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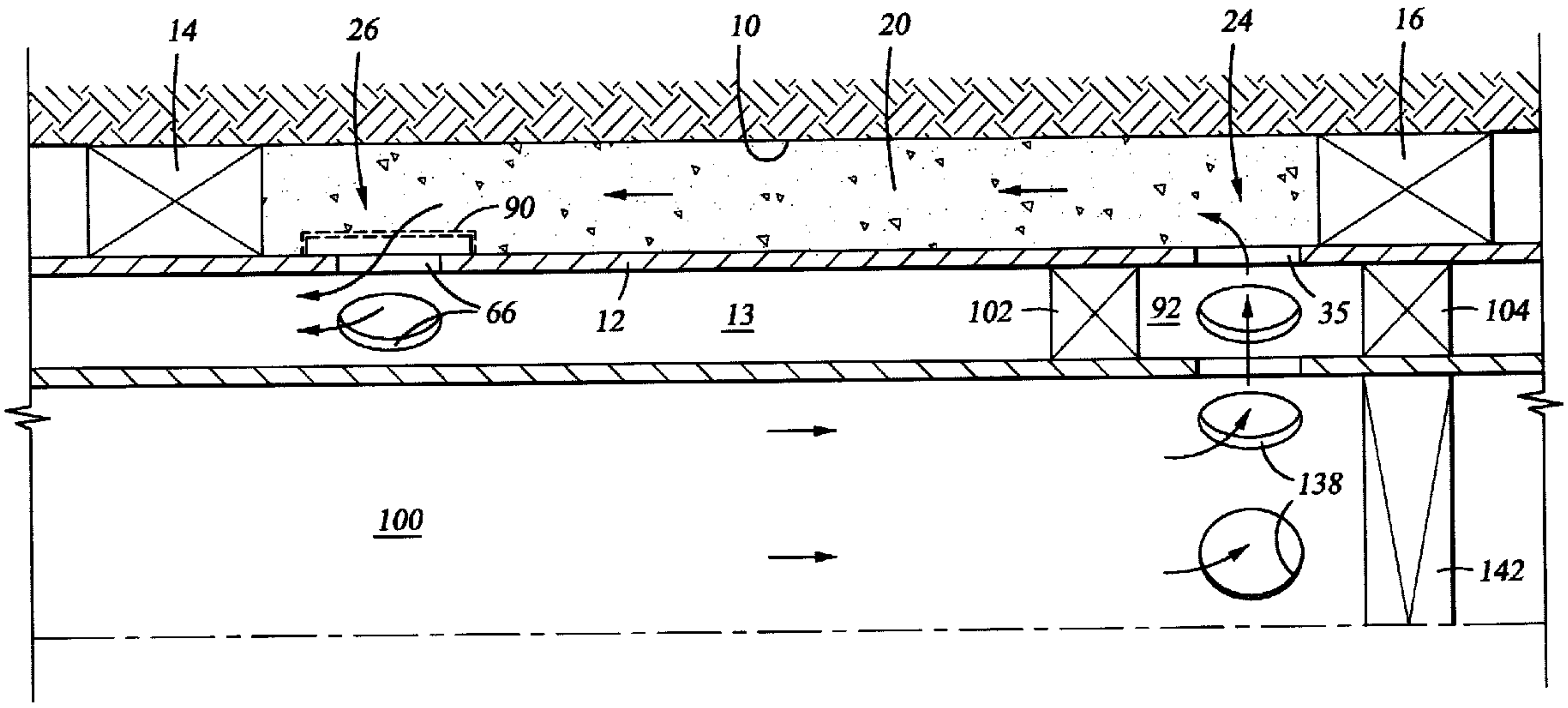

(57) Abrégé/Abstract:
An annulus collar around a well production tube is cast in cement by a procedure that axially delineates the collar between two expandable well packers in the production tube string. Between the packers are a pair of cementing valves. An ingress valve is most proximate to the lower packer whereas an egress valve is most proximate to the upper packer. Additionally, the egress valve is modified to enclose the egress valve with a screen having mesh or slot openings that correspond with a screen plugging material that is mixed with the cement.

ABSTRACT

An annulus collar around a well production tube is cast in cement by a procedure that axially delineates the collar between two expandable well packers in the production tube string. Between the packers are a pair of cementing valves. An ingress valve is most proximate to the lower packer whereas an egress valve is most proximate to the upper packer. Additionally, the egress valve is modified to enclose the egress valve with a screen having mesh or slot openings that correspond with a screen plugging material that is mixed with the cement.

POSITIVE INDICATION SYSTEM FOR WELL ANNULUS CEMENT DISPLACEMENT

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to the tools and methods for earth boring and deep well completion. In particular, the invention relates to tools, materials and operational methods for placing an annulus of cement around a pipe or tube along a defined length of well bore.

DESCRIPTION OF RELATED ART

A well annulus is that generally annular space within a wellbore that may be between the raw borehole wall and the outside of a casing pipe suspended within the borehole. The term may also be applied to the annular space between the raw borehole wall and the outside surface of a fluid production tube. The well annulus may also be that annular space between the casing inside surface and the outer surfaces of a pipe or tube that is suspended within the casing.

Packers are well completion tools that are used to segregate axially adjacent sections of the well annulus to prevent the transfer of fluids, liquid or gas, from flowing along the length of an annulus from one section to another or migrating from one earth strata to another. More generally, the packer is a structural barrier across an annulus section that usually extends along a short length of the annulus.

Characteristically, inflatable packers comprise an elastomer or rubber sleeve element around the outer perimeter of a tubular mandrel. Opposite ends of the elastomer sleeve are secured to the mandrel. The tubular mandrel wall provides structural strength to physically link elements of a tubular work string above and below the packer. Additionally, the open bore along the mandrel center provides working fluid (hydraulic oil, etc.) flow continuity from surface located pumps to other tools below the packer.

The opposing ends of a packer sleeve may be overlaid by collar elements. One or both collars may include valve devices to admit pressurized fluid from the mandrel flow bore into the interface between the elastomer sleeve and the outer surface elements of the mandrel. Sufficient pressure within the interface expands the elastomer radially from the mandrel surface out to a tight, pressure seal against the internal walls of the annulus to prevent fluid flow in either direction along the annulus past the packer.

A wellbore zone to be produced through the flow bore of a production tube or casing liner is often isolated by an annular collar that is cast in cement around the production tube or casing liner. The cement collar is also cast in intimate contact with the surrounding borehole wall or inside surface of the casing bore. This collar seals the wellbore annulus around the casing liner and also secures the casing liner within the wellbore.

A prior art procedure for placement of the uncured collar cement within the well annulus includes placement of form packers in the well annulus above and below the collar segment. For downhole placement, the packers are tool segments of the well casing liner that are secured within the casing liner pipe string at positions of axial separation corresponding to the desired length of the cement collar. Between the packers, the casing liner (or production tube) may also include a pair of selectively opened and closed cement valve elements for providing respective cement flow paths between the flow bore of the casing liner and the surrounding annulus. By means of a cementing tool, a cement flow path between one of the cement valves and the tubular flow bore of the cement tool is isolated. Cement is pumped from the surface, along the cementing tool flow bore , through transverse flow ports in the cement tool, and into the annulus around the casing liner. The other cement valve in the casing liner string receives the material in the collar annulus that is displaced by the uncured cement. This displaced material is received into an inner annulus between the cementing tool and the interior of the casing liner.

A raw borehole profile often is irregular. Although the exact dimension of the outside casing liner dimensions are known, the unknown volume within the borehole prevents a precise determination of the annulus volume between the collar packers. Consequently, a considerable excess of cement is pumped into the collar annulus simply to assure that the collar annulus is filled. Any excess cement flows through the second cement valve into the inner annulus between the casing liner interior and the cementing tool exterior. Removal of the cementing tool swabs the casing liner bore of the excess cement.

A major difficulty of the foregoing prior art process is the unknown. Notwithstanding delivery of volumetrically excessive cement, there is no certainty that the collar annulus is completely filled. It is therefor, an objective of the present invention to provide equipment and procedures to positively conclude a volumetric filling of a collar annulus.

SUMMARY OF THE INVENTION

This and other objects of the invention as will become apparent from the following detailed description are obtained by a procedure that includes a shrouding screen over the cement return (ingress) valve. The cement egress valve is positioned along the casing liner or production string, as the case may be, between the pair of collar delineating packers but closely proximate of one. The screen shrouded return valve is also positioned between the packers but closely proximate of the other packer.

In cooperation with a liner casing or production tube having a shrouding screen over the cement ingress valve, the cement injected into the collar annulus is blended with a particulate or compatible thixotropic material that is matched to the mesh or slot opening of the shrouding screen.

Fluids within the collar annulus that are volumetrically displaced by a pressure driven influx of cement have a traditional drain route through the cement ingress valve and covering screen. However, when the particulate blended cement reaches the screen element over the cement ingress valve, the particulates will not pass through the screen openings. In due time, most of the screen mesh or slot opening will be bridged over by the cement borne particulates. A well working crew at the surface will recognize the condition by an increase in the cement pump discharge pressure as a consequence.

Accordingly, in one aspect of the present invention there is provided a method of placing cement in an outer annulus around a first tube suspended within a well bore, said first tube having a first flow bore therein, said method comprising the steps of:

a. providing a pair of axially separated annulus barriers in an outer annulus around said first tube;

b. providing an ingress flow orifice in said first tube between said annulus barriers with greater proximity to a first annulus barrier;

c. providing an egress flow orifice in said first tube between said annulus barriers with greater proximity to a second annulus barrier;

d. enclosing said egress flow orifice with a screen having fluid flow openings of a selected dimension;

e. suspending a cementing tool within said first flow bore, said cementing tool having a second flow bore and a cement flow orifice between said first and second flow bores, sealing elements bridging an inner annulus between said cementing tool and said first tube to isolate a flow channel from said second flow bore into said outer annulus;

f. blending an additive with cement, said additive having the capacity to plug the fluid flow openings in said screen; and,

g. pumping the blended cement along said second flow bore into said outer annulus until said fluid flow openings in said screen are substantially plugged.

According to another aspect of the present invention there is provided a well completion apparatus comprising a downhole tube section having a pair of axially spaced annulus barriers and a pair of transverse flow orifices between said annulus barriers, one of said flow orifices having a screen with calibrated openings for interdicting particles mixed with a fluid material and discharged from the other flow orifice into an annulus between said barriers.

According to yet another aspect of the present invention there is provided a well completion apparatus comprising:

a. a well casing having a pair of axially separated cementing valves between a first pair of external annulus barriers, one of said cementing valves having an ingress orifice for transferring a fluid flow from an exterior space around said casing into an interior casing flow bore; and

b. a screen across said ingress orifice having selectively sized screen openings;

c. a fluid conduit tube within said casing flow bore having an interior flow bore, a second pair of exterior annulus barriers, a fluid flow orifice from said interior flow bore between said second pair of annulus barriers and a selectively applied flow bore obstruction.

BRIEF DESCRIPTION OF THE DRAWINGS

The advantages and further aspects of the invention will be readily appreciated by those of ordinary skill in the art as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings in which like reference characters designate like or similar elements throughout the several figures of the drawing and wherein:

FIGURE 1 is a partial section view of a well casing liner suspended within an uncased wellbore.

FIGURE 2 is a line schematic of the invention in operation.

FIGURE 3 is a partial section view of a well casing liner suspended within a cement collar.

FIGURE 4 is a partial section view of a single acting, egress cementing valve.

FIGURE 5 is a detailed enlargement of the egress cementing valve illustrated by **FIGURE 4**.

FIGURE 6 is a partial section view of the double-acting ingress cementing valve.

FIGURE 7 is a partial section view of the cementing and shifting tool.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A representative application of the invention is illustrated by **FIGURE 1** to include an open bore hole **10** having a casing liner **12** suspended therein. The casing liner may be a continuous pipe string that is supported at or near the surface, or, alternatively, may be concentrically sleeved within a larger diameter casing and suspended from an intermediate depth. An internal flow bore **13** of the casing liner is accessible at the surface as a conduit for well working fluids or as a mechanical guide channel for other tools and instruments suspended from the surface into and along the casing liner flow bore. Other applications of the invention may include, for example, a production tube within a cased and perforated bore hole.

The lower end of the casing liner may include an upper packer **14** and a lower packer **16**. Although fluid inflatable packers are preferred, it should be understood that the term "packer" is merely a convenience reference to any form of selectively engaged annulus barrier that obstructs the continuity of the annulus **18**. The packers **14** and **16** are separated by a distance D corresponding to the desired length of an annulus production collar **20** and linked by a casing liner subsection **22**. The packers **14** and **16** are located, for example, along the length of the borehole **10** in relation to a particular well fluid production zone.

Within the casing liner subsection **22**, and preferably adjacent to the lowermost packer **16**, is an egress cementing valve **24** for channeling a discharge flow of uncured, fluidized cement from a cementing tool into the collar annulus **20**. The material described herein as "cement" may also be or include other phase changing materials such as epoxies, polyesters, etc. An ingress cementing valve **26** for the return of fluid and other matter displaced by the cement occupation of the collar **20** annulus volume is preferably provided in the subsection **22** adjacent to the uppermost packer **14**.

Although the preferred sequence and order of the cementing valves is to locate the egress valve **24** in the proximity of the lower packer **16** and to locate the ingress valve **26** in the proximity of the uppermost packer **14**, those skilled in the art will understand and appreciate the fact that the sequence and order may be reversed.

With respect to **FIGURES 4** and **5**, the egress cementing valve **24** comprises a tubular housing **30** subtended at opposite ends by threaded connecting subs **32** and **34**. Near the upper connecting sub **32**, the housing **30** is perforated by one or more orifices **35**. The orifices are initially sealed by respective rupture discs **36**. Internally of the housing **30**, a closing sleeve **38** is provided with a close sliding fit against the inside wall surface of the tubular housing **30**. The closing sleeve has a limited freedom of axial translation in opposite directions along the housing for opening and closing the orifice **35** to fluid flow after the rupture discs **36** are discharged and the orifice **35** opened. A circumferential rib **40** flanked by glide ramps **42** around the inside circumference of the closing sleeve provides an operational connection to a shifting tool **106** that will be described subsequently.

Integral with and positioned between the closing sleeve **38** and the guide sleeve **46** are a plurality of axially extended, resilient collet reeds **44**. The outside perimeter of the collet reeds carries a latching shoulder **45**.

A locking piston **47** displaced by internal bore pressure is secured against axial translation by a calibrated shear pin **48**. A displacement space **49** is provided to receive the piston **47**. A radially biased piston skirt **50** closes against the end surface **52** of the guide sleeve **46**. However, the locking piston **47** will not secure the closed position of the closing sleeve **38** over the orifice **35** until the locking piston is translated into the displacement space **49**. Such translation is selectively actuated by sufficient fluid pressure within the internal flow bore **13** bearing on the end of the locking piston to shear the pin **48**. The actuation pressure is normally imposed by surface pumps not illustrated. The outer perimeter of the guide sleeve **46** carries a latching shoulder **54** that cooperates with the end of the biased skirt **50** to prevent reopening of the orifices **35** once the closing sleeve **38** has been translated to the closed position and the locking sleeve **47** has been translated into the displacement space **49**.

The ingress cementing valve **26** is described by reference to **FIGURE 6** which illustrates an upper connecting sub **62** and a lower connecting sub **64**. In threaded assembly between the two connecting subs is a tubular housing **60**. The housing **60** is perforated by orifices **66**. For downhole run-in, the orifices are closed by pressure rupture discs **67**. Internally, the housing **60** confines a closing sleeve **68**. The sleeve **68** is assembled to the internal bore of the housing **60** with a close sliding fit that overlies the orifices **66**. Collet reeds **70** carry a detent ridge **72**. The collet reeds resiliently bias the ridge into a circumferential detent channel **74** to releasably restrain the collet and closing sleeve at the open orifice position illustrated. The internal bore of the closing sleeve may include a circumferential tool rib **76** flanked by guide ramps **78**. The outer perimeter of the closing sleeve includes a radially expansible lock ring **80**.

Between the ingress valve upper sub **62** and the housing **60** is a lock piston **82** that is axially secured by a calibrated shear pin **83**. Predetermined fluid pressure within the flow bore **13** applied to the inside cross-section of the bore shears the lock pins **83**. Upon failure of the lock pins **83**, the lock piston **82** shifts into the displacement space **84** and removes the piston skirt **86** from the housing counterbore shoulder **88**. When the counterbore shoulder **88** is exposed and the closing sleeve **68** is shifted to the orifice **66** closure position, the lock ring **80** expands into the channel between the counterbore shoulder **88** and the end of the lock piston skirt **86**. This meshing of the lock ring **80** against the counterbore shoulder **88** secures the sleeve **68** from subsequent opening.

Secured around the external perimeter of the housing **60** is a calibrated screen **90**. The term screen is used herein to include all forms of sized flow paths which, for examples, may include meshed wire, parallel slots and drilled or punched orifices. Orifice or mesh opening dimensions or gage is highly dependent upon the material to be used with the collar forming cement. If the material blended with the cement is particulate, the orifices are sized to barely but confidently retain the particulate in a bridged position across the mesh or slot opening. An objective is to close the cement ingress path through the orifices **66** when the collar annulus is packed with cement.

As a consequence of the operative cooperation between the screen mesh size and the cement blended particulate size, the collar annulus **20** must be filled with cement before all openings in the screen **90** are closed.

A specific example of the foregoing might include a 12 ga. meshed or slotted screen around the ingress orifices **66** to receive a collar annulus cement blended with resieved 20/40 US Mesh Gravel. Appropriate particulates may include sand or ground glass. However, non-particulate cement additives may also be used to exploit flow properties such jelling or congealing under dynamic conditions.

With respect to **FIGURE 7**, the cementing tool **100** comprises a threaded assembly of three sectors including upper sealing elements **102** and lower sealing elements **104**. Between the sealing elements is a shifting tool **106**. The sealing elements may be substantially passive swab seals. The shifting tool **106** comprises a plurality of cylindrically distributed collet reeds **108** having symmetric ramp faces **110** flanking a tool ridge engagement slot **112**.

The reed base sleeve **114** is secured to an upper collar **116** having a concentrically sliding fit about an outer mandrel **118**. A lower collar **120** is threadably assembled with the outer mandrel but loosely overlies free tips **122** of the collet reeds **108**. An annular, spring compliance space **124** spans beneath the collet reeds.

The outer mandrel **118** is a static, threaded assembly of tube between an upper collar **126** and a lower collar **128**. The upper collar **126** assembles with the terminal end of a cement delivery conduit not illustrated. The cement delivery conduit extends to the wellbore surface and is connected at the surface to a pumped delivery system.

Between the upper and lower collars **126** and **128** is a cooperative box joint **130** and pin joint **132**. The box joint is penetrated by an inner cement discharge orifice **134**. An inner mandrel **136** extends from the upper collar **126** to the lower collar **128**. An inner cement discharge orifice **138** aligns with the outer discharge orifice **134**. Below the inner discharge orifice **138** is a bore plug seat **140** adapted to receive a surface launched bore sealing element **142** such as a ball, rod or dart.

The invention method sequence is most conveniently understood from the schematic of **FIGURE 2** which illustrates a raw borehole wall **10** having a collar annulus **20** between a casing liner **12** and the borehole wall **10**. The collar annulus extends along the borehole length between the upper packer **14** and the lower packer **16**. Between the packers **14** and **16** is the egress cementing valve **24** and the ingress cementing valve **26**. The flow orifice 66 of the ingress valve **26** is shielded by a calibrated mesh screen **90**.

The cementing tool **100** is suspended within the internal bore of the casing liner **12** thereby providing an internal annulus **13**. This internal annulus **13** is internal of the collar annulus **20**. The cementing tool is positioned along the borehole length relative to the egress valve **35**. The sealing elements **102** and **104** are located on opposite sides of the egress valve **35** and expanded to isolate the inner annulus section **92**. This isolated inner annulus **92** provides a channel for the cement flow down the cementing tool flow bore from the orifices **138** to the orifices **35** of the egress valve **24**. The annulus **92** between the cementing tool **100** and the casing liner **12** is isolated between the sealing elements **102** and **104**. Consequently, the forced flow of cement is routed further through the egress valve **35** into the collar annulus **20**.

When the tool **100** is positioned as required and the inner annulus sealing elements **102** and **104** are expanded, the dart **142** is deposited in the tool flow bore to seal the tube bore at the seat **140**. Pump pressure within the flow bore may thereafter be increased to open the rapture disc in the egress valve **35**.

The ingress valve rupture disc **67** may also be opened at this time and the collar annulus **20** proceed to receive cement.

As the collar annulus fills with cement from the egress valve **35**, downhole formation fluids, drilling fluids and other debris is forced from the collar annulus **20** through the screen **90** and into the ingress orifice **66** until the cement reaches the screen **90**. Fluids and other materials passing through the ingress orifice **66** are channeled uphole along the annulus **13** between the cementing tool **100** and the casing liner **12**. As the aggregate laden cement attempts to penetrate the screen **90**, the particulates correspondingly plug the protective mesh thereby effectively closing the ingress valve **26**. The fact that the screen **90** enclosing the ingress valve **26** has plugged is objectively reported at the well surface by the discharge pressure in the cement displacement pump. The pump discharge pressure against the fluid column bearing on the cement abruptly rises. That fluid column is carried in the tubing bore of cementing tool **100**.

With the cement collar **20** in place, the orifice **35** of egress valve **24** is closed by a translated shift of the sleeve **38**. The cementing tool sealing elements **102** and **104** are retracted and the shifting tool **106** is manipulated to engage the shifting tool engagement slot **112** with the sleeve **38** rib **40**. When engaged, the sleeve **38** is shifted to underlie the orifice **35** and thereby isolate it from the interior bore.

When the sleeve **38** shifts, the radially inward spring bias of the locking piston **47** skirt **50** contracts the locking piston radially to present an abuttment obstacle to the sleeve **38** latching shoulder **54** thereby caging the sleeve at the orifice closed position.

If desired, the orifice **55** may be reopened once by the shifting tool **106**. Again the tool slots **112** engage the ribs **40** of the ingress valve sleeve **38**. Force is applied on the tool **100** to shear the retaining pin **48** and displace the locking piston into the space **49**.

After the ingress orifice **38** is closed, the shifting tool **106** is manipulated to engage the ingress valve **26** sleeve ridge **76**. The closing sleeve **68** is shifted to underlie and close the orifice **66**. The closing sleeve **68** is held at the open position by the collet reed detent ridge **72** resting in the housing detent channel 74. When shifting force is applied to the sleeve **68**, the detent ridge **72** resiliently yields from the channel **74**, but expands to abut the housing shoulder **75**.

Shifting of the sleeve **68** to the orifice closure position also places the sleeve lock ring **80** contiguously within the piston skirt **86** of the lock piston **82**. Opening and closing of the egress orifice **66** by reverse shifting of the sleeve **68** is optional until the lock piston **82** is shifted by fluid pressure within the internal flow bore **13**. Sufficient flow bore pressure on the interior end of the lock piston **82** shears the retaining pin **84** to allow translation of the lock piston into the displacement space **84**. Such translation extracts the piston skirt from around the resiliently biased lock ring **80** which consequently expands into the circumferential channel evacuated by the piston skirt **86**.

Although the invention has been described in terms of specified embodiments which are set forth in detail, it should be understood that this is by illustration only and that the invention is not necessarily limited thereto. Alternative embodiments and operating techniques will become apparent to those of ordinary skill in the art in view of the present disclosure. Accordingly, modifications of the invention are contemplated which may be made without departing from the spirit of the claimed invention.

WHAT IS CLAIMED IS:

1. A method of placing cement in an outer annulus around a first tube suspended within a well bore, said first tube having a first flow bore therein, said method comprising the steps of:

a. providing a pair of axially separated annulus barriers in an outer annulus around said first tube;

b. providing an ingress flow orifice in said first tube between said annulus barriers with greater proximity to a first annulus barrier;

c. providing an egress flow orifice in said first tube between said annulus barriers with greater proximity to a second annulus barrier;

d. enclosing said egress flow orifice with a screen having fluid flow openings of a selected dimension;

e. suspending a cementing tool within said first flow bore, said cementing tool having a second flow bore and a cement flow orifice between said first and second flow bores, sealing elements bridging an inner annulus between said cementing tool and said first tube to isolate a flow channel from said second flow bore into said outer annulus;

f. blending an additive with cement, said additive having the capacity to plug the fluid flow openings in said screen; and,

g. pumping the blended cement along said second flow bore into said outer annulus until said fluid flow openings in said screen are substantially plugged.

2. A method of placing cement as described by claim 1 wherein the

additive blended with cement is a particulate.

3. A method of placing cement as described by claim 2 wherein dimensions of said particulate are greater than the selected dimensions of said screen.

4. A well completion apparatus comprising a downhole tube section having a pair of axially spaced annulus barriers and a pair of transverse flow orifices between said annulus barriers, one of said flow orifices having a screen with calibrated openings for interdicting particles mixed with a fluid material and discharged from the other flow orifice into an annulus between said barriers.

5. A well completion apparatus as described by claim 4 wherein said screen is slotted.

6. A well completion apparatus as described by claim 4 wherein said screen is meshed.

7. A well completion apparatus comprising:

a. a well casing having a pair of axially separated cementing valves between a first pair of external annulus barriers, one of said cementing valves having an ingress orifice for transferring a fluid flow from an exterior space around said casing into an interior casing flow bore; and

b. a screen across said ingress orifice having selectively sized screen openings;

c. a fluid conduit tube within said casing flow bore having an interior flow bore, a second pair of exterior annulus barriers, a fluid flow orifice from said interior flow bore between said second pair of annulus barriers and a selectively applied flow bore obstruction.

8. A well completion apparatus as described by claim 7 wherein said cementing valves have sliding closure sleeves.

9. A well completion apparatus as described by claim 7 wherein said conduit tube includes a valve sleeve operating collet for engaging cementing valve closure sleeves.

10. A well completion apparatus as described by claim 7 wherein said cementing valves further comprise locking sleeves for selectively securing a final position of said closure sleeves.

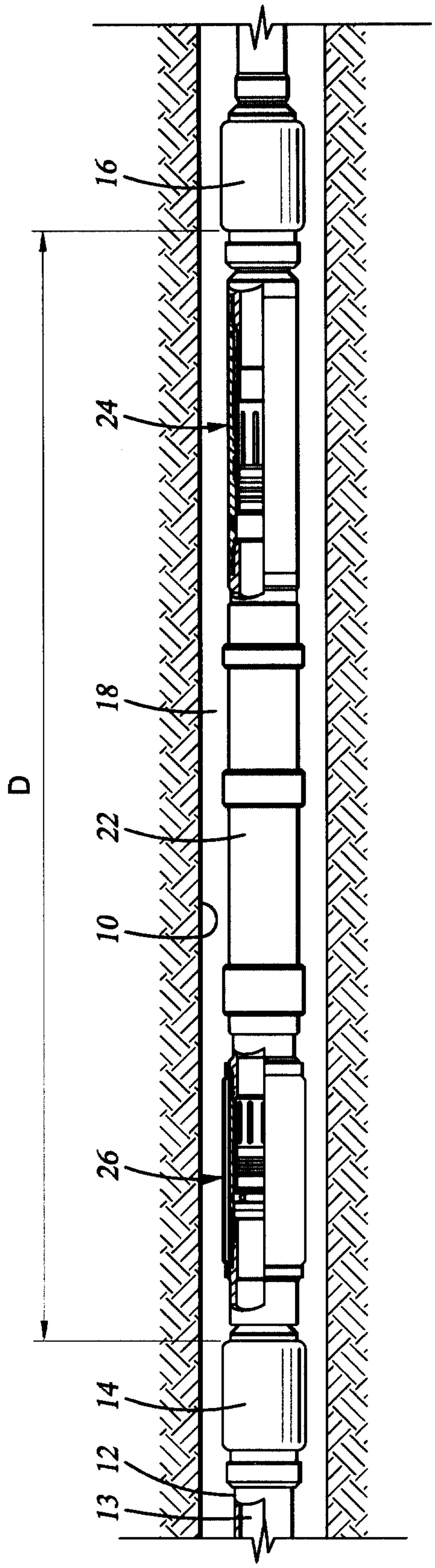

Fig. 1

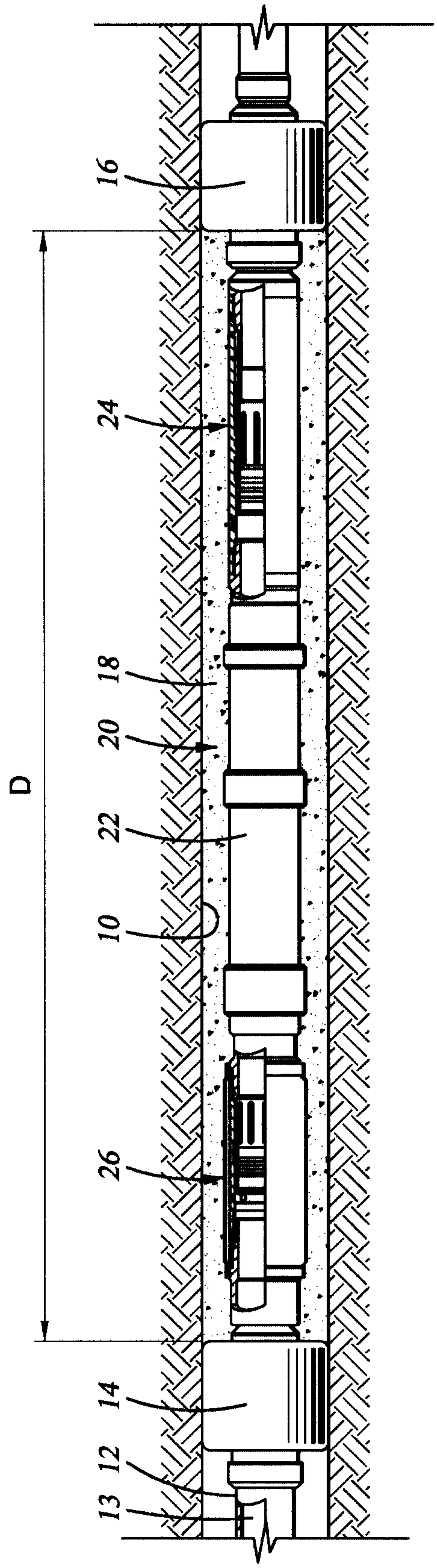

Fig. 3

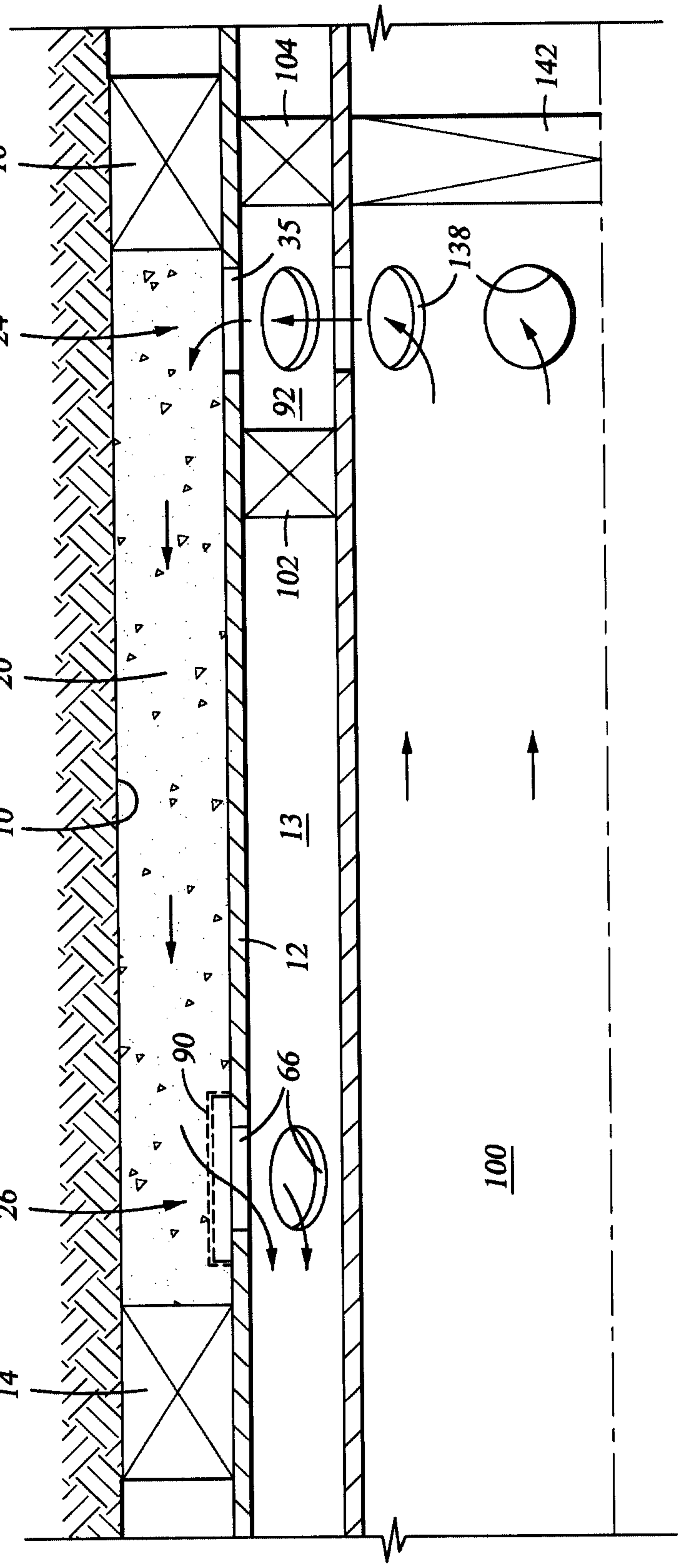

Fig. 2

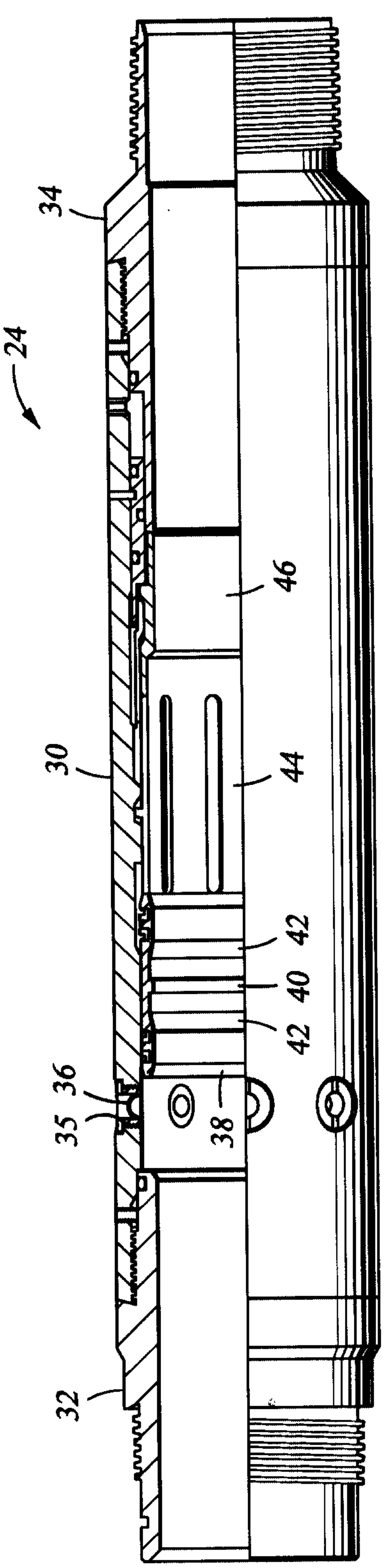
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Fig. 4

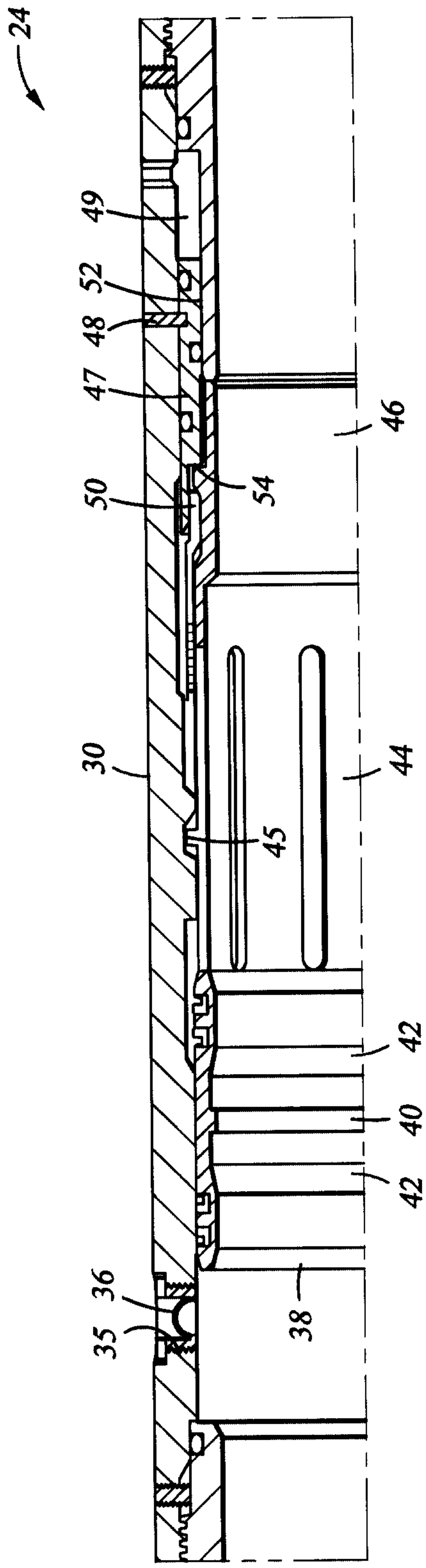
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Fig. 5

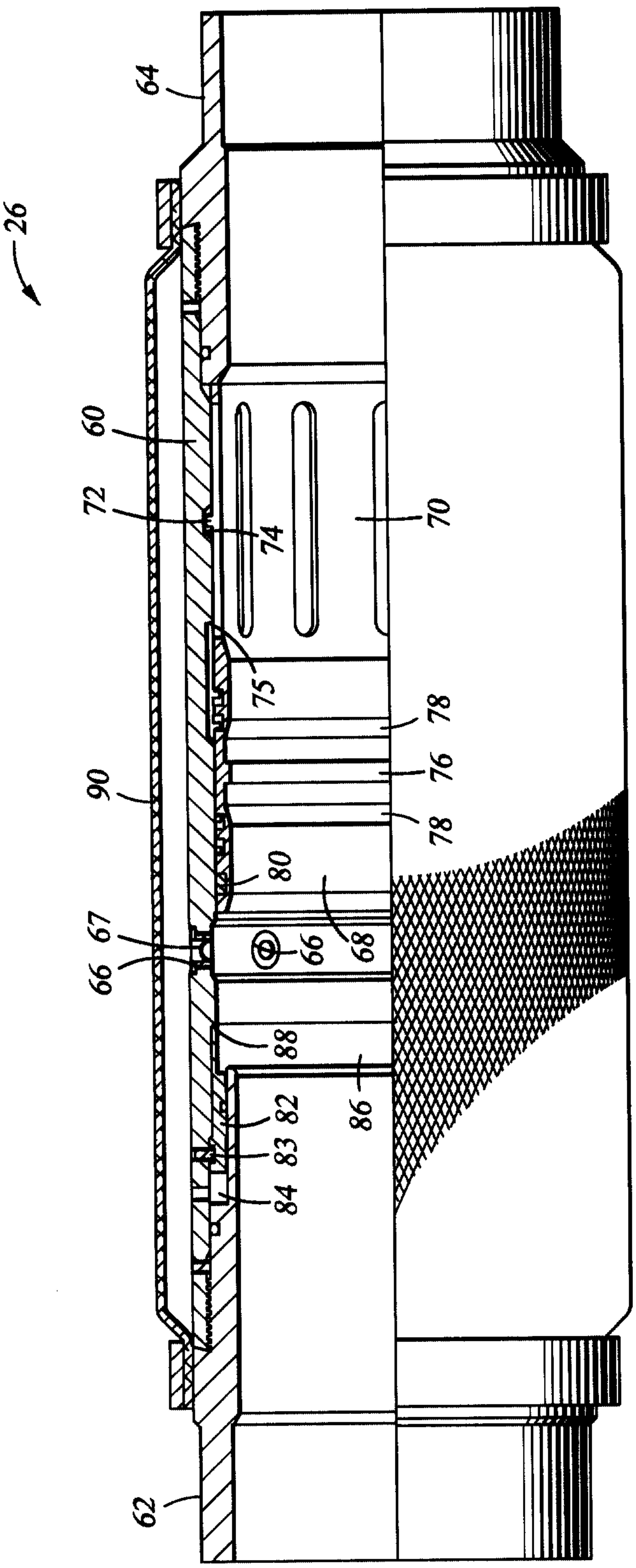

Fig. 6

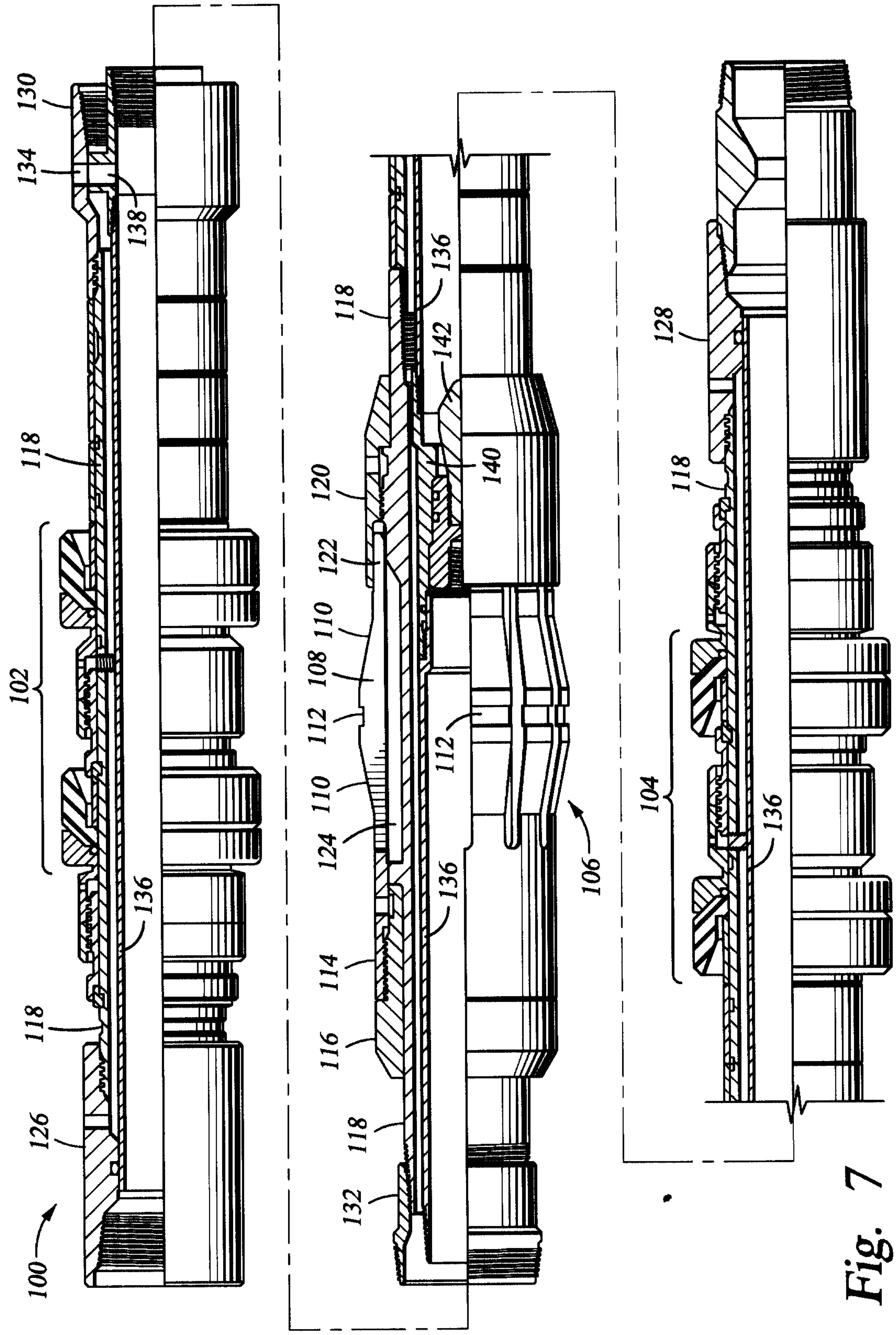

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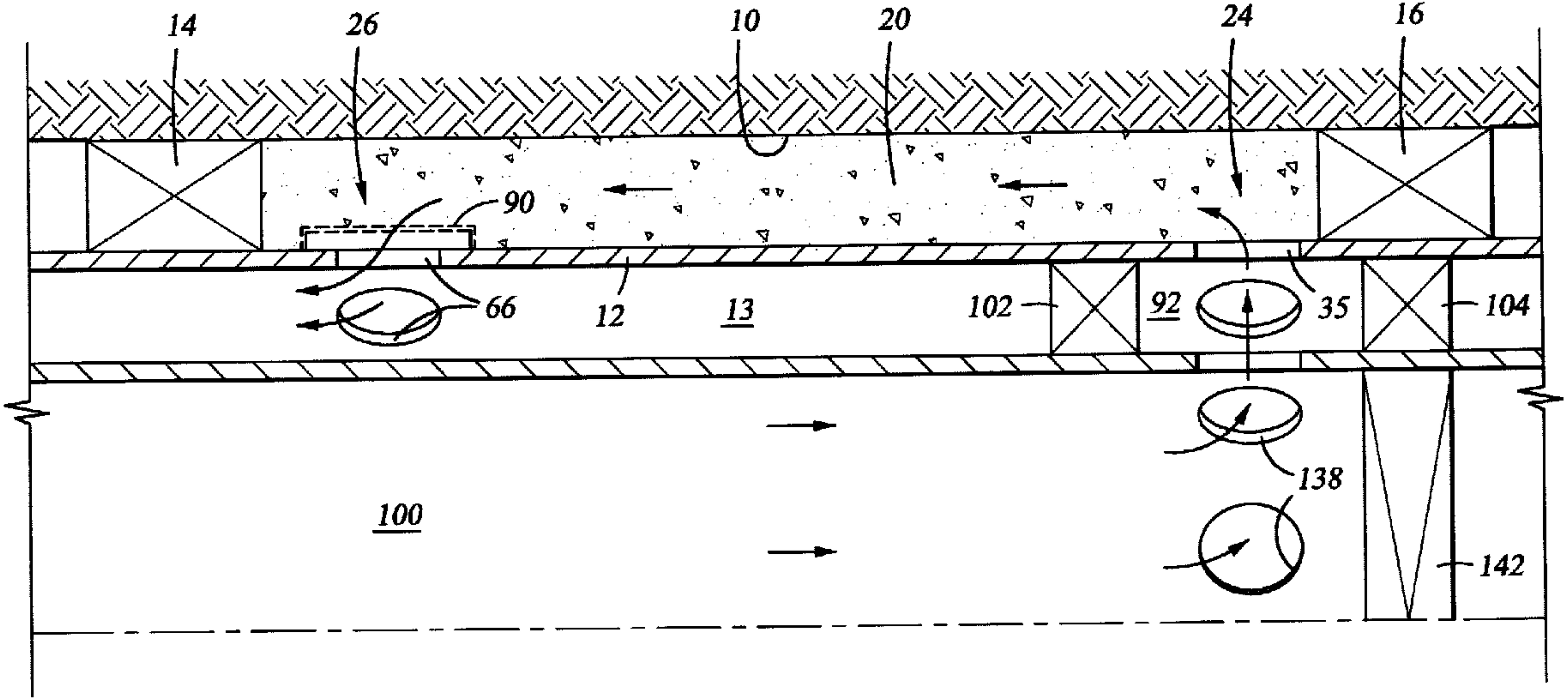
Fig. 7



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