This invention relates to well methods and apparatus and, more particularly, pertains to new and improved methods and apparatus for carrying out cementing operations in wells. Although the invention may find application in many environments, it is ideally suited for use in connection with oil or gas wells that have been permanently completed.

In a permanent-type well completion, once the tubing and packer have been set within the well casing and the well head assembly connected, they remain in place during the productive life of the well. Thus, all subsequent workover operations must be carried out by tools adapted to be passed through the tubing at the end of a wire line.

Very often a workover operation entails the forcing of cement through holes in a selected zone of the casing. Specifically, in some cases where the well casing has upper and lower perforated zones, it may be necessary to squeeze-off the upper zone. Squeeze cementing techniques have been proposed for permanently completed wells, but these methods can only be used for the very lowermost zone of casing perforations. Moreover, although squeeze cements of various types have been employed for performing cementing operations at selected depths, such prior devices were intended for use in workover operations wherein the tubing is withdrawn from the well. Thus, these devices are too large to be passed through the tubing of a permanently completed well.

It is an object of the present invention, therefore, to provide new and improved well methods and apparatus for carrying out cementing operations in a permanently completed well.

Another object of the present invention is to provide new and improved cementing apparatus for use in cementing an upper zone of perforations in well casing containing upper and lower zones of perforations.

The present invention is adapted for association with a system of well completion wherein a tubular member extends from a point above to a point below a perforated zone of well casing to be treated. In accordance with the invention, the annulus defined by the tubular member and the casing is closed to fluid flow in the vicinity of the lowermost of the aforesaid points and a cementitious material in liquid form is introduced to the annulus above the closed section thereof in an amount sufficient to be co-extensive with the perforated zone. Thereafter, the upper end of the tubular member is closed to fluid flow and fluid pressure is applied essentially simultaneously to the upper surface of the cementitious material and to any liquid in the annulus below the closed section of the annulus. The pressure is controlled so as to force cement into the perforations and, finally, excess cementitious material may be removed from the annulus and the tubular member.

Cementing apparatus embodying the present invention comprises a tubular member adapted to be positioned within well casing so as to extend from a point above to a point below a perforated zone of the casing. A packer is supported at the lower end of the tubular member and is movable between retracted and extended positions. In its retracted position the maximum lateral dimension is smaller than the tubing within the well and in its extended position the packer closes the annulus between the casing and the tubular member to fluid flow. The apparatus further comprises means defining a conduit extending from a section of the tubular member below the packer to a section above the perforated zone of the casing.

The novel features of the present invention are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which Figs. 1 and 2 are views in longitudinal cross section of upper and lower sections, respectively, of a cementing tool embodying the present invention shown in operative association with a permanent-type well completion apparatus; Fig. 3 is an enlargement of a portion of Fig. 2 enclosed by broken-line rectangle.

As shown in Fig. 1 of the drawing, the permanent-type well completion apparatus includes a string of tubing 10 permanently set in, and extending through, well casing 11. Although not illustrated, it is to be understood that tubing 10 and casing 11 extend to the surface of the earth where they are connected to conventional well head equipment.

Tubing 10 is coupled to an extension hanger landing nipple 12, in turn, coupled to an offset type mandrel 13 provided with a pocket 14 receiving a retrieving valve device 15. The valve 15 may be of known construction, such as employed in gas-lift systems, as, for instance, the type described on pages 995 and 996 of the Composite Catalog, 20th edition (1954-55), published by The Gulf Publishing Co. of Houston, Texas. Such a valve may be operable by wire line tools selectively to establish fluid communication between the inner bore of mandrel 13 (and tubing 10) and the annulus between the tubing and casing via ports 16 and 17. A tubing section 18 connects the lower end of mandrel 13 to an end bell 19 (Fig. 2), and a production packer 20 seals the annulus between casing 11 and tubing 18 to fluid flow.

Below the level of end bell 19, casing 11 is provided with upper and lower perforated zones A and B. The methods and apparatus for cementing in accordance with the present invention may be employed for plugging the perforations of zone A.

A retrievable cementing tool 21 embodying the present invention is shown in an operative position relative to tubing 10 and casing 11. To maintain the tool in this position, it is provided with a tubing hanger 22 adapted to seat in landing nipple 12 where it is appropriately sealed to fluid flow. A fishing head 23 extends up from hanger 22 and the lower end of the hanger is coupled to a tubular member or tubing extension 24 having an outer diameter smaller than the inner diameter of mandrel 13 and tubing section 18. Extension 24 is of sufficient length so that it extends downwardly through mandrel 13 and tubing section 18, passing out of end bell 19 and extending below perforated zone A. Thus, tubular member 24 extends from a point above to a point below perforated zone A.

The upper end of tool 21 including hanger 22 and fishing head 23 is hollow to define a bore 25 which fluidly connects tubing extension 24 with tubing string 10. The
lower end of extension 24 is closed by a plug 26. A coaxial tube 27 having an inner diameter slightly larger than the outer diameter of tubing extension 24 is appropriately supported as, for instance, by a group of equally spaced studs or screws 27a at the top and a similar group of equally spaced studs or screws 27b at the bottom, so that it extends between the above defined points above and below perforated zone A, the annulus between tubular members 24 and 27 being maintained open to fluid flow.

Supported at the lower end of tubing extension 24 is an umbrella-type packer 28 having a flexible cup-shaped sealing element 29 positioned with its concave side facing in an upward direction. A central portion of sealing element 29 has an opening which receives the lower end of tube 27 and defines a cylindrical extension 30 that is sealed to the tube by means of a ring clamp or strap 31. The ends 31a, 31b of clamp 31 are fastened together by a frangible bolt 32 having its head 32a positioned within tubing extension 24. As best seen in Fig. 3, the bolt extends through aligned openings in tube 24, a spacer 32b, tube 27 and ends 31a and 31b of strap 31, and a nut 32c is tightened onto the free end of the bolt. Thus, for reasons to be more apparent hereinafter, an appropriate tool may be lowered through tubing 27 and extension 24 and employed to break bolt 32 and release clamp 31.

The outer periphery of sealing member 29 is pivotally connected at spaced points to the ends of a plurality of linkages 33 whose remaining ends are pivotally connected to a collar 34. The collar 34 is slidably supported on tube 27 and a helical tension spring 35 has one end connected to the collar and the remaining end connected to bolt 32. Thus, the collar 34 is biased in a downward direction tending to open the packer 28. However, when tool 21 is within tubing 10, the packer is maintained in a retracted position illustrated in dash outline designated 28'. In this retracted position of the packer, its largest lateral dimension is smaller than the inner dimensions of all the members through which it must pass.

In order to provide a cement outlet from the inner bore of tubing extension 24 to the space above packer 28, a plurality of short tubes 36 are fitted into aligned openings in tubular members 24 and 27. The tubes 36 are appropriately sealed to the openings in the tubular members and are arranged so as not to interrupt the fluid path in the annulus between the tubular members.

To prepare the well for a cementing operation, liquids in the well are replaced by a suitable conditioning liquid, such as salt water, whose properties are appropriately adjusted in a known manner, and valve 15 is opened. Thereafter, cementing apparatus 21 is lowered through tubing 10 from the surface of the earth by means of a wire line (not shown). While the apparatus 21 passes through the tubing, packer 28 is maintained in a retracted condition denoted by the dash outline 28'. As soon as the packer passes out of end bell 19, spring 35 causes it to move to its extended position, as illustrated in full outline. Dowardward movement of tool 21 ceases when hanger 22 seats in landing 12 and since the packer is extended, the annulus between casing 11 and tubular member 27 is closed to fluid flow in a section just below perforated zone A.

An appropriate cementitious liquid is liquid form is then pumped into the end of tubing 10 at the surface of the earth; for example, a mixture Portland cement, bentonite and calcium lignosulfonate may be used. The liquid cement or slurry passes down tubing 10, through bore 25, tubing extension 24, tubes 36 and into the annulus between casing 11 and tube 27. Conditioned fluid course, traverses the foregoing path as it is replaced by the cementitious material and continues up through the annulus between tubing section 18 and tube 24, through valve 15 and through the annulus between casing 11 and tubing 10. The amount of cement employed is determined in a known manner so that cement is coextensive with perforated zone A, but is below the upper extremity of tube 27. For instance, the upper surface of the cement may be at the level denoted by a horizontal broken line L. The upper end of tubing 10 is then closed and fluid pressure is applied to the conditioning fluid, i.e., salt water, at the upper end of the annulus between casing 11 and tubing 10. Since the well is filled with conditioning fluid liquid, and since valve 15 is open, this pressure is applied to the annulus between casing 11 and tubing extension 24. Thus, fluid pressure is applied to the upper surface of the liquid cement. Moreover, since a fluid communication path is provided by the annulus between tubing extension 24 and tube 27, essentially simultaneously, fluid pressure is applied to the conditioning liquid below the sealing element 29 of packer 28. Accordingly, although squeeze pressures on the order of one to two thousand pounds per square inch may be employed, sealing element 29 is pressure equalized and it does not bear any undue stresses.

The squeeze pressure is controlled in a known manner so that there is enough time for trapped salt water and additional fresh water from dehydrating cement to be absorbed by the earth formations behind zone A without fracturing of the formation. Thereafter, the upper end of tubing 10 is opened and excess cement may be removed by reverse circulation by pumping salt water into the annulus between tubing 10 and casing 11, thus forcing the cement cement through tubes 36 and thence up through tubing extension 24, bore 25 and tubing 10 to the surface.

To remove cementing apparatus 21 from the well, an appropriate tool is lowered through tubing 10, bore 25 and extension 24, and by a jarring action bolt 32 is broken. Thus, clamp 29 is released and packer 28 becomes longitudinally movable relative to tube 27. Accordingly, a fishing head having appropriate releasing fingers for disengaging the latches of hanger 22 may be employed to raise cementing apparatus 21; however, packer 28 remains within casing 11. Thereafter, a jarring tool may be employed to force the packer to the bottom of the well and the well may be set up to produce through the perforations of zone B.

It is therefore evident that the cementing methods and apparatus embodying the present invention may be used to cement the upper zone of perforations in a permanently cemented well wherein there are bore holes in lower perforated zones. Since pressure equalization is provided for the sealing member of the packer, the sealing member carries only the weight of the cement slurry and all the component parts of the packer bear relatively light loads. This is in contrast to the heavy loads imposed on packers exposed to squeeze pressures in prior cementing operations. Consequently, apparatus constructed in accordance with the present invention may be easily made small enough to pass through well tubing which may be on the order of two inches in diameter and yet cementing operations may be carried out reliably and efficiently.

In some applications the formations behind perforated zone B may produce a considerable water loss when squeeze pressure is applied. Where this is anticipated, or found by test, a water-loss-reducing gel of known composition may be used to fill the portion of the well from its bottom to a point just above zone B. Although an expandable packer similar to that illustrated, other suitable retrievable types may be employed. Furthermore, the fluid communication path provided by the annulus between members 24 and 27 may be arranged in other suitable ways which will be readily apparent to those skilled in the art. While a particular embodiment of the present invention has been shown and described, it is apparent that changes and modifications may be made without depart-
from this invention in its broader aspects. Therefore, it is the aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. A method for treating a perforated zone of the casing of a well through which a tubular member extends from a point above to a point below the perforated zone which comprises the steps of: closing the annulus defined by the tubular member and the casing to fluid flow in the vicinity of said point below the perforated zone; introducing a cementitious material in liquid form to said annulus above the closed section thereof in an amount sufficient to be coextensive with the perforated zone; closing the upper end of the tubular member to fluid flow; applying a first fluid pressure to the upper surface of said cementitious material essentially simultaneously applying a second fluid pressure having the same value as said first fluid pressure to any liquid in said annulus below the closed section thereof so as to act upwardly against the lower surface of said cementitious material, said first and second fluid pressures cooperating to force the cementitious material into the openings in the perforated zone.

2. A method for treating a perforated zone of the casing of a well through which tubing extends to a position above the perforated zone which comprises the steps of: lowering a tubular member through the tubing to a position so as to extend from a point above to a point below the perforated zone; closing the annulus defined by said tubular member and the casing to fluid flow in the vicinity of said point below the perforated zone; introducing a cementitious material in liquid form to said annulus above the closed section thereof in an amount sufficient to be coextensive with the perforated zone; closing the upper end of said tubular member to fluid flow; applying a fluid pressure to the upper surface of said cementitious material essentially simultaneously applying said fluid pressure to any liquid in said annulus below the closed section thereof so as to act upwardly against the lower surface of said cementitious material to force said cementitious material into the openings in the perforated zone.

3. Apparatus for use in a well provided with casing having a perforated zone and with tubing extending through the casing to a position above the perforated zone comprising a tubular member adapted to be passed through the tubing and positioned within the casing so as to extend from a point above to a point below the perforated zone and having fluid passage means providing a fluid communication path through the wall thereof; a single umbrella-type packer supported below said fluid passage means at the lower end of said tubular member and adapted to be maintained in a retracted position wherein the maximum lateral dimension thereof is smaller than the inner dimension of the tubing thereby to permit passage of said packer through the tubing; spring means for moving said packer upwardly; and said packer adapted to be maintained in a retracted position wherein the maximum lateral dimension thereof is smaller than the inner dimension of the tubing thereby to permit passage of said packer through the tubing.

4. Cementing apparatus for use in a well provided with casing having a perforated zone and with tubing extending through the casing to a position above the perforated zone, said apparatus comprising: a first, hollow, cylindri-
cal member adapted to be passed through the tubing and positioned within the casing so as to extend from a point above to a point below the perforated zone; a second, hollow, cylindrical member having an inner diameter larger than the outer diameter of said first, hollow, cylindrical member supported in concentric relationship thereto and extending between said points above and below the perforated zone to define a fluid communication path between said points; a packer supported at the lower end of said second, hollow, cylindrical member and adapted to be maintained in a retracted position wherein the maximum lateral dimension thereof is smaller than the inner dimension of the tubing, thereby to permit passage of said packer through the tubing; means for moving said packer from said retracted position to an extended position closing the annulus between the casing and said second, hollow cylindrical member to fluid flow at a location above said lower point, but below the perforated zone; and means defining a fluid communication path between the interior of said first, hollow, cylindrical member and the exterior surface of the lower portion of said second, hollow, cylindrical member.

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