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(72) Inventeur/Inventor:
ROSS, RICHARD J., US

(73) Propriétaire/Owner:
BAKER HUGHES INCORPORATED, US

(74) Agent: SIM & MCBURNEY

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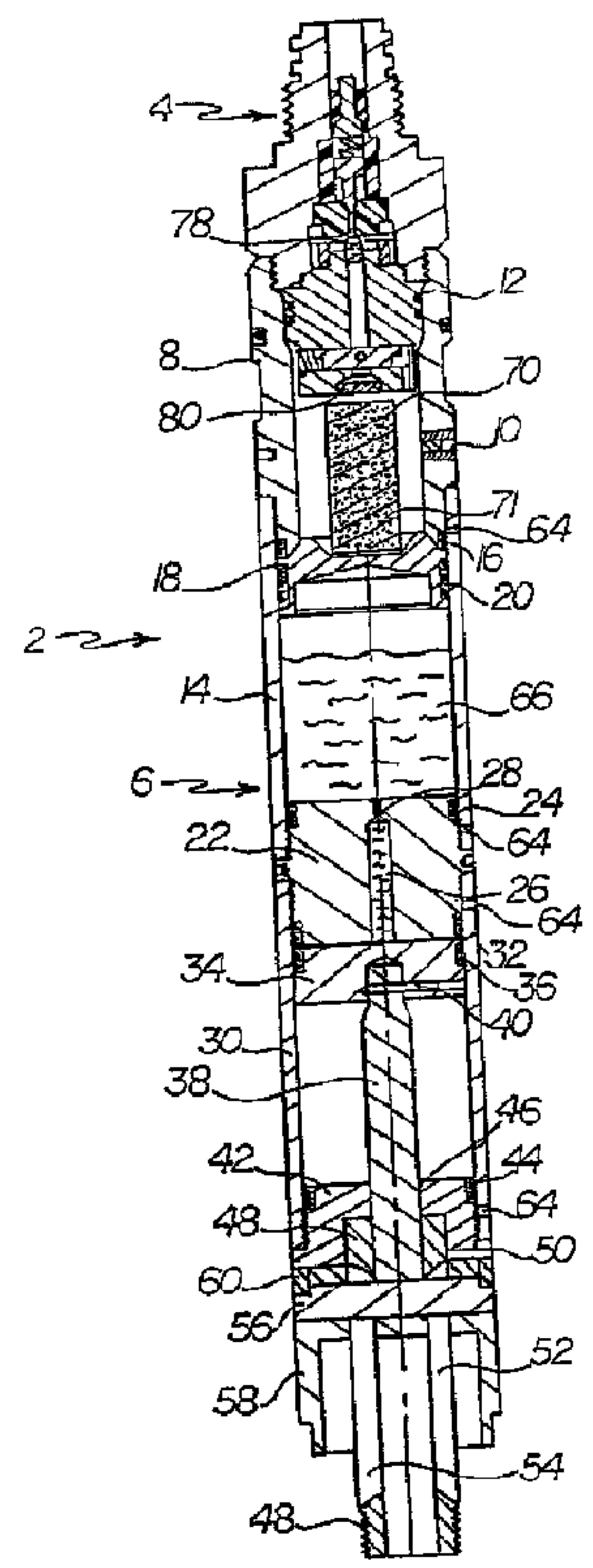

(57) Abrégé/Abstract:
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(71) Applicant: BAKER HUGHES INCORPORATED [US/US]; Suite 1200, 3900 Essex Lane, Houston, TX 77027 (US).

(72) Inventor: ROSS, Richard, J.; 8227 Thetford, Houston, TX 77070 (US).

(74) Agents: DESAI, Umesh, M. et al.; Baker Hughes Incorporated, Suite 1200, 3900 Essex Lane, Houston, TX 77027 (US).

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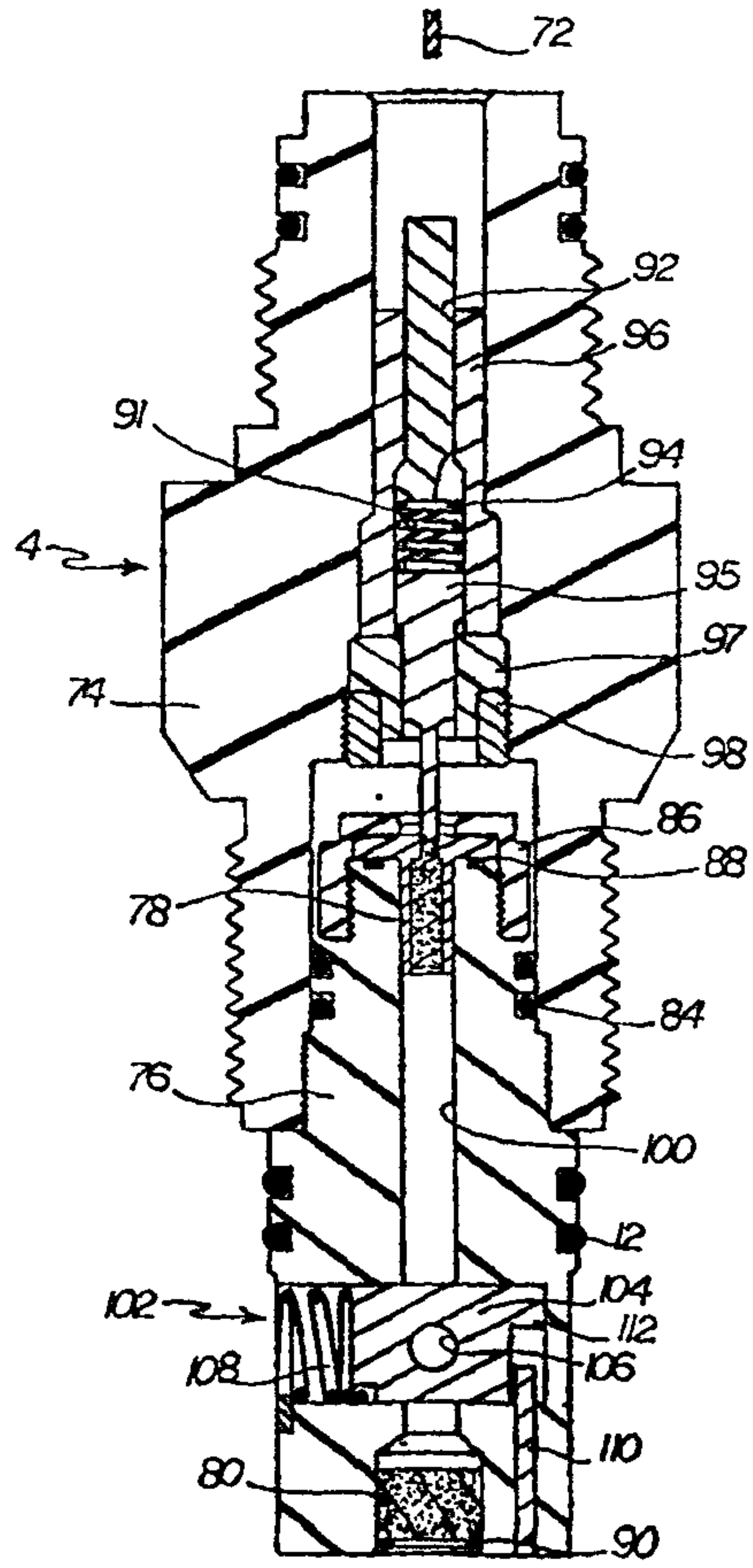

HEAT ACTIVATED BALLISTIC BLOCKER

BACKGROUND OF THE INVENTION

1. Field of the Invention:

This invention relates in general to an apparatus and method for use to provide a downhole well tool which is prevented from actuating until the downhole well tool is positioned downhole within a wellbore, and in particular to a downhole wellbore tool including a wireline pressure setting assembly having a heat activated ballistic blocker which prevents actuation of the wireline pressure setting assembly until after it is lowered downhole within a wellbore.

2. Background of the Invention:

Explosives and other pyrotechnic materials have been used in prior art downhole well tools to provide forces for performing work downhole within wellbores. A few examples of such downhole tools for providing explosive forces include perforating guns, which provide explosive forces for providing fluid flowpaths, squibs, which may be used for releasing mechanically biased members, tubing cutters, which may be used for cutting wellbore tubular members, and back-off shots, which may be utilized for providing shock to loosen threaded pipe joints within wellbores. An example of a downhole tool which is used to apply non-explosive forces is a wireline pressure setting assembly, which may be used for setting bridge plugs and packers within wellbores.

Another example of a prior art downhole well tool which incorporates use of explosives is a cable conveyed bridge plug for setting within a cased wellbore such as that shown in U.S. Patent No. 2,637,402, entitled "Pressure Operated Well Apparatus," invented by R.C. Baker et al., and issued to Baker Oil Tools, Inc. on May 5, 1953. A similar cable conveyed downhole well tool is disclosed in U.S. Patent No. 2,695,064, entitled "Well Packer Apparatus," invented by T.M. Ragan et al., and issued to Baker Oil Tools, Inc. on November 23, 1954. These patents disclose cable conveyed downhole well tools for setting a bridge plug within a wellbore casing. These cable conveyed downhole well tools were actuated by the percussion of a firing pin causing a cartridge to explode and ignite a prior art power cartridge, or combustible charge.

An example of a prior art wireline conveyed well packer apparatus is disclosed in U.S. Patent No. Re. 25,846, entitled "Well Packer Apparatus," invented by D.G. Campbell, and issued to Baker Oil Tools, Inc. on April 31, 1965. The wireline conveyed well packer apparatus disclosed includes a power charge which is ignited to generate gas for setting the well packer apparatus within a wellbore. The power charge is ignited by passing an electric current down the wireline and exploding an igniter cartridge, which causes a flame to ignite the power charge.

An example of a prior art power charge for use in downhole well tools to generate a gas to provide a force for use to set packers and bridge plugs is a combustion charge disclosed in U.S. Patent No. 2,640,547, entitled "Gas-Operated Well Apparatus," invented by R.C. Baker et al., and issued to Baker Oil Tools, Inc. on June 2, 1953. The combustion charge is comprised of combustion materials which, when ignited within a downhole well tool disclosed in the patent, will take at least one second for a maximum pressure to be attained within the downhole well tool. This prior art combustion charge includes both a fuel and a self-contained oxygen source. The combustion charge is ignited to generate a gas having a pressure which provides a force for setting the gas-operated well apparatus. The combustion charge of the gas-operated well apparatus is ignited by exploding an igniter to start the combustion reaction for burning the combustion charge. The combustion charge, once ignited, burns in a self-sustained combustion reaction to generate the gas.

A prior art wireline pressure setting assembly is disclosed in U.S. Patent No. 2,692,023, entitled "Pressure Operated Subsurface Well Apparatus," invented by M.B. Conrad, and issued to Baker Oil Tools, Inc. on October 19, 1954. This wireline conveyed downhole well tool includes a power charge which is burned in a combustion reaction to generate a gas. The power charge is ignited by electrically exploding an igniter cartridge which then emits a flame to start the power charge burning. Combustion of the power charge generates the gas having a pressure which provides force for operation of the wireline setting tool to set a downhole tool such as a packer or bridge plug within the wellbore.

The above prior art downhole well tools for converting the chemical components of a power charge into a mechanical force exerted over a distance typically require a separate igniter cartridge for igniting the power charge. Additionally, other pyrotechnic wellbore devices utilize an igniter, as well as incorporate the igniter and the pyrotechnic device into a singular package. Typically, explosive components are used for prior art igniter materials, such as, for example, gunpowder or lead azide. These types of igniter materials are easily ignited and represent hazards both to operators utilizing these materials in downhole well tools, and to successful completion of wellsite operations. Some of these types of primary ignition or igniter materials are susceptible to ignition from applications of small amounts of electric current, or even discharge of static electricity.

Wellsite operations utilizing prior art downhole well tools which present hazards if operated outside of the wellbore would be safer if prevented from operating until lowered downhole with a wellbore. Such a safety feature would enhance operator safety, as well as promote successful wellsite operations.

The US-A-5,052,489 discloses a safety assembly for selectively actuating well tools. This assembly according to the US-A-5,052,489 comprises blocking barrier members or a release mechanism together with the blocking barrier members. The release mechanism holds a coil spring in compression. A thermally sensitive bonding material secures a stop member in place relative to a shaft. A heating cartridge is used to heat the bonding material. Additionally, a first barrier prevents contact of the firing pin and the primer cartridge, and a second barrier prevents free transmission of explosive forces from the primer explosive to the booster charge. The barriers are formed of a non stable material which is softened, melted, dissolved or disintegrated by the increase in ambient temperature as the tool is lowered in the wellbore. Then, at a predetermined temperature, it is possible for the firing pin to penetrate through the first barrier onto the primer cartridge. Simultaneously, the material of the second barrier drains out of the passage between the primer explosive and the booster charge. In this state, the system is armed and explosion can be ignited by heating the thermally sensitive bonding material up to a predetermined temperature at which this thermally sensitive bonding material loses its bonding property. In this case, the release mechanism releases the firing pin. The firing pin is then pressed through the molten first barrier material toward the primer explosive and causes the primer to explode. The explosive forces are then freely transmitted to the booster charge and ignite the explosion of this booster charge.

If the primer fails and no explosion is ignited after the contact of the firing pin and the primer explosive, it is necessary to return the well tool to the surface. Although in this case, due to temperature lowering, the material of the first barrier resolidifies, now maintaining a part of the firing pin, the material of the second barrier resolidifies not on its previous position. The passage between the primer explosive and the booster charge remains free. So an accidental detonation of the primer in every case will cause the ignition of the booster charge. Due to this reason, the lifting of the well tool out of the wellbore in a case when the primer fails is a very dangerous undertaking for the staff. Only when the well tool is already at the surface again is it possible to close the passage between the primer explosive and the booster charge by manually rotating a rotatably mounted cylindrical spool situated between the primer explosive and the booster charge and including a lateral passage from an armed position into a disarmed position. However, in every case, this spool must be manually returned to the armed position before the well tool is lowered into the wellbore again.

The US-A-5,070,788 discloses another method and apparatus for disarming and arming explosive detonators. The exlosive detonators according to the US-A-5,070,788 use barrier members between a donor charge and a receptor charge whereby these barrier members are formed of a fusible metal alloy which will remain solid until subjected to the elevated temperatures of wellbore fluids. In one preferred embodiment, the explosive detonator has a fusible metal alloy barrier member disposed in an inner chamber to separate donor charge and receptor charge. A coiled actuator made of shape memory metal having a two-way memory actuates to move a displacement member located in an outer chamber. The elevated wellbore temperature heats the coil actuator, which actuates to shift the displacement member. The actuator will actuate when heated to a higher temperature than the temperature required to melt the barrier member. Once displacement member is moved upwards within the outer chamber, the liquified fusible metal alloy of the molten barrier member will discharge through openings into the outer chamber to leave the detonation pathway between the donor charge and the receptor charge unobstructed. Then the detonator is armed for service. When the well tool including this detonator is lifted out of the wellbore again, the two-way memory actuator returns to its previous position thereby actuating the displacement member in the outer chamber to press the liquid metal through the openings between the outer and the inner chamber into the inner chamber where the metal alloy resolidifies, obstructs the detonation pathway between the donor charge and the receptor charge and in such a way disarms the detonator.

The disadvantage of such an arrangement is the danger which rises when the detonator is lifted up too fast. In this case a situation may arise where the displacement member has not enough time to press a sufficient amount of liquid metal alloy into the inner chamber again before the metal alloy resolidifies. Then the pathway between the donor charge and the receptor charge is not sufficiently obstructed to prevent an accidental explosion. Although the system according to the US-A-5,070,788 is in fact already safer for the staff than the system according to the US-A-5,052,489, a certain potential of danger remains.

SUMMARY OF THE INVENTION

It is one objective of an aspect of the present invention to provide a method and apparatus for use in a wellbore to prevent an igniter from igniting a pyrotechnic device within a downhole well tool until after the downhole well tool is positioned downhole within the wellbore.

It is another objective of an aspect of the present invention to provide a method and apparatus for use in a wellbore to automatically provide an ignition pathway between an igniter and a pyrotechnic device within a downhole well tool after the downhole well tool is lowered downhole within the wellbore.

It is yet another objective of an aspect of the present invention to provide a method and apparatus for use in a wellbore to prevent an igniter from igniting a propellant within a wellbore pressure setting assembly until after the wellbore pressure setting assembly is lowered downhole within the wellbore.

It is further another objective of an aspect of the present invention to provide a method and apparatus for use in a wellbore to automatically provide an ignition pathway between an igniter and a power charge containing a propellant within a wireline pressure setting assembly once the wireline pressure setting assembly is lowered downhole within the wellbore.

According to one aspect of the present invention there is provided an apparatus for use in a wellbore to prevent an igniter from igniting a pyrotechnic device within a downhole well tool until after said downhole well tool is disposed downhole within said wellbore, said apparatus comprising:

a housing having an ignition pathway extending therein, through which said igniter reacts for igniting said pyrotechnic device;

a solid blocking member which is movable between a plurality of positions for selectably obstructing said ignition pathway to prevent said igniter from igniting said pyrotechnic device; and

an actuator for lowering downhole within said wellbore with said downhole well tool and heating to an activation temperature, at which said actuator moves said solid blocking member from a blocking position obstructing said ignition pathway to an ignition position for allowing said igniter to ignite said pyrotechnic device.

According to another aspect of the present invention there is provided an apparatus for use in a wellbore to prevent an igniter from igniting a power charge within a wellbore pressure setting assembly until after said wellbore pressure setting assembly is disposed downhole within said wellbore, said apparatus comprising:

a tubular housing having a passageway extending longitudinally therein, said passageway providing an ignition pathway through which said igniter reacts for igniting said power charge within said wellbore pressure setting assembly;

a blocking member which is movable between a plurality of positions for selectably obstructing said passageway to block said ignition pathway and prevent said igniter from igniting said power charge; and

an actuator for lowering downhole within said wellbore with said wellbore pressure setting assembly and heating to an activation temperature, at which said actuator moves said blocking member from a blocking position obstructing said passageway to an ignition position for allowing said igniter to ignite said power charge.

According to yet another aspect of the present invention there is provided a method for preventing an igniter from igniting a pyrotechnic device within a downhole well tool until after said downhole well tool is disposed downhole within a wellbore, said method comprising the steps of:

securing a housing to a downhole well tool so that a passageway extending longitudinally within said housing extends between said igniter and said pyrotechnic device;

obstructing said passageway with a blocking member for preventing said igniter from igniting said pyrotechnic device;

providing an actuator which is operable for moving said blocking member between a plurality of positions;

lowering said wellbore pressure setting assembly and said housing downhole within said wellbore; and

heating said actuator to substantially an activation temperature, at which said actuator moves said blocking member from a position obstructing said passageway to a position for allowing said igniter to ignite said pyrotechnic device.

Additional objects, features and advantages will be apparent in the written description which follows.

BRIEF DESCRIPTION OF THE DRAWING

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself however, as well as a preferred mode of use, further objects and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a partial longitudinal section view of a wellbore depicting a wireline tool string which includes the downhole well tool of the preferred embodiment of the present invention;

Figure 2 is a longitudinal section view of the downhole well tool of the preferred embodiment of the present invention, which includes a wireline pressure setting assembly which is shown prior to running downhole within a wellbore and prior to actuation within the wellbore; and

Figure 3 is a longitudinal section view of a portion of a wireline pressure setting assembly of the preferred embodiment of the present invention, which depicts a firing head having a connector housing and an igniter housing, and which is shown prior to lowering to a downhole position within a wellbore; and

Figure 4 is a longitudinal section view of the firing head of **Figure 3**, shown after lowering downhole within a wellbore and activating the heat activated ballistic blocker of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to **Figure 1**, a partial longitudinal section view depicts wellbore **B** having casing **C** within which wireline tool string **T** is secured to wireline **W**. Electrical power supply **E** is schematically shown for providing power to tool string **T**. Wireline tool string **T** includes downhole well tool **2** which, in the preferred embodiment of the present invention, is a wireline pressure setting assembly. Tool string **T** further includes a packer **P** which is releasably secured to downhole well tool **2** for positioning and setting within casing **C**.

With reference to **Figure 2**, a longitudinal section view shows downhole well tool **2** prior to being lowered downhole within a wellbore and prior to actuation. In the preferred embodiment of the present invention, downhole well tool **2** is, in general, a wellbore pressure setting assembly, and in particular, downhole well tool **2** is a wireline pressure setting assembly having an elongated tubular body, and including firing head **4** and pressure setting tool **6**.

Pressure setting tool **6** includes pressure chamber **8**. Pressure chamber **8** includes a manual bleeder valve **10** for bleeding pressure from within pressure chamber **8** after operation of downhole well tool **2**. An upper end of pressure chamber **8** threadingly engages firing head **4** and fluid flow therebetween is prevented by seal **12**.

Upper cylinder **14** is threadingly coupled to a lower end of pressure chamber **8**, and seal **16** prevents fluid flow therebetween. Within upper cylinder **14** is floating piston **18**, which is a pressure responsive member. Floating piston **18** is movable within upper cylinder **14** and, during operation of downhole well tool **2**, is urged to move downward by gas pressure within pressure chamber **8**. Seal **20** prevents fluid flow between an outer circumference of floating piston **18** and an interior diameter of upper cylinder **14**.

Cylinder connector **22** is threadingly coupled to a lower end of upper cylinder **14**. Seal **24** prevents fluid flow between an outer circumference of an upper end of cylinder connector **22** and an interior of the lower end of upper cylinder **14**. Cylindrical connector **22** includes flow port **26** having orifice **28** which substantially measures three-sixteenths of an inch in diameter at an upper end of flow port **26**.

Lower cylinder **30** has an upper end which is threadingly coupled to a lower portion of cylindrical connector **22**. Seal **32** prevents fluid flow between an outer circumference of the lower end of cylindrical connector **22**, and an interior of the upper end of lower cylinder **30**.

Secondary piston **34** is disposed interiorly of and is movable within lower cylinder **30**. Secondary piston **34** is a second pressure responsive member and is movable within lower cylinder **30**. Seal **36** seals between an outer circumference of secondary piston **34** and an interior diameter of lower cylinder **30**.

Piston rod **38** is secured to secondary piston **34** by lock pin **40**, and is also movable within lower cylinder **30**.

Cylinder head **42** is threadingly coupled to the lower end of lower cylinder **30**. Seal **44** prevents fluid flow between the outer circumference of cylinder head **42** and the interior diameter of lower cylinder **30**. Seal **46** prevents fluid flow between an interior surface of cylinder head **42** and an outer circumference of piston rod **38**, which is movable with respect to cylinder head **42** and seal **46**.

Mandrel **48** has an upper end which is threadingly secured within cylinder head **42**. Set screw **50** prevents rotation of mandrel **48** within cylindrical head **42** after mandrel **48** is threadingly secured within cylindrical head **42**. Mandrel **48** includes longitudinally extending slot **52**, and longitudinally extending slot **54** which are two diametrically opposed longitudinally extending slots through an outer tubular wall of mandrel **48**.

Cross link **56** inserts through longitudinally extending slot **52** and longitudinally extending slot **54**, and is movable longitudinally within slots **52** and **54**. Cross link **56** further inserts through piston rod **38** and sleeve **58** to couple sleeve **58** to piston rod **38**. Cross link retaining ring **60** retains cross link **56** within sleeve **58** to maintain cross link **56** in engagement within sleeve **58** and piston rod **38**. Lock screw **62** (not shown) secures cross link retaining ring **60** to sleeve **58**.

Sleeve **58** is a driven member which is driven downward by piston rod **38** and cross link **56** when secondary piston **34** is urged into moving downward during operation of downhole well tool **2**.

Pressure equalization ports **64** and manual bleeder valve **10** are provided for releasing fluid pressure from within pressure chamber **8**, upper cylinder **14**, and lower cylinder **30** after operation of downhole well tool **2**. Pressure equalization ports **64** are provided at seal **16**, seal **24**, and seal **44**. During disassembly of downhole well tool **2** after operation within wellbore **B**, thread pressure equalization ports **64** allow release of pressure from within downhole well tool **2** by passing over seal **16**, seal **24**, and seal **44**, respectively, prior to the threaded connections of these seals being completely uncoupled. Thread pressure equalization ports **64** thus allow pressure to be released from the interior of downhole well tool **2** prior to fully uncoupling portions of downhole well tool **2**.

Hydraulic fluid **66** is contained between floating piston **18** and secondary piston **34** to provide an intermediate fluidic medium for transferring force between floating piston **18** and secondary piston **34**. As shown in **Figure 2**, prior to actuating pressure setting tool **6**, hydraulic fluid **66** is primarily disposed within upper cylinder **16**.

During operation of pressure setting tool **6** to move sleeve **58** with respect to mandrel **48**, a gas pressure generated within pressure chamber **8** urges floating piston **18** downward. Downward movement of floating piston **18** presses hydraulic fluid **66** through orifice **28** and flow port **26** to drive secondary piston **34** downward. Movement of secondary piston **34** downward within lower cylinder **30** causes piston rod **38**, cross link **56**, and sleeve **58** to move downward with respect to lower cylinder **30** and mandrel **48**. Firing head **4**, pressure chamber **8**, upper cylinder **14**, cylinder connector **22**, lower cylinder **30**, cylinder head **42**, and mandrel **48** remain stationery as floating piston **18**, hydraulic fluid **66**, secondary piston **34**, piston rod **38**, cross link **56**, sleeve **58**, and cross link retaining ring **60** move within pressure setting tool **6**.

Still referring to **Figure 2**, power charge **70** is shown disposed within pressure chamber **8** prior to actuation for providing pressure to urge floating piston **18** downwards within upper cylinder **14**. In the preferred embodiment of the present invention, chemical components within power charge **70** serve as a propellant which burn to generate a gas having a pressure which urges floating piston **18** downwards. Power charge **70** is self-contained since it is packaged within a singular container in the preferred embodiment of the present invention.

Referring now to **Figure 3**, a longitudinal section view of a portion of the wireline pressure setting assembly of the preferred embodiment of the present invention, downhole well tool **2**, depicts firing head **4**. Firing head **4** threadingly secures to the upper end of pressure chamber **8**, and is sealed by seal **12** as discussed above. Firing head **4** is electrically connected to power supply **E** (not shown in **Figure 3**) by, in part, power conductor **72**. Firing head **4** includes connector housing **74**, and igniter housing **76**. Igniter housing **76** houses primary igniter **78**, such as a BP3A primary igniter, and further houses secondary igniter **80**. BP3A primary igniter **78**, secondary igniter **80**, and power charge **70**, are manufactured by and available from Baker Oil Tools Inc., a division of Baker Hughes Inc., both of Houston, Texas. In the preferred embodiment of the present invention, primary igniter **78** and secondary igniter **80** include explosive materials for igniting power charge **70**.

An upper end of connector housing **74** is threaded for connection to a wireline tool string (not shown in **Figure 3**). A lower end of connector housing **74** threadingly engages an upper end of pressure chamber **8** (not shown in **Figure 3**). Igniter housing **76** is threadingly coupled within the lower end of connector housing **74** by a left-hand threaded connection. Seal **12** sealingly engages between an outer circumference of igniter housing **76** and an interior diameter of pressure chamber **8** to prevent fluid flow therebetween. Seal **84** sealingly engages between an outer circumference of igniter housing **76** and an interior diameter of the lower end of connector housing **74** to prevent fluid flow therebetween.

Cartridge cap **86** retains primary igniter **78** within an upper end of igniter housing **76**. Seal **88** sealingly engages between cartridge cap **88** and primary igniter **78**. Secondary igniter **80** is held within igniter housing **76** by snap ring **90**.

Electrical connector assembly **91** is utilized to electrically connect a wireline, or wireline tool string, to primary igniter **78**. Electrical connector assembly **91** includes upper connector pin **92**, connector spring **94**, and lower connector pin **95**. Electrical connector assembly **91** is insulated by insulator sleeve **96** and pin insulator **97** to prevent electrical continuity between connector housing **74** and electrical connector assembly **91**. Insulator sleeve

96 and pin insulator **97** are made from suitable insulating materials, such as, for example, polytetrafluoroethylene, which is available from E.I. DuPont De Nemours and Company under the registered trademark TEFLON®. Connector lock ring **98** threadingly engages within connector housing **74** to hold insulator sleeve **96**, pin insulator **97**, and electrical connector assembly **91** in place within connector housing **74**.

Connector spring **94** is a biasing member which, in the preferred embodiment of the present invention, pushes between both upper connector pin **92**, and lower connector pin **95** to provide electrical continuity therebetween. Connector spring **94** also urges upper connector pin **92** upwards and lower connector pin **95** downward and into electrical contact with the upper end of primary igniter **78**.

Still referring to **Figure 3**, bore **100** extends longitudinally through igniter housing **76** for providing a portion of an ignition pathway extending between primary igniter **78** and secondary igniter **80**. Heat activated ballistic blocker **102** is shown in **Figure 3** disposed within igniter housing **76** in a blocking position, obstructing bore **100**.

Heat activated ballistic blocker **102** includes: valve plug **104** having passageway **106**, torsion member **108**, and rotation stop pin **110**. Valve plug **104** is, in the preferred embodiment of the present invention, a steel cylindrical plug which inserted into a cylindrical bore extending laterally into igniter housing **76**, across bore **100**. In the preferred embodiment of the present invention, valve plug **104** does not provide a fluid tight seal across bore **100**, but rather obstructs bore **100** to prevent sufficient thermal energy for igniting secondary igniter **80** from passing through bore **100**.

Passageway **106** is a bore drilled laterally through valve plug **104** for selectably forming another portion of ignition pathway between primary igniter **78** and secondary igniter **80**. Valve plug **104** further includes a rotation stop shoulder **112**. Valve plug **104** is a blocking member which may be selectably rotated within igniter housing **76** for selectably obstructing bore **100** for blocking the ignition pathway between primary igniter **78** and secondary igniter **80**, and for selectably aligning passageway **106** with bore **100** for providing an ignition pathway therethrough.

Heat activated ballistic blocker **102** further includes torsion member **108** which provides an actuator for selectably rotating to actuate rotating plug **104** between a blocking position, in which rotating plug **104** obstructs bore **100**, and an ignition position, in which passageway **106** is aligned with bore **100** for providing an ignition pathway therethrough. The actuator for a ballistic blocker of the present invention, such as torsion member **108**, should be chosen so that it will not actuate at the highest temperature at which it will be exposed to at the ground level surface of the wellbore, prior to being lowered to a position downhole within the wellbore.

In the preferred embodiment of the present invention, torsion member **108** is a thermally responsive member made from a shape memory metal alloy, which will undergo a thermoelastic martensitic reversion at a predeterminable temperature, such as, for example, a nickel-titanium shape memory metal alloy, which will undergo a thermoelastic martensitic reversion when heated to substantially 120° Fahrenheit. Torsion member **108** is coiled, or wound, in the shape of a spring from wire formed of a nickel-titanium alloy commonly known as "shape-memory alloy," or "memory metal alloy."

Shape memory metal alloys are characterized by their ability to undergo a thermoelastic martensitic transformation, a crystalline phase change that occurs within a transition temperature range. These alloys may be worked, in an austenitic state wherein martensitic structure is not present, to one shape or configuration, cooled to below the transformation temperature range to produce the martensitic structure at low temperature, and worked into another shape or configuration. Upon exposure of the memory metal article to a temperature above the transformation temperature range, the martensitic structure dissipates and the article returns to the shape or configuration given it in the austenitic state. During this transformation, the return of the article to the shape given it in the austenitic state occurs violently, in a high-stress transformation, which permits the article to perform work during the transformation. In the preferred embodiment of the present invention, the shape memory metal alloy is TINEL alloy K, purchased in wire form from Raychem Corporation, and has a minimum transformation temperature of substantially not less than 120° Fahrenheit.

Accordingly, torsion member **108** can be formed in the austenitic state to have a selected austenitic-state condition having a first shape. Torsion member **108** then may be cooled below the transformation temperature range to yield an actuator having a second shape when transformed to a martensitic structure at room temperature. Torsion member **108** will then have a first shape when heated to the austenitic state, and a second shape when cooled to the martensitic state. Therefore, the shape of torsion member **108** will vary depending on its crystal structure, i.e., whether torsion member **108** is in a martensitic state, or is transformed to an austenitic state by exposure to elevated temperatures above the transformation temperature range.

Preferably, torsion member **108** is formed of a "two-way" memory metal that transforms back and forth between the austenitic and martensitic crystal structures repeatedly, dependent on the ambient temperature conditions to which it is exposed. Thus, torsion member **108** will have two different shapes: a first shape at ambient temperatures above the transformation temperature range, and a second shape at ambient temperatures below the transformation temperature range.

This transformation temperature range for the material selected determines the activation temperature for heat activated ballistic blocker **102**. Thus, the activation temperature is selectable by choosing different materials to form torsion spring **100** from.

With reference to **Figure 4**, firing head **4** is shown with valve plug **104** depicted in the ignition position, after moving from the blocking position depicted in **Figure 3**. Referring now to **Figures 3** and **4**, rotation stop pin **110** is provided for preventing further rotation of valve plug **104** once valve plug **104** is moved to the ignition position from the blocking position. Rotation stop shoulder **112** (not visible in **Figure 4**) of valve plug **104** is provided for engaging rotation stop pin **110** when valve plug **104** is in the blocking position. Rotation stop pin **110** is held within igniter housing **76** by a press fit within a drill hole passing longitudinally into the lower face of igniter housing **76**.

It should be noted, however, that although heat activated ballistic blocker **102** is disposed between primary igniter **78** and secondary igniter **80** in the preferred embodiment of the present invention, in other embodiments of the present invention, heat activated ballistic blocker **102** may be disposed in alternative positions, such as, for example, between secondary igniter **80** and power charge **70** to prevent secondary igniter **80** from igniting power charge **70** until after downhole well tool **2** is lowered to a downhole position within a wellbore having well temperatures that are higher than the activation temperature for ballistic blocker **102**.

Operation of downhole well tool **102** is now discussed with reference to the **Figures**, beginning now with reference to **Figure 3**. Upon lowering downhole within the wellbore, downhole well tool **2** is exposed to temperatures within the surrounding wellbore which raise the temperature of torsion member **108** to an activation temperature, which in the preferred embodiment of the present invention is substantially equal to or above 120° Fahrenheit. Once torsion member **108** reaches the activation temperature, it undergoes a thermoelastic martensitic reversion in which it changes shape and rotates valve plug **104** from the blocking position of **Figure 3**, to the ignition position shown in **Figure 4**, in which passageway **106** is aligned with bore **100**. Primary igniter **78** can now be ignited for igniting power charge **70** and setting packer **P** once downhole well tool **2** is lowered to a selected position within wellbore **B.**

Referring to **Figure 1**, electrical power is then selectively applied from electrical power supply **E**, through wireline **W**, and to wireline tool string **T**. Electrical power then passes from wireline tool string **T**, through, referring back to **Figure 3**, power conductor **72** and electrical connector assembly **91**, and to primary igniter **78**. The electrical circuit is completed by primary igniter **78** contacting connector housing **74**. Still referring to **Figure 3**, connector housing **74** and igniter housing **76** provide an electrical ground for completing an electrical circuit between power conductor **72** and primary igniter **78** and power supply **E** (shown in **Figure 1**).

With reference to **Figures 1** and **4**, power charge **70** is ignited by passing electrical current from an electrical power supply, such power supply **E**, and through a wireline **W** to a wireline tool string **T**, through electrical connector assembly **91**, and to primary igniter **78**. Primary igniter **78** includes a gunpowder load which is ignited by the electrical current conducted through electrical connector assembly **91**. Primary igniter **78** burns to generate thermal energy which passes through bore **100** and passageway **106**, which together provide an ignition pathway for the thermal energy to pass through between primary igniter **78** and to secondary igniter **80**, for igniting secondary igniter **80**. Referring to **Figure 2**, secondary igniter **80** is ignited and generates heat which then ignites chemical components **71** within power charge **70**. Power charge **70** then burns in a self-sustained combustion reaction to generate a gas, having a pressure which pushes floating piston **18** downward.

In the preferred embodiment of the present invention, power charge **70** will burn in a self-sustained chemical reaction, which, in the preferred embodiment of the present invention, is a combustion reaction for generating the gas. The combustion reaction of the preferred embodiment is a slow combustion reaction, burning at a rate so that a maximum level of gas pressure within pressure chamber **8** will not be reached before a one second period of time has elapsed. This is to be distinguished from explosive reactions in which explosive material is either detonated, deflagrated, or generally burns with a rate of reaction which takes no more than a time period of several milliseconds to burn the explosive materials.

Referring to **Figures 1** and **2**, movement of floating piston **18** downward pushes hydraulic fluid **66** through orifice **28** and flow port **26** to push secondary piston **34** downward. Secondary piston **34** is connected to piston rod **38**, cross link **56**, and sleeve **58**. Movement of secondary piston **34** downward within lower cylinder **30** moves sleeve **58** downward with respect to mandrel **48**. Relative movement of sleeve **58** with respect to mandrel **48** is applied to a downhole tool, such as packer **P**, for applying a force over a distance to set packer **P** within casing **C**. (Packer **P** not shown in a set position.)

If downhole well tool **2** is not operated after lowering into a wellbore to a depth sufficient to raise the temperature of torsion member **108** to substantially the activation temperature, torsion member **108** will reset heat activated ballistic blocker **102** for obstructing bore **100** during removal from the wellbore. Torsion member **108** will rotate valve plug **104** back to the blocking position upon cooling to temperatures below the activation temperature during removal from the wellbore.

The preferred embodiment of the present invention offers several advantages over prior art setting tools. One advantage is that the primary igniter cannot ignite the secondary igniter, or the power charge, until after the tool string is lowered downhole within the wellbore to sufficient wellbore depths having high enough temperatures to heat the torsion member to the activation temperature, at which the torsion member rotates the valve plug to the ignition position to provide an ignition pathway therethrough.

Further, the preferred embodiment of the present invention provides a downhole well tool for automatically providing an ignition pathway between the primary igniter and the secondary igniter only after the downhole well tool is lowered downhole within the wellbore.

Additionally, the preferred embodiment of the present invention provides a low cost method and apparatus for preventing actuation of a downhole well tool prior to running the downhole well tool to a position downhole within a wellbore.

Although the downhole well tool of the present invention has been described herein as including a wireline conveyed pressure setting assembly, other embodiments of the present invention may include other types of wellbore pressure setting assemblies, such as, for example, a tubing convened pressure setting assembly, and thus is not limited to either wireline conveyed pressure setting assemblies, or tubing conveyed pressure setting assemblies. Additionally, alternative embodiments of the downhole well tool of the present invention may include perforating guns, such as those for conveying and actuating explosive shaped charges, in addition to tubing cutters, back-off tools and other types of explosive and pyrotechnic devices. Further, the downhole well tool of the present invention is not limited to use with either pyrotechnic, or explosive actuators. While the invention has been shown in only one of its forms, it is thus not limited but is susceptible to various changes and modifications without departing from the spirit thereof.

What is claimed is:

1. An apparatus for use in a wellbore to prevent an igniter from igniting a pyrotechnic device within a downhole well tool until after said downhole well tool is disposed downhole within said wellbore, said apparatus comprising:

a housing having an ignition pathway extending therein, through which said igniter reacts for igniting said pyrotechnic device;

a solid blocking member which is movable between a plurality of positions for selectably obstructing said ignition pathway to prevent said igniter from igniting said pyrotechnic device; and

an actuator for lowering downhole within said wellbore with said downhole well tool and heating to an activation temperature, at which said actuator moves said solid blocking member from a blocking position obstructing said ignition pathway to an ignition position for allowing said igniter to ignite said pyrotechnic device.

2. The apparatus of claim 1, wherein said igniter is a primaryigniter which is included within said housing, and said apparatus further comprises:

a secondary igniter disposed within said housing for igniting said pyrotechnic device in response to being ignited by said primary igniter; and

said solid blocking member, when in said blocking position, is disposed between said primary and secondary igniters for preventing said primary igniter from igniting said secondary igniter, and thus preventing said primary igniter from igniting said pyrotechnic device.

3. The apparatus of claim 1, wherein said solid blocking member is moved laterally aside of said ignition pathway when moved from said blocking position to said ignition position.

4. The apparatus of claim 1, wherein said solid blocking member is moved laterally across said ignition pathway and into said blocking position during removal of said downhole well tool from said wellbore, at least when said igniter has not been ignited.

5. The apparatus of claim 1, wherein said actuator is heated to said activation temperature by exposure to downhole wellbore temperatures.

6. The apparatus of claim 1, further comprising:

a wellbore pressure setting assembly; and

a settable downhole well tool for lowering within said wellbore, and urging into a setting engagement within said wellbore.

7. The apparatus of any one of claims 1, 2, 5 or 6 wherein said actuator rotates said blocking member from a blocking position obstructing said ignition pathway to said ignition position for allowing said igniter to ignite said pyrotechnic device.

8. The apparatus of claim 7, wherein said actuator is formed from a shape memory metal.

9. The apparatus of claim 7, wherein said actuator positions said blocking member into said blocking position during removal of said downhole well tool from said wellbore, at least when said igniter has not been ignited.

10. The apparatus of claim 7, wherein said igniter is retained within said housing.

11. The apparatus of claim 10, further comprising:

explosive materials.

12. The apparatus of claim 10, further comprising:
a perforating gun having a plurality of shaped charges.

13. The apparatus of claim 10, further comprising:
an explosive device for severing wellbore tubular members.

14. An apparatus for use in a wellbore to prevent an igniter from igniting a power charge within a wellbore pressure setting assembly until after said wellbore pressure setting assembly is disposed downhole within said wellbore, said apparatus comprising:

a tubular housing having a passageway extending longitudinally therein, said passageway providing an ignition pathway through which said igniter reacts for igniting said power charge within said wellbore pressure setting assembly;

a blocking member which is movable between a plurality of positions for selectably obstructing said passageway to block said ignition pathway and prevent said igniter from igniting said power charge; and

an actuator for lowering downhole within said wellbore with said wellbore pressure setting assembly and heating to an activation temperature, at which said actuator moves said blocking member from a blocking position obstructing said passageway to an ignition position for allowing said igniter to ignite said power charge.

15. The apparatus of claim 14, wherein said actuator moves said blocking member to said ignition position by rotating said blocking member.

16. The apparatus of claim 15, wherein said igniter is retained within said housing for lowering within said wellbore.

17. The apparatus of claim 16, further comprising:
said wellbore pressure setting assembly; and

a settable downhole well tool for lowering within said wellbore, and urging into a setting engagement within said wellbore.

18. The apparatus of claim 14 wherein:

said blocking member is a valve plug which is movable for rotating between a plurality of positions for selectably obstructing said passageway to block said ignition pathway and prevent said igniter from igniting said power charge; and

said actuator is a torsion member formed from a shape memory metal for lowering downhole within said wellbore with said pressure setting assembly and exposing to downhole wellbore temperatures, which heat said torsion member to an activation temperature at which said torsion member rotates said valve plug from said blocking position obstructing said passageway to said ignition position for allowing said igniter to ignite said power charge.

19. The apparatus of claim 18, wherein said torsion member positions said valve plug into said blocking position during removal of said pressure setting assembly from said wellbore, at least when said igniter has not been ignited.

20. The apparatus of claim 18, further comprising:

said pressure setting assembly; and

a settable downhole well tool for lowering within said wellbore, and urging into a setting engagement within said wellbore.

21. A method for preventing an igniter from igniting a pyrotechnic device within a downhole well tool until after said downhole well tool is disposed downhole within a wellbore, said method comprising the steps of:

securing a housing to a downhole well tool so that a passageway extending longitudinally within said housing extends between said igniter and said pyrotechnic device;

obstructing said passageway with a blocking member for preventing said igniter from igniting said pyrotechnic device;

providing an actuator which is operable for moving said blocking member between a plurality of positions;

lowering said wellbore pressure setting assembly and said housing downhole within said wellbore; and

heating said actuator to substantially an activation temperature, at which said actuator moves said blocking member from a position obstructing said passageway to a position for allowing said igniter to ignite said pyrotechnic device.

22. The method of claim 21, wherein said actuator is heated to said activation temperature by exposure to downhole wellbore temperatures.

23. The method of claim 21 or 22, further comprising the step of:

forming said actuator from a shape memory metal.

24. The method of any one of claims 21 to 23, wherein said actuator positions said blocking member into said position obstructing said passageway during removal of said wellbore pressure setting assembly from said wellbore, at least when said igniter has not been ignited.

25. The method of any one of claims 21 to 24 wherein said actuator rotates said blocking member from a position obstructing said passageway to a position for allowing said igniter to ignite said pyrotechnic device.

26. The method of any one of claim 21 to 25 wherein said pyrotechnic device is a power charge.

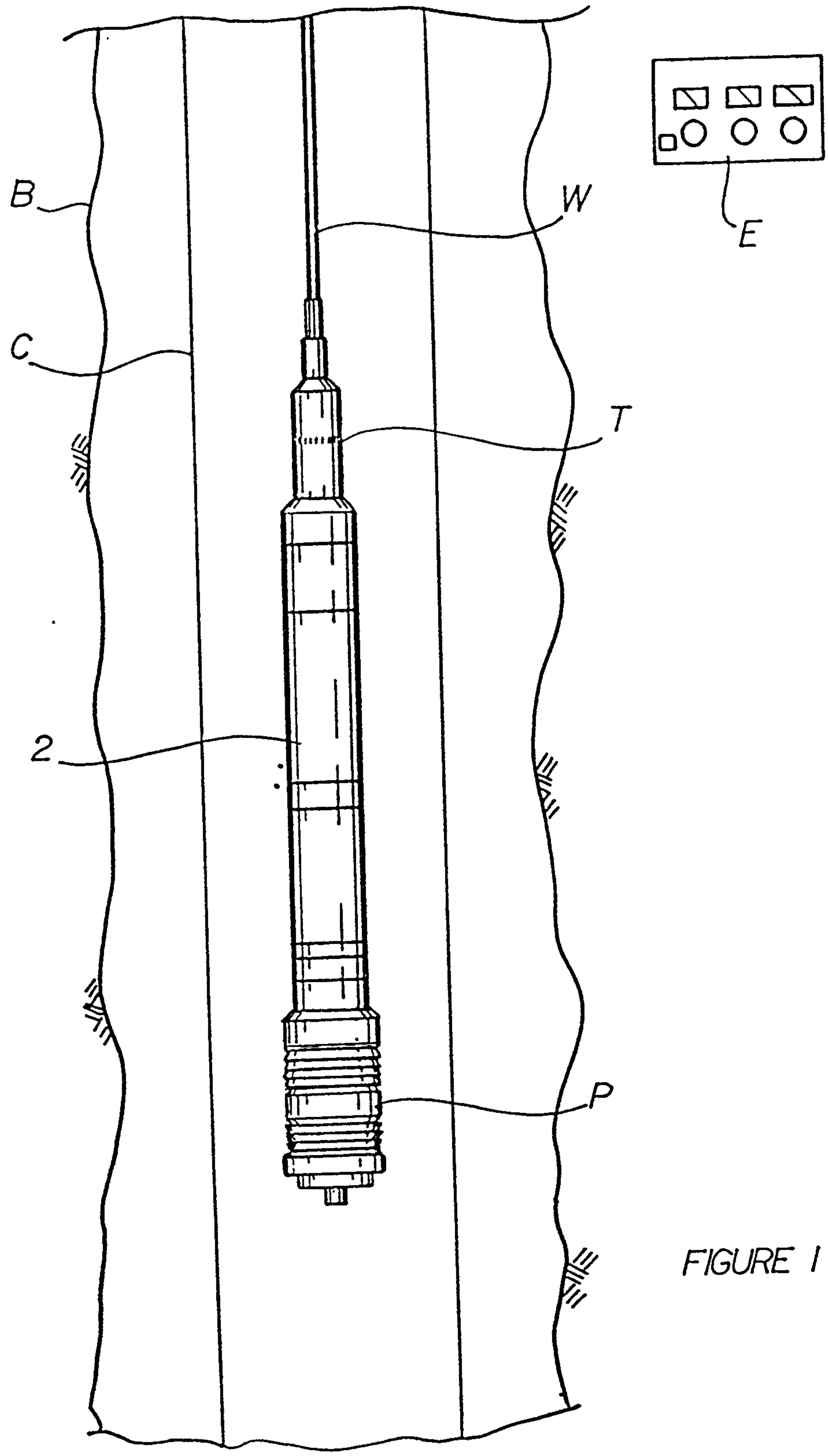

FIGURE 1

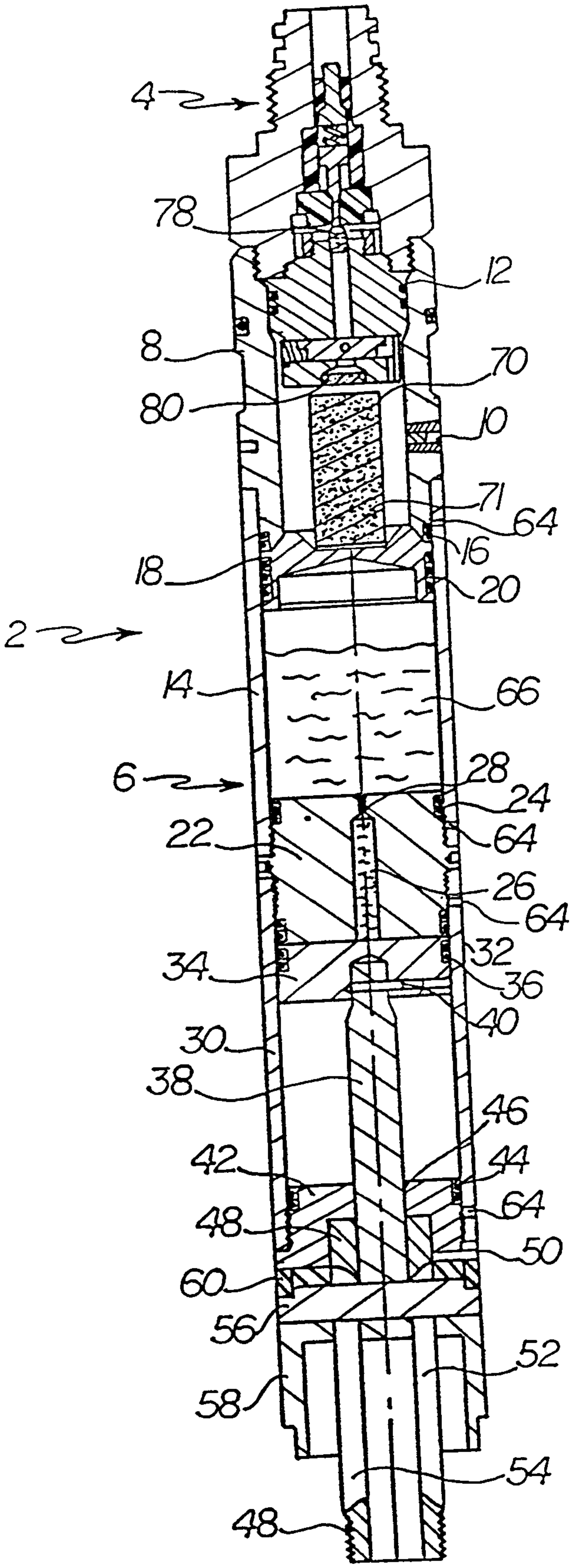
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FIGURE 2

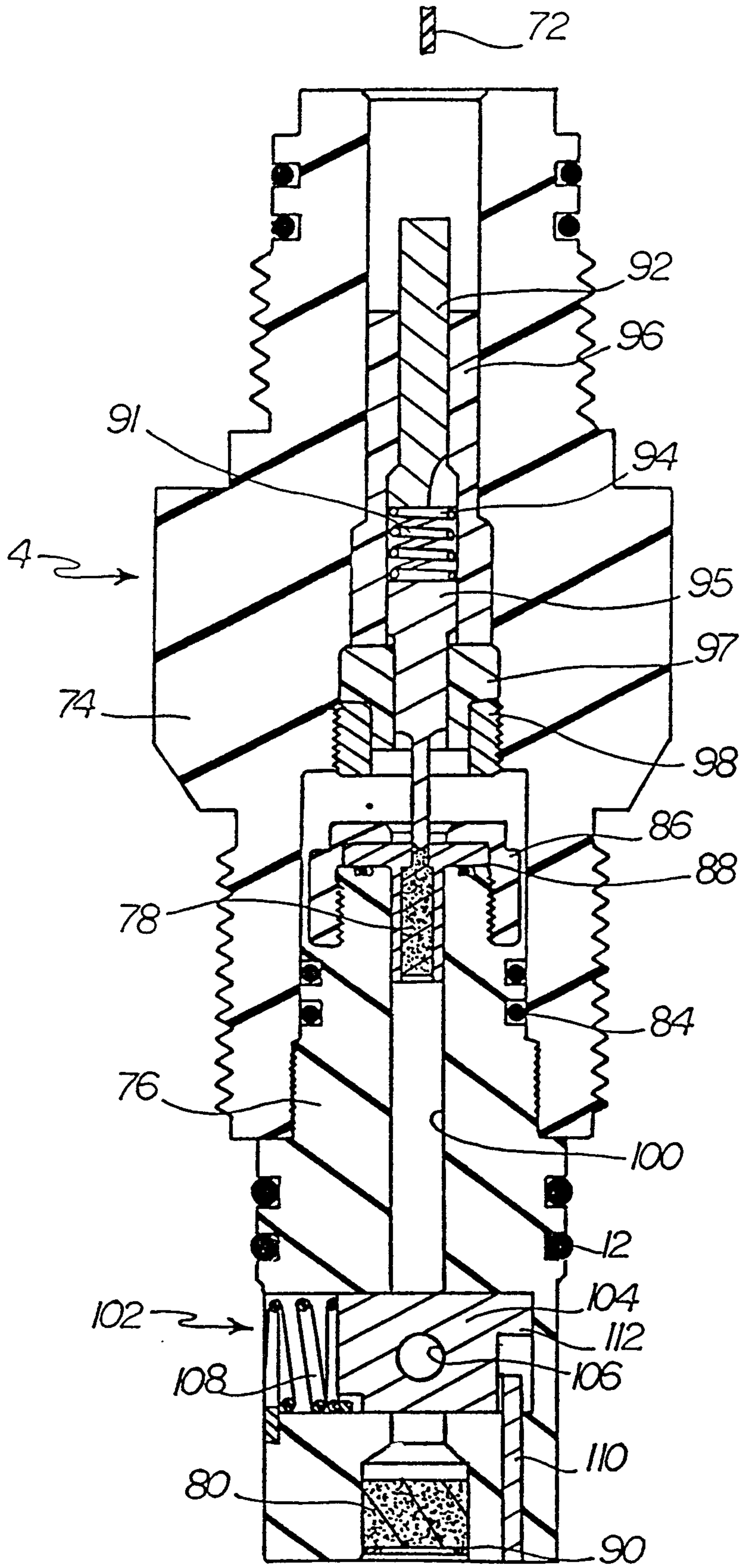
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FIGURE 3

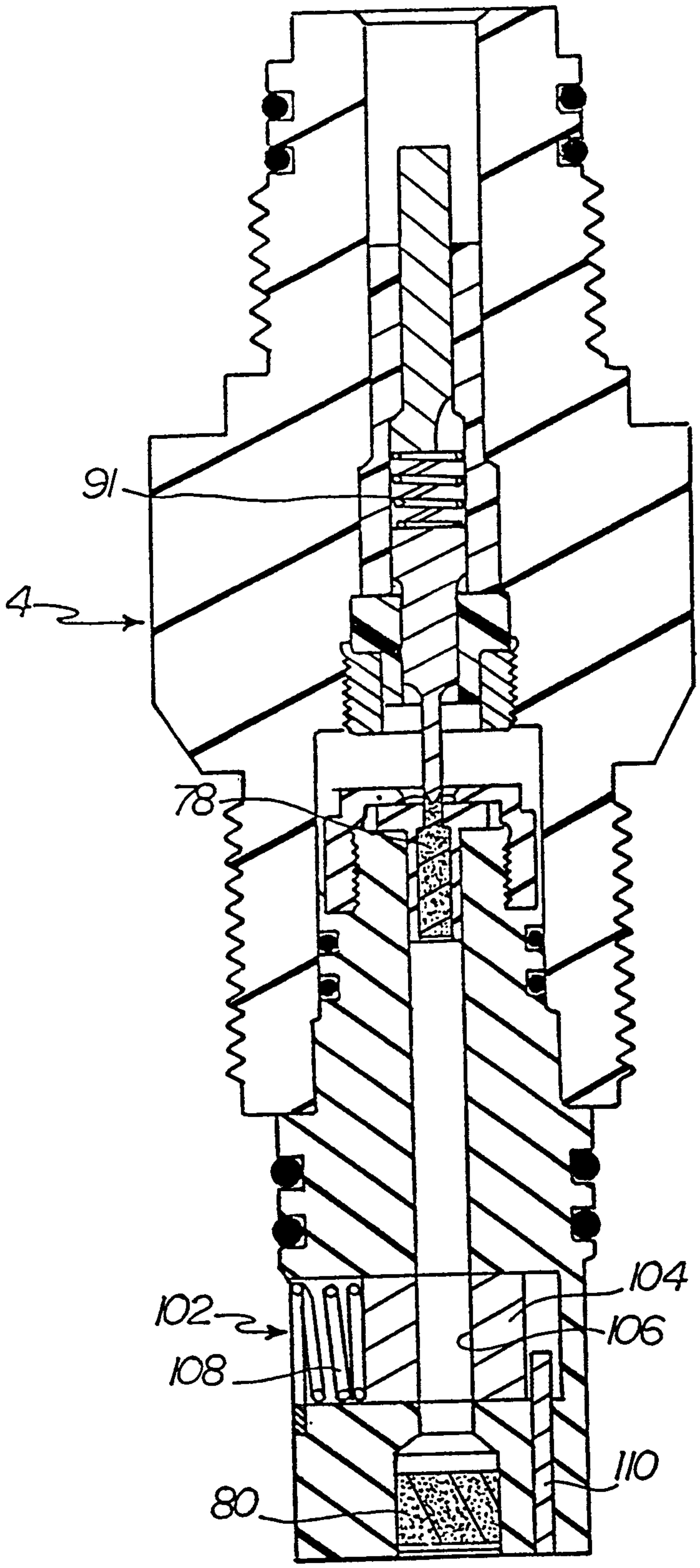
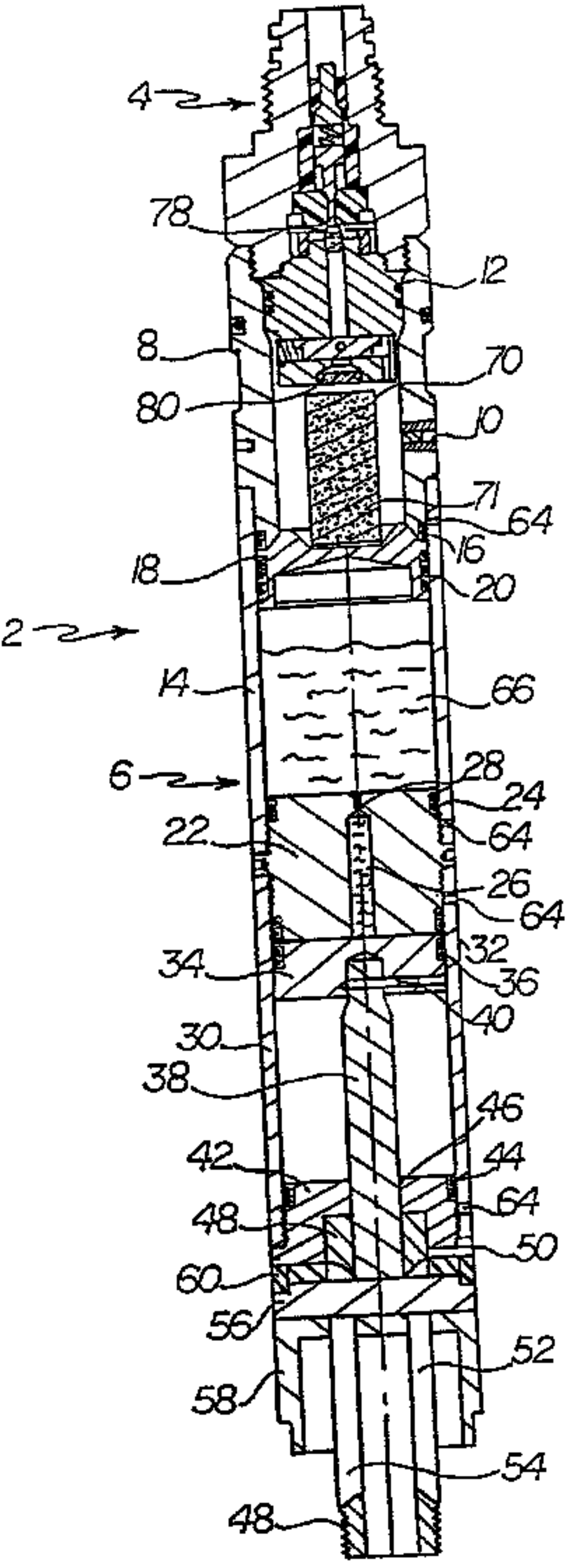


FIGURE 4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