formation, the improvement which comprises placing a cementitious liquid mixture between the casing string and the well hole and continuously kneading the cementitious liquid mixture after it is in place in the space between the casing and the well hole prior to the setting of said mixture by rotating said casing and transmitting weight of the casing by kneading means attached to said casing, to each portion of said cementitious liquid mixture immediately adjacent the casing and moving the said portions of kneaded cementitious liquid mixture from



adjacent said kneading means in an unobstructed path outward from said casing toward said wall and back inward to said casing, releasing gas from said cementitious liquid and passing all said released gas upward in said space, and the said kneading is performed by a series of solid rigid laterally extending imperforate spiral extensions, firmly attached to a portion of said well casing and said spiral extensions each extending laterally of the casing with a pitch that is at the same angle to the axis of the well casing, whereby the kneading action is similar throughout said liquid during said rotation and the rotation of said extensions in said cementitious liquid prior to its setting is in the direction in which all said extensions present a similarly downwardly facing imperforate surface, and said extensions reach less than the full distance from the outside surface of the casing to the internal diameter of the well hole.

**2.** Process as in claim **1** wherein the kneading is continued until the cementitious liquid has thickened to at least twice its initial viscosity and the pressure differential to which the cementitious liquid is subjected during such rotation is between 33 and 67 p.s.i., across said kneading means.

**3.** Process as in claim **1** wherein the extensions each operate over a length of well casing that is continuous through the major portion of each length of well casing forming said string of well casing, and the attachment of said elements to said casing bears a major portion of the weight of said casing string during said rotation of said casing and said extensions.

**4.** Process as in claim **1** where the energy input rate is no less than ¼ H.P. per cubic foot of annulus.

**5.** Process as in claim **4** where the kneading is accomplished with an energy input rate of about ½ H.P. per cubic foot of annulus whereby a zone of maximum temperature and pressure differential is created adjacent said extensions, and said cementitious liquid in said annulus is continuously circulated through said zone prior to its setting.

**6.** Apparatus for oil well cementing in a well hole comprising, in combination, a string of oil well casing lengths in said well hole, said string comprising a series of lengths of imperforate casing joined by expanded joints of greater outer diameter than the diameter of said casing lengths, space between said casing and said hole, preformed rigid, solid spiral rods, each having, as seen from above, a counterclockwise downward path of generation and extending more laterally from said casing than said joints, each said spiral rod being firmly attached at spaced apart points to each of a plurality of said lengths and extending laterally therefrom to a peripheral surface thereof, there being a space between said well hole and said peripheral surface of said solid spiral rods, and means at the surface connected to said string for rotating said string opposite to the direction of rotation of the downward path of generation of said spiral.

**7.** An apparatus for oil well cementing in a well hole comprising, in combination, a string of imperforate oil well pipe lengths in said well hole, said string comprising a series of lengths of pipe joined in sequence by intermediate collars, said collars having a greater outer diameter than the diameter of said pipe length, preformed rigid, solid spiral rods each having, as seen from above, a counterclockwise downward path of generation and the same angle of pitch relative to the length of each said pipes, each said spiral rod being firmly attached at spaced apart points to and reinforcing each of a plurality of said imperforate lengths and extending more laterally therefrom than said collars, there being a space between the interior of said well hole and each said spiral rod, said spiral rods each being firmly attached to a pipe length at 180° intervals, the strength of the attachment between each of said lengths and each of said spiral rods being as great as the strength of said length, means at the surface connected to said string for rotating said string in a direction

opposite to the direction of rotation of the downward path of generation of said spiral, and means for adding cement into said string and into said space between said string and said hole during rotation of said string.


**References Cited by the Examiner**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 220,572 | 10/79 | Burgess | 166—242 X |
| 1,355,368 | 10/20 | Underwood | 29—193 |
| 1,358,938 | 11/20 | Danglemeyer | 153—67 |
| 1,460,632 | 7/23 | Wigle et al. | 166—241 |
| 1,807,050 | 5/31 | Stolz | 166—21 |
| 1,959,367 | 5/34 | Kennedye | 308—4 |
| 1,959,368 | 5/34 | Kennedye | 166—21 |
| 2,191,189 | 2/40 | Wade | 29—193 |
| 2,284,969 | 6/42 | Adkinson | 166—21 X |
| 2,325,462 | 7/43 | Arthur | 153—67 |
| 2,675,082 | 4/54 | Hall | 166—21 |





| | | | |
|---|---|---|---|
| 2,868,299 | 1/59 | Gist | 166—173 |
| 3,087,550 | 4/63 | Tyrrell | 166—241 X |

OTHER REFERENCES

Mills: "Rotating While Cementing Proves Economical," The Oil Weekly, December 4, 1939, pages 14 and 15 relied upon.

Composite Catalog of Oil Field and Pipe Line Equipment, 21st Edition, (1955–56), volume 2, Gulf Publishing Company, Houston, Texas, pages 3642 and 3643.

Uren: Petroleum Production Engineering (Development) Fourth Edition, 1956, McGraw-Hill Book Company, Inc. page 388.

Holt et al.: "Rod Welded to Casing Helps Cementing," World Oil, July 1964, pages 97 and 98.



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