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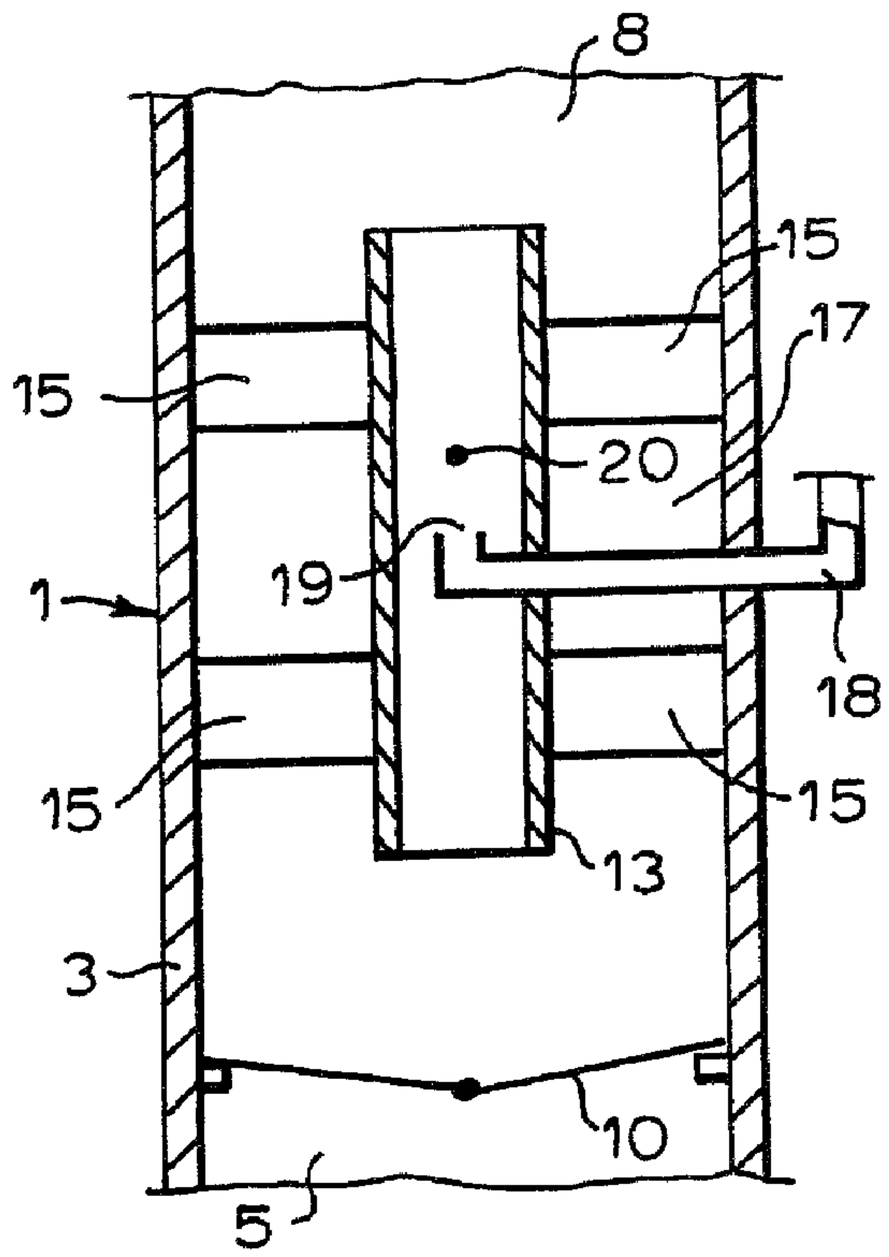
(54) Title: COMPRESSING COMBUSTIBLE GAS FLOWING THROUGHOUT A CONDUIT



(57) Abrégé/Abstract:
Method of compressing combustible gas flowing through a conduit (3) provided with a non-return inlet valve (10) arranged at its inlet end (5) and with an open-ended tubular (13) arranged in the conduit (3) comprising (a) allowing combustible gas to enter into the conduit (3); (b) supplying oxidant to the combustible gas in the tubular (13), the amount of oxidant being equal to the amount of oxidant required to combust at least part of the combustible gas in the tubular (13); (c) allowing the mixture of combustible gas and oxidant to ignite in the tubular (13), which ignition yields a high pressure wave front closing the non-return inlet valve (10) and pushing gas out of the tubular (13) and entraining gas flowing through the annular space (17) and a low pressure wave front; and (d) allowing the non-return inlet valve (10) to open on arrival of the low pressure wave front, followed by steps (a) through (d).

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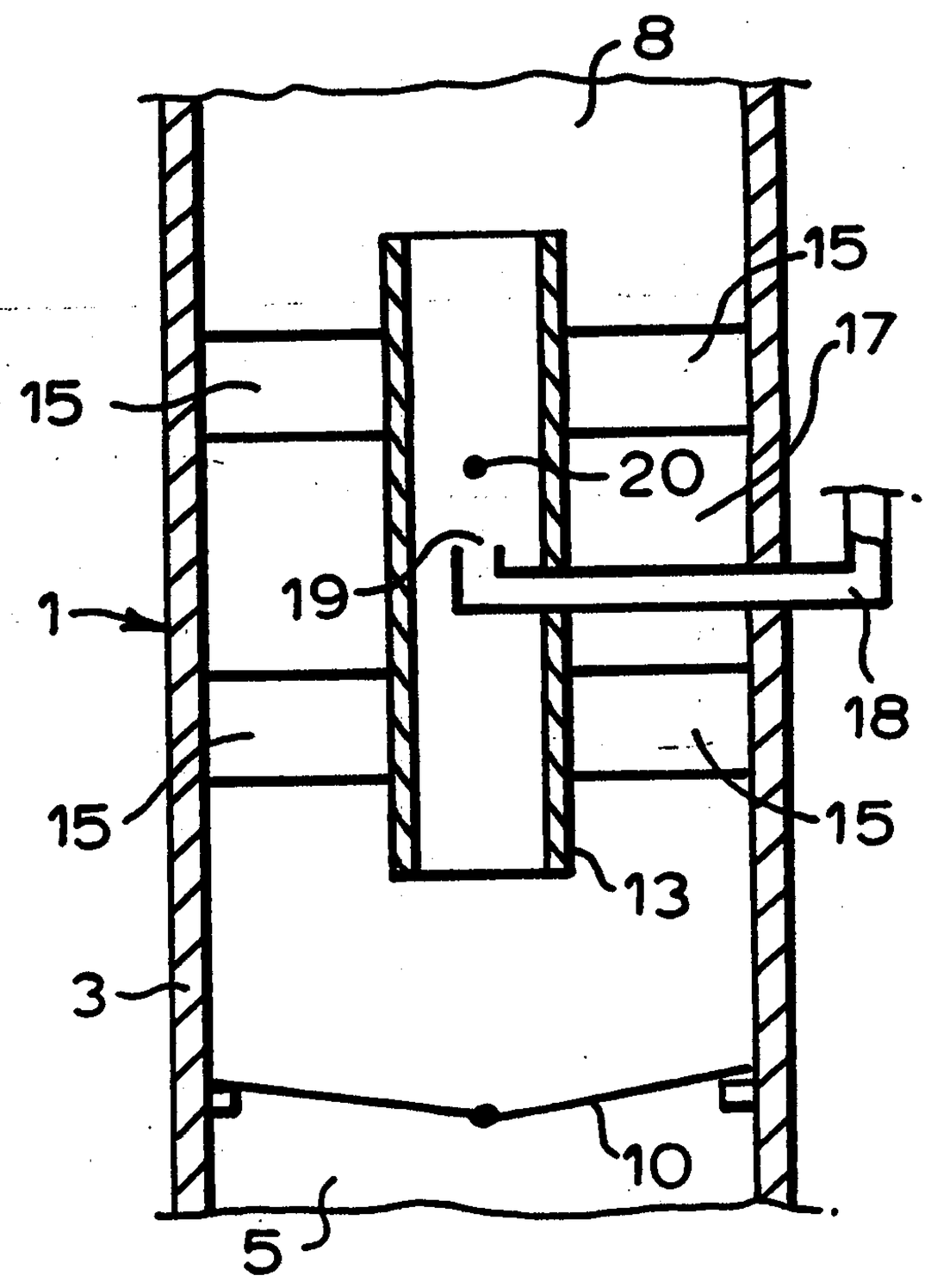
(54) Title: COMPRESSING COMBUSTIBLE GAS FLOWING THROUGH A CONDUIT

(57) Abstract

Method of compressing combustible gas flowing through a conduit (3) provided with a non-return inlet valve (10) arranged at its inlet end (5) and with an open-ended tubular (13) arranged in the conduit (3) comprising (a) allowing combustible gas to enter into the conduit (3); (b) supplying oxidant to the combustible gas in the tubular (13), the amount of oxidant being equal to the amount of oxidant required to combust at least part of the combustible gas in the tubular (13); (c) allowing the mixture of combustible gas and oxidant to ignite in the tubular (13), which ignition yields a high pressure wave front closing the non-return inlet valve (10) and pushing gas out of the tubular (13) and entraining gas flowing through the annular space (17) and a low pressure wave front; and (d) allowing the non-return inlet valve (10) to open on arrival of the low pressure wave front, followed by steps (a) through (d).



COMPRESSING COMBUSTIBLE GAS FLOWING THROUGH A CONDUIT

The present invention relates to compressing combustible gas flowing through a conduit. An example of such combustible gas is natural gas.

A suitable application of the present invention is downhole compression of natural gas, this is done to enhance the production from an underground natural gas reservoir. Natural gas is produced from an underground reservoir containing natural gas through a tubing arranged in a well drilled to the reservoir. During production, the cumulative amount of natural gas produced increases and consequently the reservoir pressure will decrease. As a result of the decrease in reservoir pressure the production rate decreases and, in order to maintain the production rate at an economically acceptable level the gas has to be compressed and suitably gas is compressed downhole. This downhole gas compression will result in an increased economic cumulative production.

An alternative application of the present invention is compression of natural gas flowing through a pipeline to increase the rate of natural gas transported through the pipeline.

USA patent specification No. 2 899 287 discloses a method of compressing an oxidant-containing gas flowing through a conduit provided with a tubular arranged coaxially in the conduit which tubular has an inlet end and an outlet end and is provided with a non-return inlet valve at its inlet end. The known method comprises the steps of

(a) supplying fuel into the tubular;

(b) allowing oxidant to enter into the tubular through the non-return inlet valve;

(c) allowing the mixture of fuel and oxidant to ignite, which ignition yields a high pressure wave front closing the non-return

inlet valve and pushing gas out of the outlet end of the tubular and a low pressure wave front; and

(d) allowing the non-return inlet valve to open on arrival of the low pressure wave front, followed by steps (a) through (d).

In the known method the pressure increase for the compression stage is very small, the pressure at the outlet end of the conduit is about 2 or 3% above the pressure at the inlet end. For pumping natural gas such a pressure increase for a compression stage is unacceptably small. Therefore it is an object of the present invention to provide a method of compressing a combustible gas which will yield a much larger pressure increase per compression stage.

To this end the method according to the invention of compressing combustible gas flowing through a conduit having an inlet end and an outlet end and being provided with a non-return inlet valve arranged at its inlet end and with an open-ended tubular arranged coaxially in the conduit which tubular has a cross-sectional area which is smaller than the cross-sectional area of the conduit comprises the steps of

(a) allowing combustible gas to enter into the conduit through the non-return inlet valve;

(b) supplying oxidant to the combustible gas in the tubular, the amount of oxidant being equal to the amount of oxidant required to combust at least part of the combustible gas in the tubular;

(c) allowing the mixture of combustible gas and oxidant to ignite, which ignition yields a high pressure wave front closing the non-return inlet valve and pushing gas out of the tubular and a low pressure wave front; and

(d) allowing the non-return inlet valve to open on arrival of the low pressure wave front, followed by steps (a) through (d).

Applicant has found that to obtain a large pressure increase it is required to let the combustible gas flow intermittently through the conduit so that the high pressure wave front is fully utilized to push the gas out of the tubular allowing to entrain the combustible gas passing through the annular space.

The invention further relates to an apparatus for carrying out the method of compressing combustible gas which apparatus comprises a conduit having an inlet end and an outlet end, a non-return inlet valve arranged at the inlet end of the conduit, an open-ended tubular arranged coaxially in the conduit downstream of the non-return inlet valve, a localized ignition source arranged in the tubular, and an oxidant supply debouching into the tubular, wherein the cross-sectional area of the tubular is smaller than the cross-sectional area of the conduit and wherein an annular passage is defined between the tubular and the conduit.

The invention will now be described by way of example in more detail with reference to the accompanying drawing showing schematically a cross-sectional view of the apparatus for carrying out the method of compressing combustible gas according to the invention.

The apparatus 1 for compressing combustible gas comprises a conduit 3 having an inlet end 5 and an outlet end 8, which conduit 3 is provided with a non-return inlet valve 10 arranged at the inlet end 5 of the conduit 3.

In the conduit 3 is arranged coaxially an open-ended tubular 13 downstream of the non-return inlet valve 10. The open-ended tubular 13 is fixed in the conduit 3 by means of struts 15. The cross-sectional area of the open-ended tubular 13 is smaller than the cross-sectional area of the conduit 3 so that an annular passage 17 is defined between the outer wall of the open-ended tubular 13 and the inner wall of the conduit 3.

The apparatus 1 furthermore comprises an oxidant supply 18 of which the outlet opening 19 debouches into the open-ended tubular 13, and a localized ignition source 20 arranged in the open-ended tubular 13 downstream of the outlet opening 19 of the oxidant supply 18. The localized ignition source 20 is connected to a supply of electric power (not shown) for allowing the source 20 to glow.

The apparatus 1 is arranged in a pipe for transporting combustible gas, for example the apparatus 1 is arranged in a tubing (not

shown) arranged in a well through which natural gas can rise from the bottom of the well to surface.

During normal operation natural gas flows through the tubing and enters the apparatus 1 through the non-return inlet valve 10 arranged at the inlet end 5 of the conduit 3. The gas flows through the annular space 17 and through the open-ended tubular 13. Oxidant is supplied to the combustible gas in the open-ended tubular 13, wherein the amount of oxidant is sufficient to combust at least part of the combustible gas in the open-ended tubular 13. Suitably the amount of oxidant equals the amount of oxidant required to combust the combustible gas in the open-ended tubular 13.

Electric power is supplied to the localized ignition source 20 and the mixture of combustible gas and oxidant is allowed to ignite in the open-ended tubular 13. This ignition yields a high pressure wave front closing the non-return inlet valve 10 and pushing gas out of the open-ended tubular 13 and a low pressure wave front. The gas flowing out of the open-ended tubular 13 entrains gas flowing through the annular space 17.

The amount of gas combusted in the open-ended tubular 13 is smaller than the total amount of combustible gas flowing through the conduit 3.

Upon arrival of the low pressure wave front at the non-return inlet valve 10, the non-return inlet valve 10 opens allowing natural gas to enter into the apparatus 1, and the above described sequence of steps starts again to compress the natural gas.

When the localized ignition source 20 is sufficiently heated, the localized ignition source acts as a hot spot so that supply of electric power can be interrupted.

The oxidant is a gas containing free oxygen, an example of suitable oxidant is air, a further example is air enriched with oxygen. The oxidant can furthermore contain water, which upon vaporizing in the open-ended tubular 13 will furthermore increase the pressure.

The non-return inlet valve 10 can be provided with a control device (not shown) allowing opening of the non-return inlet valve 10 at a pre-determined pressure difference across the valve. An

example of the control device is a spring, another example is a magnetic latch.

It will be appreciated that more than one apparatus according to the present invention can be arranged in series, each following apparatus compressing the gas compressed by the previous one. If required, the compressed gas can be cooled between two successive compression stages.

The conduit 3 has a constant inner diameter; in an alternative embodiment of the invention, the conduit comprises in the direction of flow a narrowing section, a section having a constant diameter (in which section the open-ended tubular is arranged) and a widening section.

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CLAIMS:

1. A method of compressing a combustible natural gas flowing at a downhole location in a natural gas production wall through a conduit which contains a non-return inlet valve arranged at its inlet end and a tubular which is open at both ends such that an annular passage is defined between the conduit and tubular, which method comprises the steps of

(a) allowing gas to enter into the conduit through the non-return inlet valve;

(b) creating a combustible mixture in the tubular by supplying such an amount of oxidant that at least part of the combustible natural gas is combustible in the tubular;

(c) igniting the mixture in the tubular, which ignition yields a high pressure wave front closing the non-return inlet valve and pushing gas out of the tubular and a low pressure wave front; and

(d) allowing the non-return inlet valve to open on arrival of the low pressure wave front, followed by steps (a) through (d).

2. An apparatus for carrying out the method of compressing gas according to claim 1, comprising a conduit, a non-return inlet valve arranged at the inlet end of the conduit, a tubular arranged coaxially in the conduit downstream of the non-return inlet valve such that an annular passage is defined between the tubular and the conduit, a localized ignition source arranged in the tubular, characterized in that the conduit is locatable at a downhole location in a natural gas production well, that the tubular is open at both ends and equipped with an oxidant

supply through which such an amount of oxidant can be supplied that at least part of the natural gas is combusted in the tubular.

3. The apparatus according to claim 2, wherein the non-return inlet valve is provided with a control device allowing opening the inlet valve at a pre-determined pressure difference.

4. The apparatus according to claim 2, wherein the localized ignition source is formed by a glow plug.

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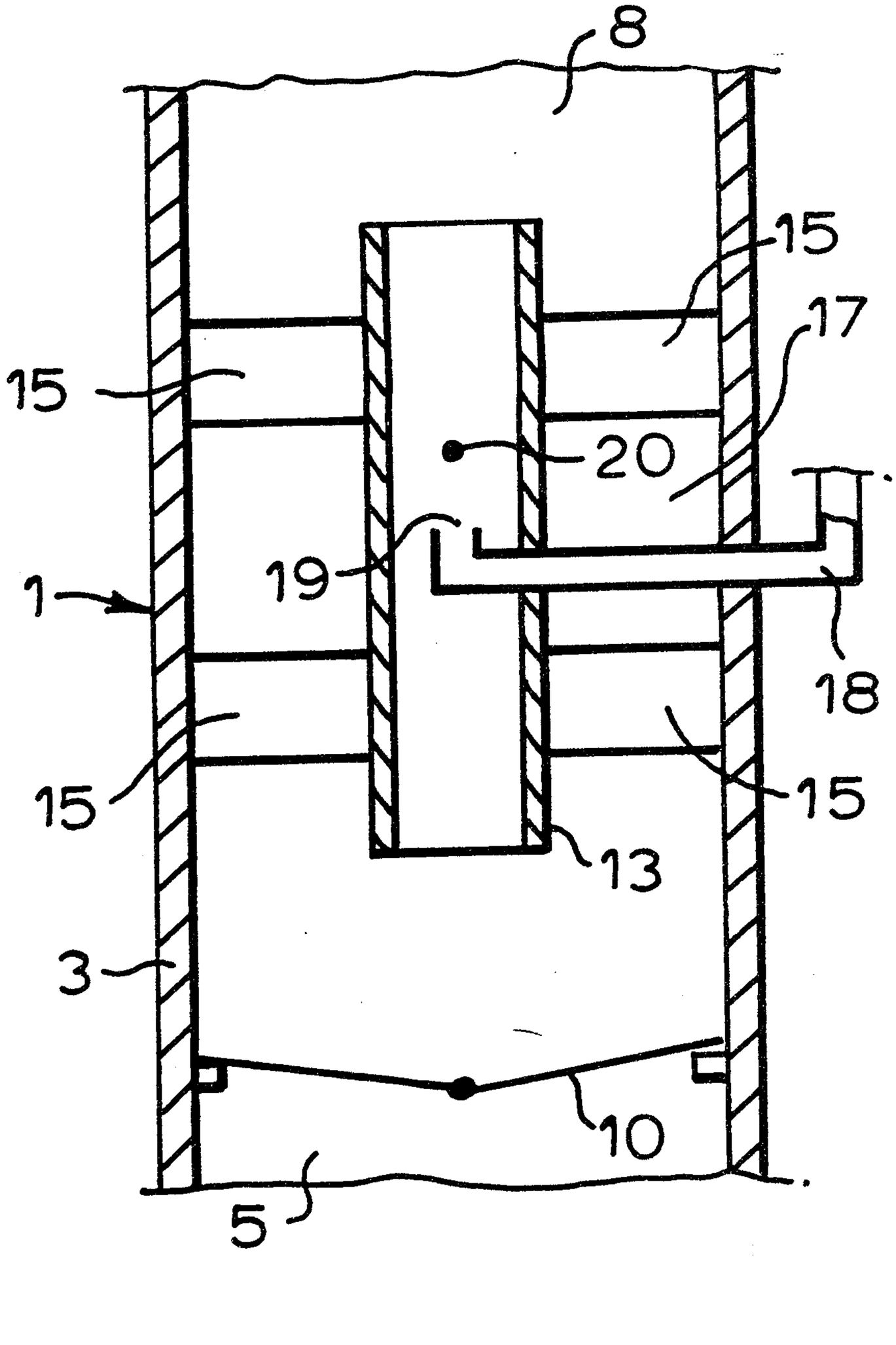

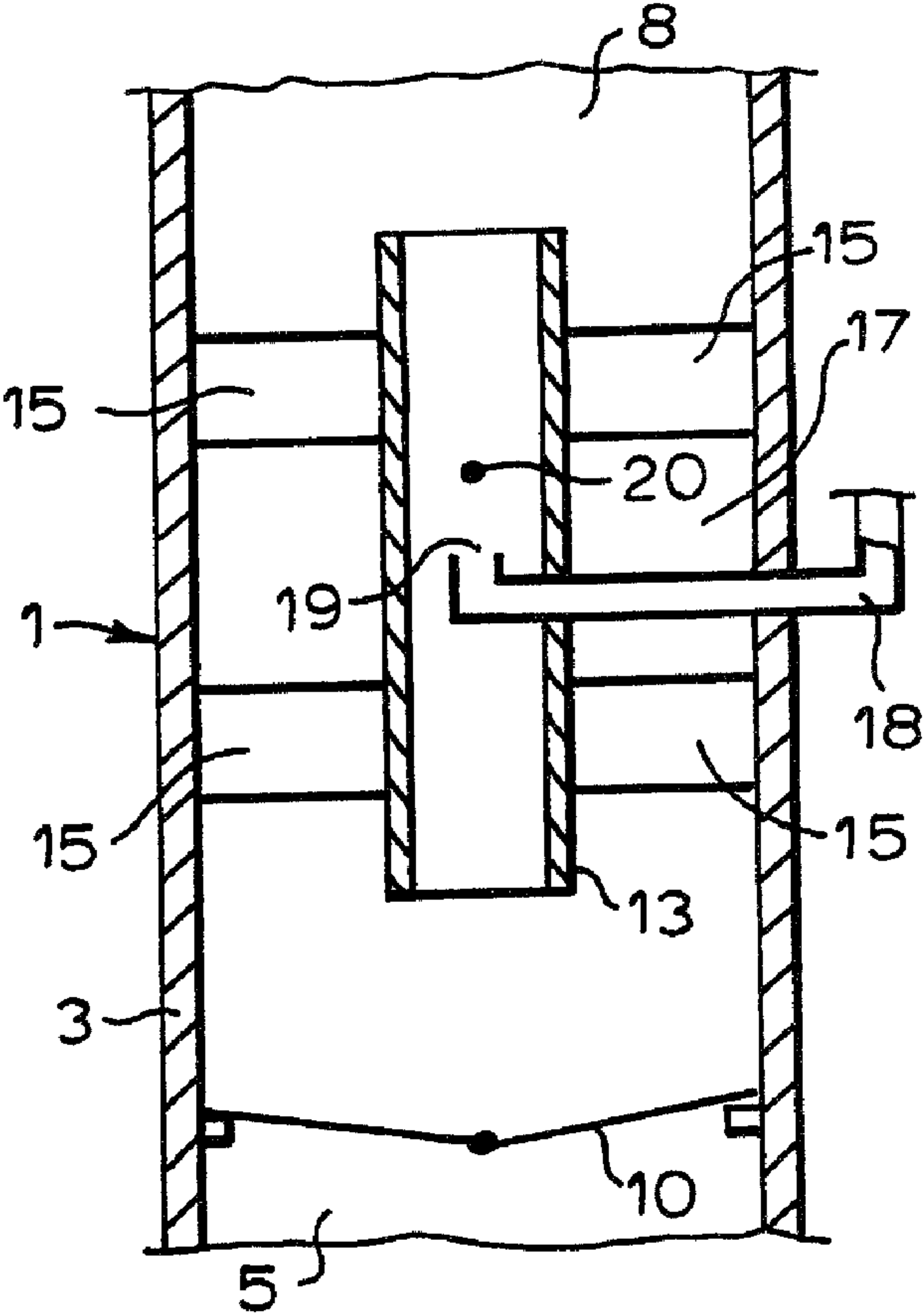
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