

March 13, 1962

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3,024,843

SETTING TOOL - PROPELLANT OPERATED

Filed July 22, 1957

4 Sheets-Sheet 1

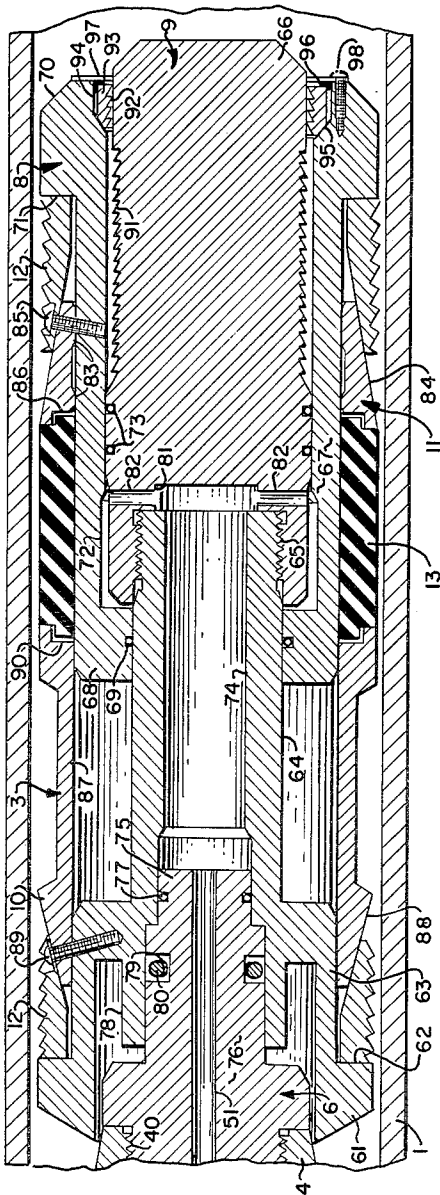


Fig 1a

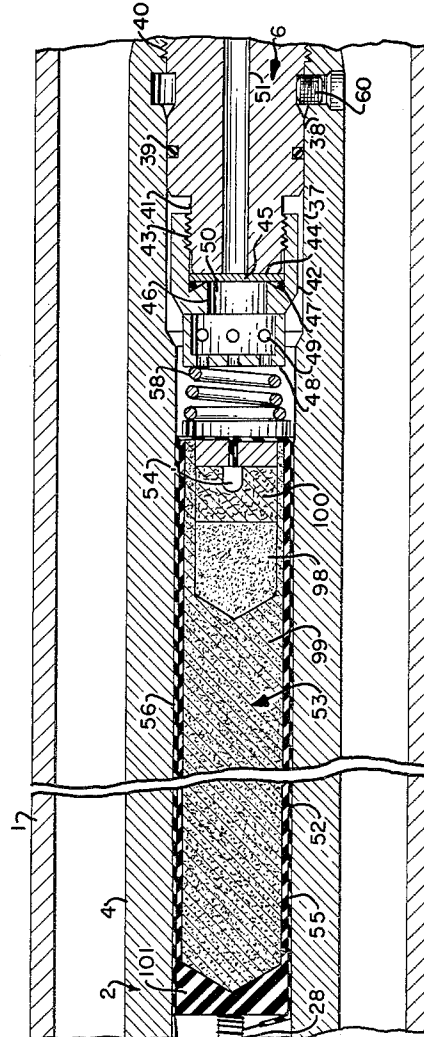


Fig 1b

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4 Sheets-Sheet 2

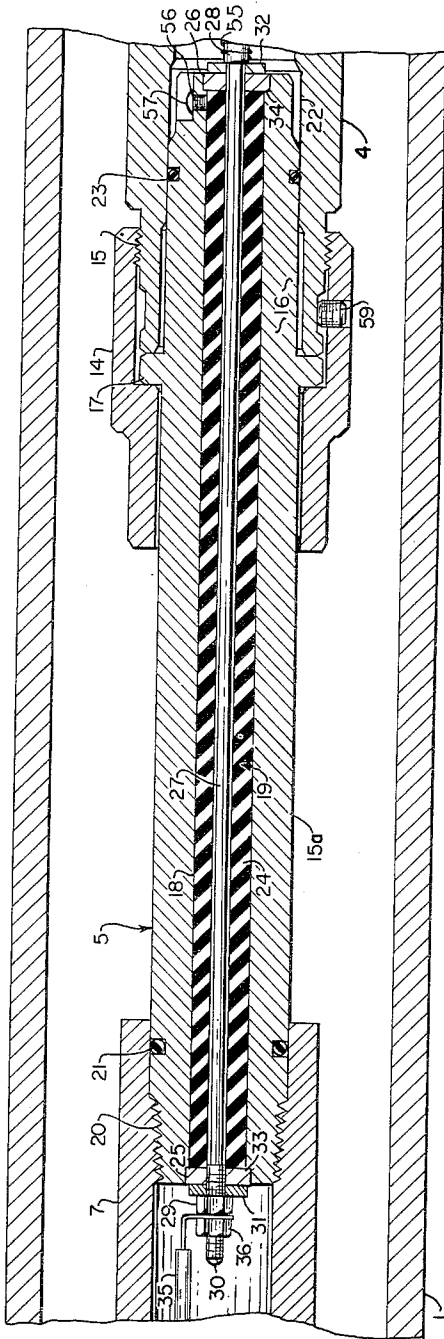


Fig 1c

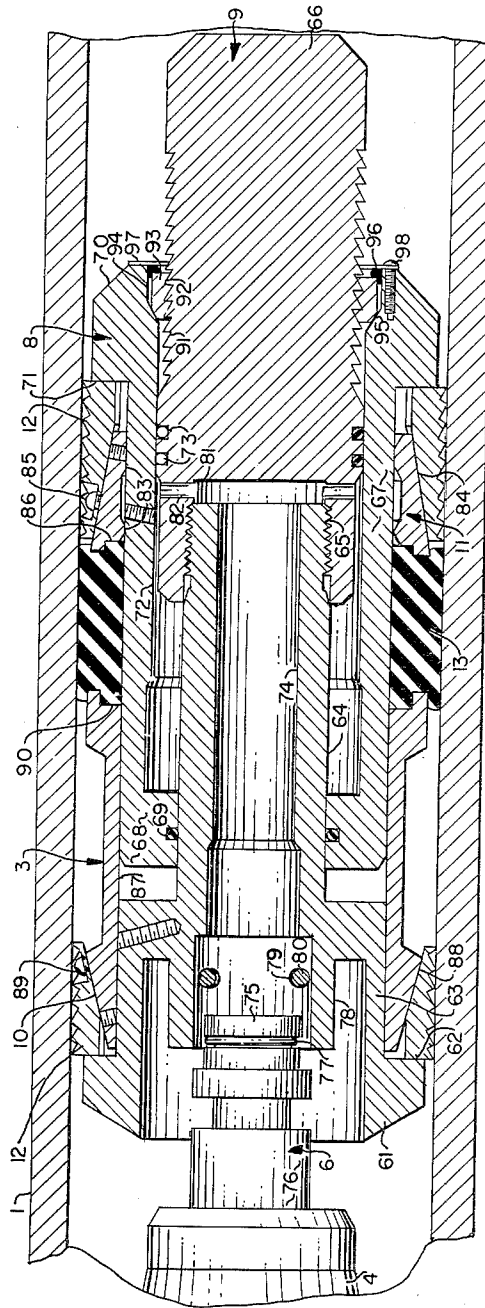


Fig 2

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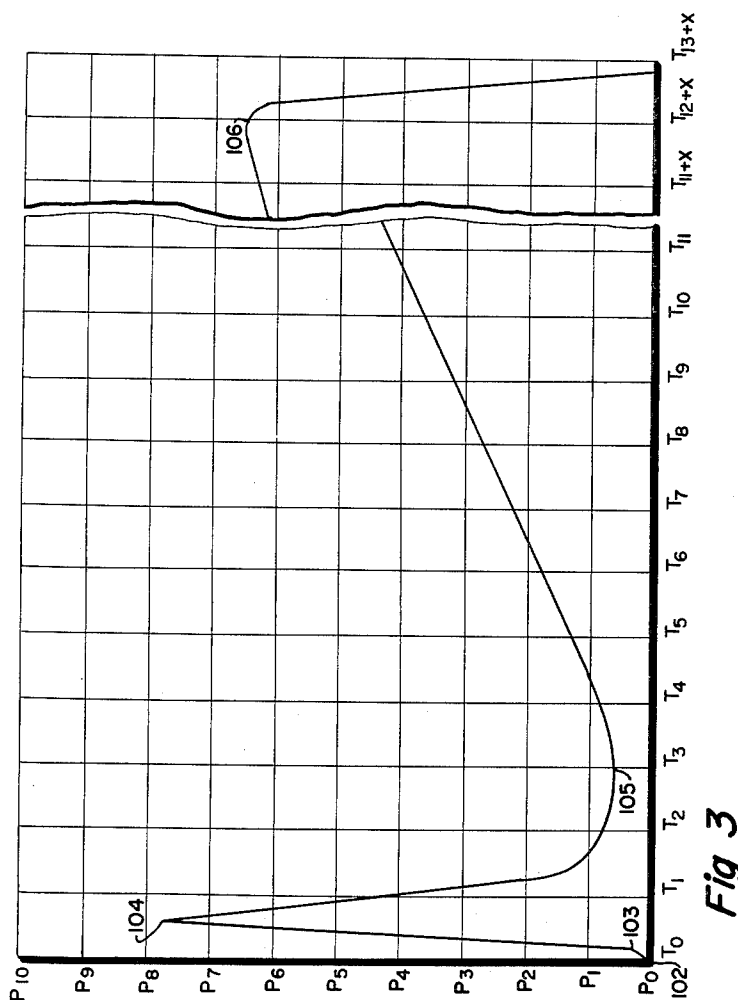
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SETTING TOOL - PROPELLANT OPERATED

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4 Sheets-Sheet 3



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4 Sheets-Sheet 4

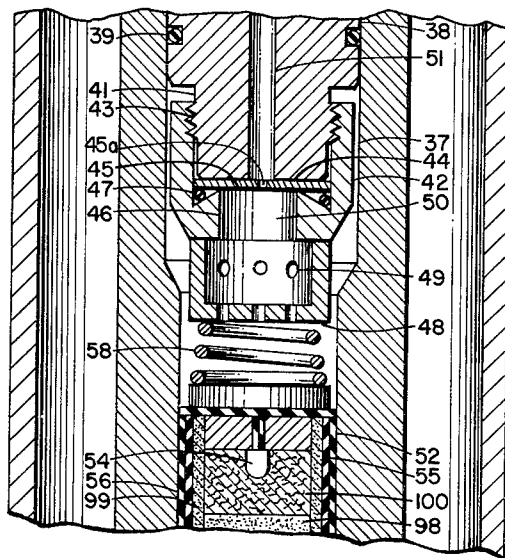


Fig 4

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SETTING TOOL—PROPELLANT OPERATED

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Filed July 22, 1957, Ser. No. 673,260

9 Claims. (Cl. 166—63)

This invention relates to oil well bridging plugs of the type which are run into a well on a wire line and are "set" (locked in position and expanded) by means of high pressure gas generated by the burning of propellants in a closed chamber. Such devices are well known in the art.

The invention described herein is a modification of the inventions described and illustrated in my copending patent applications filed simultaneously herewith Serial Nos. 673,298, 673,339 and 673,340.

Heretofore it has been attempted to "set" bridging plugs of the foregoing type in either of two ways: (1) by the sudden application of pressure generated by the rapid burning of "gun powder or other explosive material," as described in U.S. Patent No. 2,189,937 issued February 13, 1940, to O. T. Broyles, or (2) by the slower application of pressure generated by the relatively slow burning of propellants such as the "rocket fuels" described in U.S. Patent No. 2,640,547 issued June 2, 1953, to R. C. Baker and Thomas M. Ragan.

Both of the foregoing methods are subject to operating disadvantages. With fast burning propellants of the gun powder type, the mechanical parts of the packer expanding assembly may be actuated so rapidly that the packer elements are not properly expanded and locked, with the result that the packer will not seal against a differential pressure across the packer element. With slow burning propellants of the rocket fuel type, the burning rate is sometimes so slow that, due to heat dissipation within the tool, insufficient pressure is generated to "set" the tool. This latter trouble occurs particularly when the back pressure in the well, against which the tool is operating, is low, as would be the case in shallow wells or in wells having a low fluid level.

The terms "slow-burning" and "fast-burning" as applied to propellants of the type in question usually refer to burning rates expressed in inches per second at atmospheric pressure (14.7 p.s.i.) or at some designated pressure such as 1000 p.s.i. The burning rates for propellants usually increase as the pressure in the combustion chamber increases. At extremely high chamber pressures, on the order of 20,000 p.s.i. to 50,000 p.s.i., the burning rates for most "slow-burning" propellants may become so rapid as to approach a detonation. Thus it may be said that there are no "slow-burning" propellants at such high chamber pressures. It has been found that some propellants which burn slowly at low pressures (for example: 0.08 inch per second at 1000 p.s.i.) burn so slowly at atmospheric pressure that they merely smolder. The rate of dissipation of heat from such propellants, when burned in a conventional chamber, is so rapid as to prevent a pressure build up sufficiently to maintain an adequate burning rate, that is, a burning rate which will maintain a gas pressure in the chamber sufficient to operate the device in question. In some instances the propellant may become extinguished. Slow-burning propellants of the type in question are disclosed in patent application Serial No. 109,409, assigned to the same assignee as in the present application.

In the operation of a telescopic wire-line bridging plug of the general type to which this invention relates, it is desirable that the operating cycle extend over a period of time of several seconds, preferable on the order

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of 10 seconds to 30 seconds, or more. Propellants of the gun powder type are consumed in considerably less than one second and are not suitable for use without modification. Propellants of the slow-burning type, on the other hand, burn too slowly at pressures below the required operating pressure, which may be on the order of 10,000 to 50,000 p.s.i.

Since the propellants which may be used to raise the initial pressure and temperature in the combustion chamber are of the extremely rapid burning type, being entirely consumed in less than one second, and since it may require several seconds to establish a satisfactory burning rate for the slow-burning propellant, it is obvious that a sudden pressure drop, following the consumption of the rapid-burning propellant, may result in extinction of the slow-burning propellant before it has reached a satisfactory self-sustaining burning rate.

In order to prevent the extinction of the slow-burning propellant, or slowing down its burning rate below a useful rate, it is desirable to establish an initial pressure in the combustion chamber which is substantially higher than the normal burning pressure and may be higher than the final operating pressure. This arrangement permits the use of a minimum amount of propellant for operating the tool, in which space is at a premium. By raising the initial pressure well above the operating pressure, the slow-burning propellant is caused to start burning at an initially high rate, so that the subsequent loss of heat (due to the reduced burning time) is held to a minimum. Thus a minimum amount of propellant will be required in order to produce the gas volume needed to perform the work in question.

A combined statement of Charles' and Boyle's law, while derived for an ideal gas, is sufficiently accurate for actual gases for most engineering purposes, and may be expressed as:

$$p_t v_t = p_0 v_0 \left(1 + \frac{t}{273} \right)$$

p_t is the pressure at final temperature
 v_t is the volume at the final temperature
 p_0 is the pressure at 0° C.
 v_0 is the volume at 0° C.
 t is the final temperature in °C.

Because of the very high initial pressure of the gases within the bridging plugs of the type shown in my copending patent applications Serial Nos. 673,298, 673,339 and 673,340, it is necessary that the bodies of the packers be provided with relatively thick walls in order to withstand these pressures. In some instances, particularly in the case of packers for use in well casings having relatively small diameters, it is difficult to provide sufficient wall thickness, in the space available, to withstand these pressures.

It is an object of the present invention to provide a separate tool for setting the packer, which tool can be made with walls thick enough to withstand the very high initial gas pressures without exceeding the permissible diameter thereof.

It is an object of the present invention to provide a bridging plug design and a propellant formulation which will permit the use of slow-burning propellants under various conditions of use.

Another object of the invention is to provide an arrangement whereby fast-burning propellants are employed to raise the chamber pressure above the pressure at which the slow-burning propellants will burn at their desired rate for proper actuation of a bridging plug.

Another object is to provide, in the propellant combustion chamber, an initial pressure above the normal

burning pressure for the slow-burning propellant in less than one second.

Another object is to provide in less than one second, an initial pressure which is higher than the pressure developed by slow-burning propellant.

Other objects and advantages of the invention will be apparent from the following description and drawings illustrating one embodiment of the invention.

FIGURES 1a, 1b, and 1c are longitudinal cross-sectional views, illustrating one embodiment of the invention in the running-in position, in the well casing, FIGURE 1a commencing from the lower end of the device at the right of the figure to the break at the left, FIGURE 1b showing from the break at the left of FIGURE 1a at the right to the break to the left, and FIGURE 1c showing from the break at the left of FIGURE 1b at the right to the sleeve supporting a part detached from the device when in set position.

FIGURE 2 is an elevation partly in longitudinal cross sectional view illustrating the device of FIGURE 1a in the set position in the well casing.

FIGURE 3 is a pressure-time chart showing a possible gas pressure curve over a period of time the pressures being taken in the combustion chamber.

FIGURE 4 is a longitudinal cross sectional view similar to FIG. 1b and showing an alternative embodiment of the disc 45.

Referring to FIGURES 1a, 1b and 1c the numeral 1 indicates a well casing. Disposed within the well casing 1 and supported by a wire line, not shown, is bridging plug setting tool 2 (FIG. 1b) and a bridging plug 3 (FIG. 1a), in the running-in position.

The setting tool 2 comprises four major parts which are non-movable in relation to each other. These parts are: means which provide a combustion chamber 4 (FIG. 1b), top plug 5, bottom plug 6 (FIG. 1a) and wire line cable head 7 (FIG. 1c).

The bridging plug 3 comprises six major parts which are movable relative to each other. These parts are: a cylinder 8, a piston 9, a floating sleeve 10, a floating body 11, upper and lower wedge slips 12 and a compressible packer sleeve 13.

The setting tool 2 is provided at its upper end with a reduced diameter to which is connected the union nut 14 (FIG. 1c), by means of the threads 15. The cylindrical top plug 5 is provided with the upper shank 15A, the lower shank 16, the enlarged flange 17, between the upper shank 15A and lower shank 16, the axial hole 18 in which is mounted the insulated electrical connecting device 19. The wire line cable head 7, of a suitable type, details not shown, is attached to the upper end of upper shank 15A by means of the threads 20. A suitable sealing means, such as the O ring 21, is provided to prevent fluid leakage through the threads 20.

The lower shank 16 of the top plug 5, is adapted to fit into the axial bore 22 provided in the combustion chamber means 4. A suitable sealing means, such as the O ring 23, is provided on the lower shank 16, to seal between the exterior surface on the lower shank 16 and the interior surface of the bore 22.

The top plug 5 is attached to the means forming a combustion chamber 4 by means of its enlarged flange 17, union nut 14 and the threads 15. The plug 5 may be removed from the means forming a combustion chamber 4 by unscrewing the threads 15.

The electrical connecting device 19, mounted in the annular hole 18 of the top plug 5, consists of the tubular insulating material 24 within the axial hole 18, supported between the insulating-sealing end washers 25 and 26 and retained in place in the top plug 5 by means of the electrical rod 27, the lower enlarged head 28 of the electric rod 27, the nut 29 and the threads 30. The electric rod 27 passes through the axial hole in the tubular insulating material 24, the holes in insulating-sealing washers 25 and 26 and through the holes in support washers 31 and

32. The insulating-sealing washers 25 and 26 are mounted in countersunk bores 33 and 34 provided in the top plug 5. The electrical connecting device 19 seals the axial hole 18 by means of the tubular insulating material 24 and the insulating-sealing end washers 25 and 26 being compressed and expanded between the support washers 31 and 32 by means of the electric rod 27, the enlarged head 28, the nut and the thread 30 to form a sealing unit.

The insulated electric cable 35 is attached to the electric rod 27 by means of the nut 36 and the thread 30. The insulated electric cable 35 may extend to the surface, by any suitable means as now commonly used in the oil fields.

The setting tool 2 is provided at its lower end with the axial bore 37. The bottom plug 6 has the upper extension shank 38 adapted to fit into the axial bore 37 and seal said axial bore 37 by means of a suitable sealing means, such as, the O ring 39. The plug 6 is attached to the combustion chamber means 4 by means of the threads 40. The upper extension shank 38 has at its upper end the reduced tubular portion 41 to which is attached the end cap 42 by means of the threads 43. A disc 45 is placed between the upper surface 44 of the reduced tubular portion 41, of the shank 38 and the lower surface of the inner turned flange 46 of the end cap 42 and retained in place by means of the threads 43. The disc 45 may be sealed by means of suitable packing means, such as the O ring 47. A suitable screen, such as the screen member 48, with screen openings 49, is placed directly above the end cap 42 to prevent the entrance of propellant materials into the axial hole 50 of end cap 42 and the axial hole 51 of the lower end plug 6. The means forming a combustion chamber 4 has the axial bore 52 which communicates between the bores 22 and 37 of combustion chamber 4. A charge of gas generating propellant grain 53 is positioned in the axial bore 52 of the means forming a combustion chamber 4 between the top plug 5 and the bottom plug 6. An electric squib igniter 54 is positioned in the lower end of the propellant grain 53. The insulated lead 55 of the igniter 54 is connected to the enlarged head 28 of the electrical rod 27 and the insulated lead 56 of the igniter 54 is grounded to the top plug 5 by any suitable means, such as the screw 57 (FIG. 1c), to complete the electrical circuit. A resilient means, such as the spring 58, may be used to support the propellant grain 53 above the screen member 48. Locking means, such as the set screws 59 and 60, may be provided to lock the top plug 5 and the bottom plug 6 into place.

The piston 9, of the bridging plug 3, is provided at its upper end with an enlarged head 61, a downwardly facing annular shoulder 62, a tubular body 63 having a downwardly depending tubular shank 64 of still further reduced diameter, to which is connected, as by threads 65, an enlarged piston member 66.

The cylinder 8 is slidably mounted on the shank 64 and piston member 66. To this end, the cylinder 8 is provided with a tubular upper portion 67 which slidably engages the outer surface of the piston member 66 and has an inwardly turned flange 68 at its upper end, slidably engaging the exterior surface of the tubular shank 64. A suitable sealing means, such as an O ring 69, is mounted in the flange 68 in sealing relations with the exterior surface of the tubular shank 64. The lower portion of the cylinder 8 is enlarged as indicated at 70 to provide an upwardly facing annular shoulder 71 which supports the lower wedge slips 12 when in their retracted position, as shown in FIGURE 1A. The interior of cylinder 8, below the flange 68, is enlarged in diameter to form an expansion chamber 72. Sealing means, such as the O rings 73, is positioned in the exterior surface of the piston member 66 in sealing engagement between the walls of the cylinder 8 and the member 66.

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The shank 64 is provided with an axial passageway or chamber 74. The upper end of passageway 74 is closed by a valve member 75, formed on the lower extension shank 76 of the bottom plug 6 of the setting tool 2. A sealing means, such as the O ring 77 is provided on the valve member 75 to engage the upper interior end of the passageway 74. Within the tubular body 63 is the upwardly extending tubular body 78 forming an extension of the shank 64 and the passageway 74. Within the tubular body 63 is the upwardly extending tubular body 78 forming an extension of the shank 64 and the passageway 74. Transverse holes 79 are provided in the tubular body 78 to receive the lower extension shank 76 retaining shear pins 80. The shear pins 80 serve to shearably and slidably connect the setting tool 2 to the bridging plug 3. The upper portion of the piston member 66 is provided with the upper bore portion 81 just below the lower end of the shank 64. The piston member 66 is provided with the holes 82, communicating between the bore portion 64 and the expansion chamber 72.

The floating body 11 is tubular in form with its interior surfaces 83 in slidable engagement with the exterior surfaces of the cylinder 8. The lower portion of the floating body 11 is tapered downwardly and inwardly to form a frusto conical seat 84 for the lower wedge slip 12. The lower wedge slips 12 are normally held in their retracted position, resting upon the shoulder 71, by any suitable means such as the shear pins 85, attached to the cylinder 8.

The upper end of the floating body 11 terminates in an upwardly facing annular shoulder seat 86 which serves as a seat for the lower end of the cylindrical, resilient packer sleeve 13.

The floating sleeve 10 is tubular in form with its interior surface 87 in a slidable engagement with the exterior surface of the tubular body 63 and the exterior surface of the tubular upper portion 67 of the cylinder 8. The upper portion of the floating sleeve 10 is tapered upwardly and inwardly to form a frusto conical seat 88 for the upper wedge slips 12. The upper wedge slips 12 are normally held in their retracted position, against shoulder 62, by any suitable means, such as shear pins 89 attached to the piston 9.

The lower end of the floating sleeve terminates in a downwardly facing annular shoulder seat 90 which serves as a seat for the upper end of the cylindrical resilient packer sleeve 13.

In order to lock the cylinder 8 and the piston 9 in the set position, the outer surface of the piston member 66 is provided with a series of vertically spaced, upwardly facing teeth 91. The teeth 91 are adapted to engage a series of vertically spaced, downwardly facing teeth 92 formed on the inner face of the wedge locks 93 mounted in recess 94 formed in the lower end of the cylinder 8. The bearing wall 95 of the recess 94 is tapered upwardly and inwardly. A compression body, of any suitable material such as an O ring 96, is mounted in the recess 94 between the lower surface of the wedge locks 93 and the upper surface of the retainer plate 97. The retainer plate 97 is attached to the cylinder 8, by any suitable means such as the screws 98.

The cylindrical, resilient packer means 13 is mounted between the shoulder seats 86 and 90 and has its interior surface in slidable engagement with the exterior of the cylinder 8.

Any suitable electrical means, such as a wire line service unit, may be used to initiate combustion of the propellant grain 53 by firing the electric igniter 54. Other means, not described, can be used to ignite the propellant grain 53.

The propellant grain 53 consists of a small amount of fast burning propellant 98 inserted into the lower end of a cylindrical slower burning propellant 99. A quantity of igniter material 100, such as a mixture of

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black powder and magnesium, is placed between the electric squib igniter 54 and the fast burning propellant 98 to assist in ignition of the propellant grain 53. The propellant grain 53 is provided with the external covering 101 to give an end burning slow burning propellant 99.

FIGURE 2 illustrates the bridging plug of FIGURE 1 in a set position in the well casing 1. Upon application of electrical current, from any suitable source, such as a wire line service unit, the electric squib igniter 54 is fired, igniting the igniter material 100 and initiating the burning of propellant 98 and 99.

High pressure gas is generated by the burning, in less than one second, of all of the fast burning propellant 98 and the initial burning of the slow burning propellant 99. The disc 45, as illustrated in FIG. 4, is made of a heat fusible material adapted to melt under temperature to release the high pressure, and be provided with a small orifice 45a, to help in gas expansion and pressure equalization.

The gas pressure generated by the burning of the propellant grain 53 within the internal volume of the setting tool 2 and the bridging plug 3 causes the cylinder 8 to move upwardly on the shank 64 of the piston 9, and in so doing shears the pins 89 and 85, releasing the upper and lower wedge slips 12. Continued upward movement of the cylinder 8 with respect to the piston 9 pushes the floating sleeve 10 and the floating body 11 upwardly. The compressible packer sleeve 13, being restrained between the shoulders 90 and 86, is compressed and expanded laterally until packer sleeve 13 is engaged with the inner wall of the casing 1, as indicated in FIGURE 2. Upward movement of the cylinder 8 in respect to the piston 9, forces the upper and lower wedge slips 12 into contact with the well casing 1 due to movement on the frusto conical seats 88 and 84. Also, at the same time, upward movement of the cylinder 8 in respect to the piston 9 causes the teeth 92 of the wedge lock 93 to engage the teeth 91 of the piston 9 to lock the cylinder 8 against any subsequent downward movement, thus maintaining the packer sleeve 13 in sealing engagement with the well casing 1. Continued buildup of pressure, after pressure equalization described above, within the setting tool 2 and bridging plug 3, will cause the retaining shear pin 80 to shear, releasing the setting tool 2 from the bridging plug 3 and releasing the gas pressure.

The retaining shear pins 80 are sheared out at a much lower pressure than that developed in the disc 45 sealed axial bore 52 combustion chamber during the combustion of the fast burning propellant 98. The disc 45 prevents the premature shearing of the retaining shear pins 80 due to the burning, in less than one second, of all of the fast burning propellant 98.

The expanded packer sleeve 13 together with the expanded upper and lower wedge slips 12 will enable the bridging plug 3 to withstand high differential pressures of several thousands of pounds per square inch in either direction.

The shearing of the retaining shear pins 80 releases the setting tool 2 and the wire line cable head 7 from the bridging plug 3. The wire line head 7 and setting tool 2 may be removed from the well.

FIGURE 3 illustrates a chart that represents the burning of the propellant grain 53 in the setting tool 2, pressures set up in the combustion chamber being indicated in the chart by pressure lines indicated by the capital letter "P" with subscript numbers, such as P_5 . The pressure increases as the subscript number increases. The time lines of the chart are indicated by the capital letter "T" with subscript numbers and subscript numbers plus x. The time interval x has been cut out of the chart. The time interval increases in seconds as the subscript numbers increase. Ten seconds would be T_{10} .

Referring to FIGURE 3, the point 102, on the chart,

is the ignition point or time of the propellant grain 53. The point 103 is the time and pressure point where the fast burning propellant 98 and the slow burning propellant 99 is ignited. The curve developed between the points 102 and 103 may be produced by the igniter 54 and the igniter material 100. The point 104, is the time and pressure point, where the maximum pressure is reached due to the burning of the fast burning propellant 98, in less than one second. The pressure developed between the points 103 and 104 is produced by the burning of the fast burning propellant 98 and a small amount of the slow burning propellant 99. The pressure begins to immediately fall after the point 104 is reached due to shearing-out of the disc 45 and expansion downward into the bridging plug 3. The point 105 is the time and pressure point, where the pressure equalizes in the setting tool 2 and the bridging plug 3. The curve developed between the points 104 and 105 is produced by the equalization of the gas pressure and the burning of a small additional amount of the slow burning propellant 99. The point 106, is the time and pressure point, where the gas develops enough pressure to shear the retaining shear pins 80 and release the pressure from the chambers of the bridging plug 3 and the setting tool 2 into the casing 1. The pressure, developed between the points 105 and 106, is produced by the burning of the slow burning propellant 99 over a time interval ending at T_{12+x} . The time interval can, however, be any time greater than one second. The development beyond the point 106, is produced by the gas escaping into the well casing.

The foregoing description illustrative only of one embodiment of the invention which is not to be limited thereto but is of the scope defined by the appended claims.

I claim:

1. A bridging plug apparatus having a separate setting device comprising: a bridging plug to be set in a well by force generated upon the plug when lowered into a desired position, a setting tool having a chamber therein, a first gas producing propellant material arranged within said setting tool chamber, a second gas producing propellant material having a burning rate faster than said first propellant material arranged within said setting tool chamber, means for igniting said second material arranged within said setting tool chamber, passageway means attached to said setting tool and communicating with said setting tool chamber, said passageway means shearably attached to said bridging plug, means for releasing gas under pressure in excess of the normal pressure generated by the burning of the second propellant material, and said gas releasing means interposed in said passageway means.

2. A device as in claim 1 wherein said means for releasing gas under pressure comprises a disc fabricated of a normally solid material adapted to melt at a predetermined temperature.

3. A device as in claim 1 wherein said means for releasing gas under pressure comprises, a disc fabricated of a normally solid material adapted to melt at a predetermined temperature and having an orifice therein.

4. Apparatus as in claim 1 wherein said ignition means comprises, an electrically energized device and a third

combustible material in ignitable relationship with each other.

5. A well packing apparatus having a separate setting device therefor for use in a well casing comprising: a piston, a cylinder partially closed at one end receiving said piston in telescoping relation, said piston having an enlarged portion extending through said cylinder partially closed end, said cylinder having an enlarged portion, a plurality of wedge slips encompassing and abutting said cylinder and said piston enlarged portions, a packer sleeve encompassing said cylinder and positioned between said wedge slips, a plurality of means for expanding said wedge slips positioned between said sleeve and said slips, means for forming a substantially closed chamber at a remote location from said piston and cylinder, a first gas producing propellant material arranged within said chamber forming means, a second gas producing propellant material arranged in proximate relation to said first burning material within said chamber forming means, means for igniting said first burning material arranged within said chamber forming means, means for releasing gas under pressure in response to the pressure within said chamber forming means in excess of the normal burning pressure of said first burning propellant material, means for conveying gas under pressure from said gas release means to said cylinder, and said gas conveying means attached to said chamber forming means and said cylinder and in communication therewith.

6. A device as in claim 5, and in addition, pressure-actuated shearable means for connecting the setting device to the well packing apparatus, whereby the gas under pressure introduced into said cylinder from said substantially closed chamber means is effective to shear said connecting means from said well packing apparatus after complete operation of the well packing apparatus to enable withdrawal of said setting device from the well casing.

7. A well packing apparatus as defined in claim 5 and in addition a means for locking said piston to said cylinder to prevent movement in one direction, said locking means adding to said piston and said cylinder.

8. A well packing apparatus as defined in claim 5 in which said gas releasing means has an orifice therethrough.

9. A well packing apparatus as defined in claim 5 in which said gas releasing means is made of a fusible material.

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