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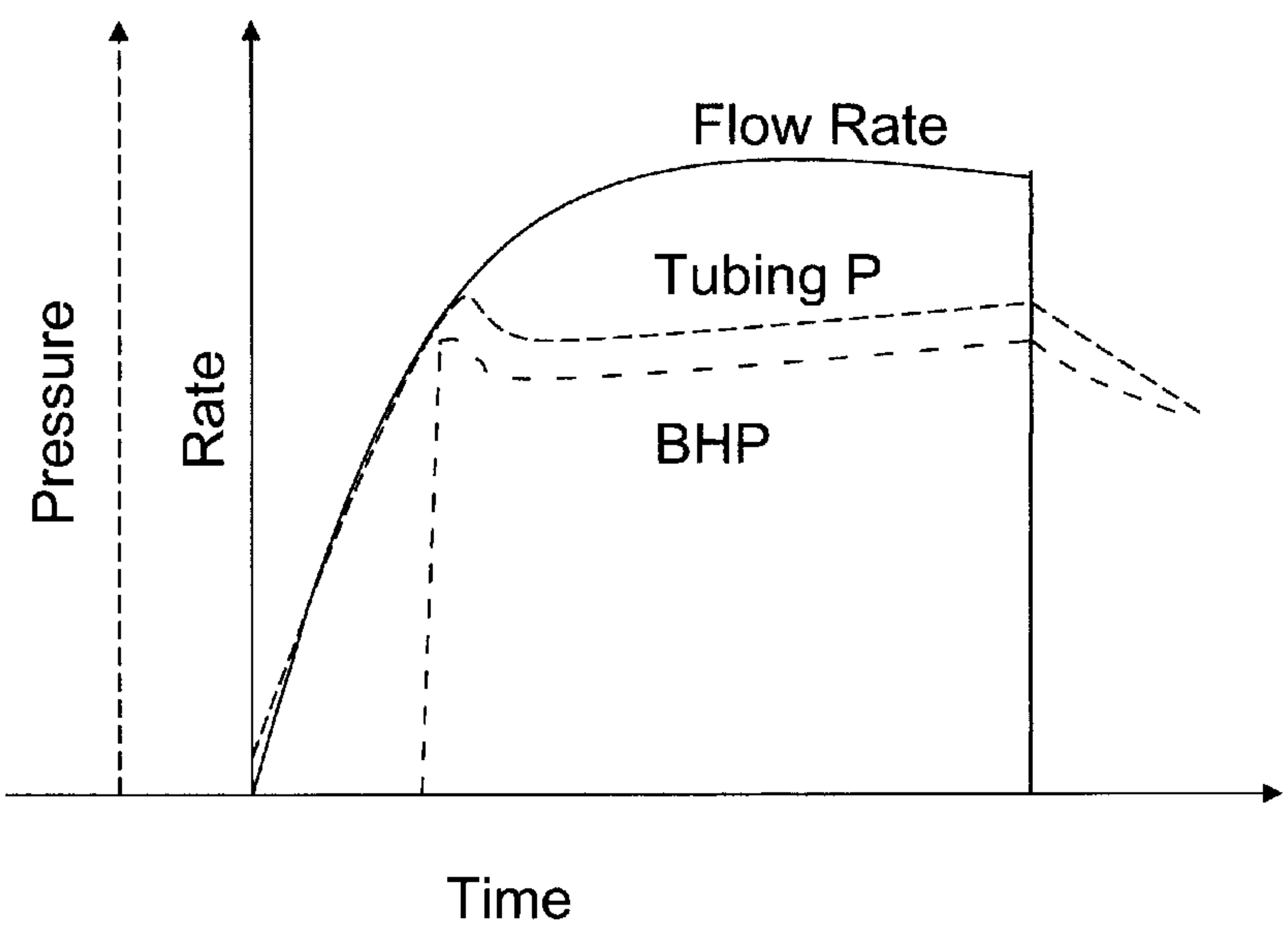
Single Fire Shock Release Simulated Response



"SHOCK-RELEASE FLUID FRACTURING METHOD AND APPARATUS"

FIELD OF THE INVENTION

The invention relates to method and apparatus for improving the extent of fracturing of formations using a shock release of fracturing fluid.

BACKGROUND OF THE INVENTION

Conventional fluid fracturing of subterranean formations comprises positioning a tool in a cased wellbore traversing a zone to be fractured. The tool straddles perforations in the cased wellbore. Fluid is pumped down a tubular conduit from surface to the subterranean tool at a flow rate and pressure sufficient to hydraulically fracture the formation.

The exact nature of the resulting fractures is not fully known and will vary for different formations. As set forth in US Patent 4,995,463 to Kramm et al., issued in 1991, the fracture mechanics and fluid flow behaviour in cleated, coal bed formations is substantially different that those in sandstone and the like which are more conventionally known for oil and gas operations.

SUMMARY

Where the fracturing fluid used for hydraulically fracturing formations is a compressible fluid, such as those in the gaseous phase, such fracturing processes expose the formation to gradually greater and greater pressures until either the extend of fracturing is achieved or the losses through developed fractures exceeds the rate of fluid injection. It is believed that some formations are less effectively fractured using gradual exposure to hydraulic pressures.

In one aspect of the invention a shock tool is provided comprising a valve adapted to bottom hole tool assembly for accumulating fracturing fluid at fracturing pressures for rapid release to the formation. This apparatus is well suited for a novel fracturing methodology wherein the valve opens suddenly for maximum shock to the formation. Coal bed methane seams of formations can be particularly well suited to such a fluid hammer fracturing methodology. After a first zone is shocked, the tool can be moved to a new zone, or multiple shocks can be applied cyclically at the selected zone.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a tool assembly for location at a subterranean formation and incorporating an embodiment of a shock tool of the present invention;

Figure 2 is a cross-sectional view of an embodiment of the shock tool in the closed position;

Figure 3 is a partial cross sectional view of the poppet valve of the tool according to Fig. 2;

Figure 4 is a cross-sectional view of an embodiment of the shock tool in the open position;

Figure 5 is a partial cross sectional view of the poppet valve of the tool according to Fig. 4;

Figure 6 is a side by side comparison of the tool in the close and open positions;

Figures 7A, 7B and 7C are charts comparing conventional fracturing (Prior Art), fracturing using a accumulated shock release of fracturing fluid with full pressure release, and cyclical shock fracturing; and

Figure 8 is a cross-sectional view of the embodiment of the shock tool according to Fig. 3, in the closed position, while running in showing casing annulus fluid flow being circulated back uphole through the relief valve of the shock tool and the bore of the conveyance string.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to Fig. 1, a tool assembly is provided for conveyance and actuation in a cased wellbore. The tool assembly incorporates a shock tool according to an embodiment of the present invention. The tool assembly is lowered downhole into the casing on a conveyance string such as on jointed tubulars or coiled tubing. The conveyance string has a bore for conducting fracturing fluids to the tool. An annulus is formed between the tool assembly and the casing.

The tool assembly comprises conventional connector means for attaching the tool assembly to the conveyance string. Generally, the tool assembly comprises the shock tool, the connector means for connecting the shock tool to the conveyance string, means for connection the shock tool to an injection packer and other tool components for enabling tripping and operations of the tool.

The injection packer can be of conventional construction and comprises opposing uphole and downhole seals such as packers, sealing elements (compression/tension). As shown, one type of injection packer is a straddle packer tool having elastomeric cups as sealing elements which separate high pressure fracturing fluid from lower pressure in the annulus above and below the tool assembly. The uphole and downhole cups are spaced by a pup joint. The pup joint has an injection port for fluid communication with that part of the annulus isolated between the opposing cups. The injection packer is located with the uphole and downhole cups straddling perforations in the casing enabling exposure of the fracturing fluid through the injection port and to the formation. Typically, the downhole end of the tool assembly can be fit with an instrumentation probe housing and bullnose.

The shock tool is a pressure-actuated valve for accumulating fracturing fluid at a threshold pressure for sudden or shock release through the injection packer. The resulting shock might be equivalent to a water-hammer effect. A large stored energy is released into the formation.

Generally, as seen in Fig. 2, the shock tool has a tubular body having a bore connected at an inlet end to a source of fracturing fluid, such as the conveyance string. The bore of the shock tool is connected at a discharge end for the direction of accumulated fracturing fluid to the formation.

The body is fit with a sleeve forming a bypass annulus which communicates between the uphole end and the downhole end of the shock tool. The bypass annulus is fit with a valve for enabling and disabling flow through the bypass annulus. In a closed position, fracturing fluid can accumulate to a fracturing pressure at the uphole end of the shock tool. In the open position fracturing fluid flows through the bypass annulus for fluid communication with the formation.

In one embodiment, the valve is formed of a piston movable axially within the sleeve for opening and closing a valve port formed in an uphole end of the sleeve. The valve opens at a release pressure (Figs. 4,5) , which can be a release or fracturing pressure, and closes (Figs. 2,3) when an effective flow of fracturing fluid has affected the formation.

As shown in Fig. 7A, a typical fracturing operation with gaseous fluids such as nitrogen comprise pumping gas downhole to the formation at a rate which exceeds the loss of fluid into the formation. Thus tubing pressure and bottom hole pressure increase in unison. At a certain pressure, the formation fractures and fluid rates are usually increased for a period to accommodate increased flow into the fractures.

With reference to Figs. 7B and 7C, apparatus such as the shock tool enables a new methodology of operation which comprises pumping fracturing fluid, such as gaseous nitrogen, down coiled tubing to the shock tool and building pressure to a pre-determined pressure tuned to the formation. The bottom hole pressure remains at formation pressure as the tubing pressure builds. The shock tool opens and there is a sudden release of the fracturing fluid to impact the formation.

Once the valve opens, the bottom hole pressure equilibrates to substantially the same as the accumulated tubing pressure, applying the full fracturing pressure substantially immediately to the formation. It is believed that a coal bed methane formation is particularly favourably affected by a shock application of the fracturing fluid.

Once the valve is open can permit the pressure to dissipate, or as shown in Fig. 7B, one can continue to flow fracturing fluid through the valve and into the formation for a period and then permit the pressure to dissipate. Alternatively, as shown in Fig. 7C, one can cycle the pressure. Cycling of the pressure could be advantageous for some formations can could include nearly complete dissipation of fluid pressure before closing the valve and re-accumulating fluid pressure for a subsequent shock fracturing operation. Alternatively, a series of lesser pressure differential cycles could be applied, wherein the shock tool is opened, some pressure is released, pressure is accumulated and released again in rapid cycles.

Due to the compressibility of gases, fracturing fluids such as nitrogen are advantageously applied using the shock methodology.

The shock tool can have its valve operated by a variety of techniques including pressure, motors and remote triggering tool. Returning to Figs. 2 – 5, one embodiment that is particularly useful is a poppet-operated valve shock tool.

As stated above, the body is fit with a sleeve forming the bypass annulus. The sleeve is cylindrical and is secured within the body with a threaded cylindrical uphole sub which sandwiches the sleeve between a supporting shoulder at the downhole end and a sealing shoulder at the uphole sub.

The valve is formed by a poppet piston movable axially within the sleeve at an uphole end for opening and closing a valve port formed in an uphole end of the sleeve. The valve port is in fluid communication with the bypass annulus. When the valve is closed, the valve port is blocked by the piston. The downhole end of the sleeve is fit with open downhole ports for enabling flow therethrough.

The poppet piston is locked until a locking cylinder is caused to release at the fracturing pressure, enabling a snapping open of the poppet piston and substantially instantaneous release of the fracturing fluid. The poppet piston is biased to the closed position. The biasing, such as by a valve spring is determined to reset the poppet piston one the pressure on the poppet piston ahs dissipated.

With reference to Figs. 3 and 5, the poppet-operated valve comprises: an annular locking piston which is actuated by a trigger arrangement. The trigger arrangement comprises a trigger piston movable axially within the annular locking piston. Once the fluid pressure acting against the trigger piston overcomes the trigger spring, a profiled trigger spool shifts within the annular locking piston and thereby releases the annular locking piston for movement relative to the sleeve operating the valve.

The locking piston is releasably locked to the sleeve by balls which shift between two positions. In one position (Fig. 3), the balls lock the annular locking piston to the sleeve preventing the valve from opening. In the other position (Fig. 5), the balls lock the trigger piston to the annular locking piston.

The balls shift laterally within ports in the annular wall of the annular locking piston to alternatively straddle laterally between the sleeve and the annular locking piston (locked closed) and between the annular locking piston and the trigger spool (unlocked open). The sleeve is fit with profiled grooves to partially accept the balls and enable axial movement of the trigger spool within the annular locking piston. At fracturing pressure, the trigger spool can move axially downhole to align the trigger spool grooves and ports in the annular wall of the annular locking piston. At low fluid pressures, trigger spring can bias the trigger spool uphole to reset the locking arrangement.

The trigger spool is likewise fit with annular grooves to partially accept the balls and enable axial movement of the annular locking piston and trigger spool relative to the sleeve. At fracturing pressure, the annular locking piston, trigger piston and supported poppet piston can shift downhole to open the valve. At low fluid pressures, the valve spring biases the poppet valve uphole to close the valve.

The bypass annulus can be sized with a similar cross-section flow area as the bore of the conveyance string or injection packer to avoid introducing a pressure drop.

With reference to Fig. 8, the sleeve can be fit with pressure relief valves for enabling uphole flow from the downhole end of the shock tool and into the bore of the conveyance string or tubing. This is especially useful while running in the tool assembly for avoiding pressure build up at the injection packer which can pre-set the uphole seal or cups.

In one embodiment, while running in, fluid, conveniently the same fluid as the fracturing fluid, is injected into the annulus between the casing and tool assembly. Fluid flows past the uphole cups, separating them from the casing wall to avoid pre-activation and wear. The annulus fluid flows into the injection packer backwards through the injection port, then uphole into the shock tool, through the tool's bypass annulus and through the relief valves for circulation to the surface. The relief valves are ineffective during the normal accumulation and shock release modes of the shock tool.

The predetermined fracturing pressure accumulated at the shock tool can be about the fracture gradient of the formation or the overburden strength of about 20kPa/meter of depth or greater. For example, fracturing fluid pressure for a zone depth of about 600 meters could be initially set for 12 to 25 MPa.

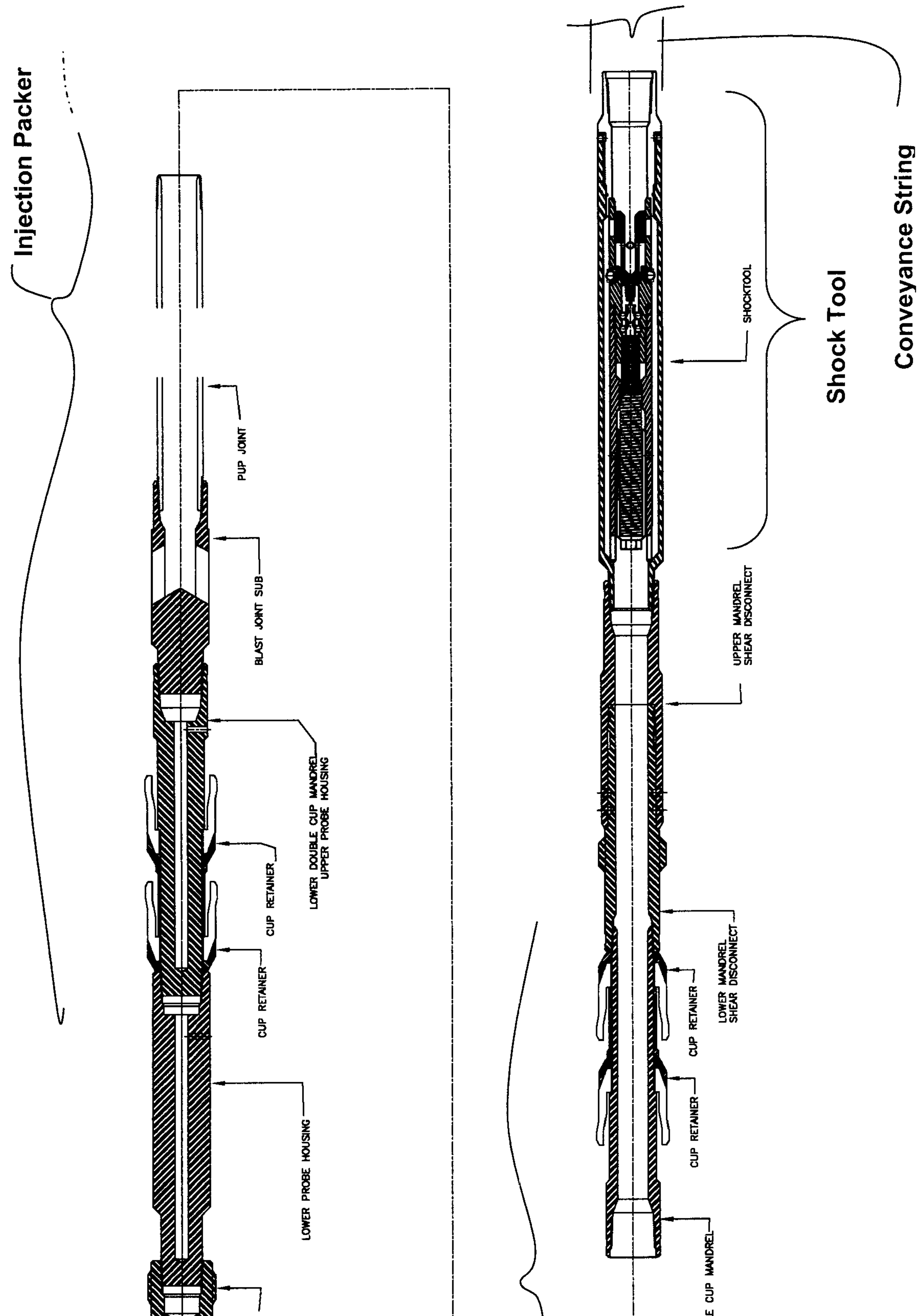

Injection Packer
Conveyance String
Shock Tool
SHOCKTOOL
PUP JOINT
BLAST JOINT SUB
LOWER DOUBLE CUP MANDREL
UPPER PROBE HOUSING
CUP RETAINER
CUP RETAINER
LOWER PROBE HOUSING
BULLNOSE
UPPER MANDREL
SHEAR DISCONNECT
LOWER MANDREL
SHEAR DISCONNECT
CUP RETAINER
CUP RETAINER
UPPER DOUBLE CUP MANDREL

Fig. 1

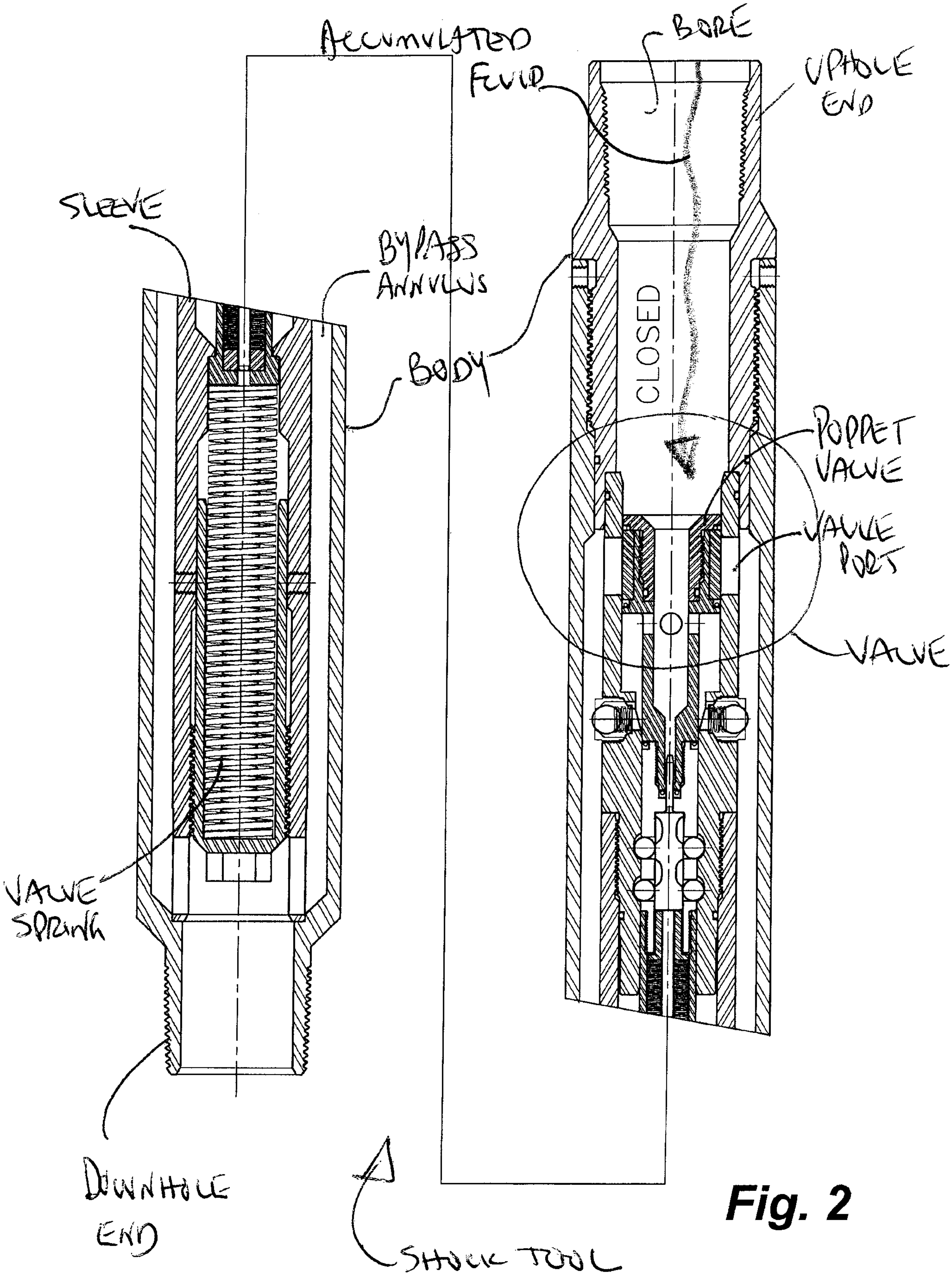

ACCUMULATED
FLUID
BORE
UPHOLE
END
SLEEVE
BYPASS
ANNULUS
BODY
CLOSED
POPPET
VALVE
VALVE
PORT
VALVE
VALVE
SPRING
DOWNHOLE
END
SHOCK TOOL

Fig. 2

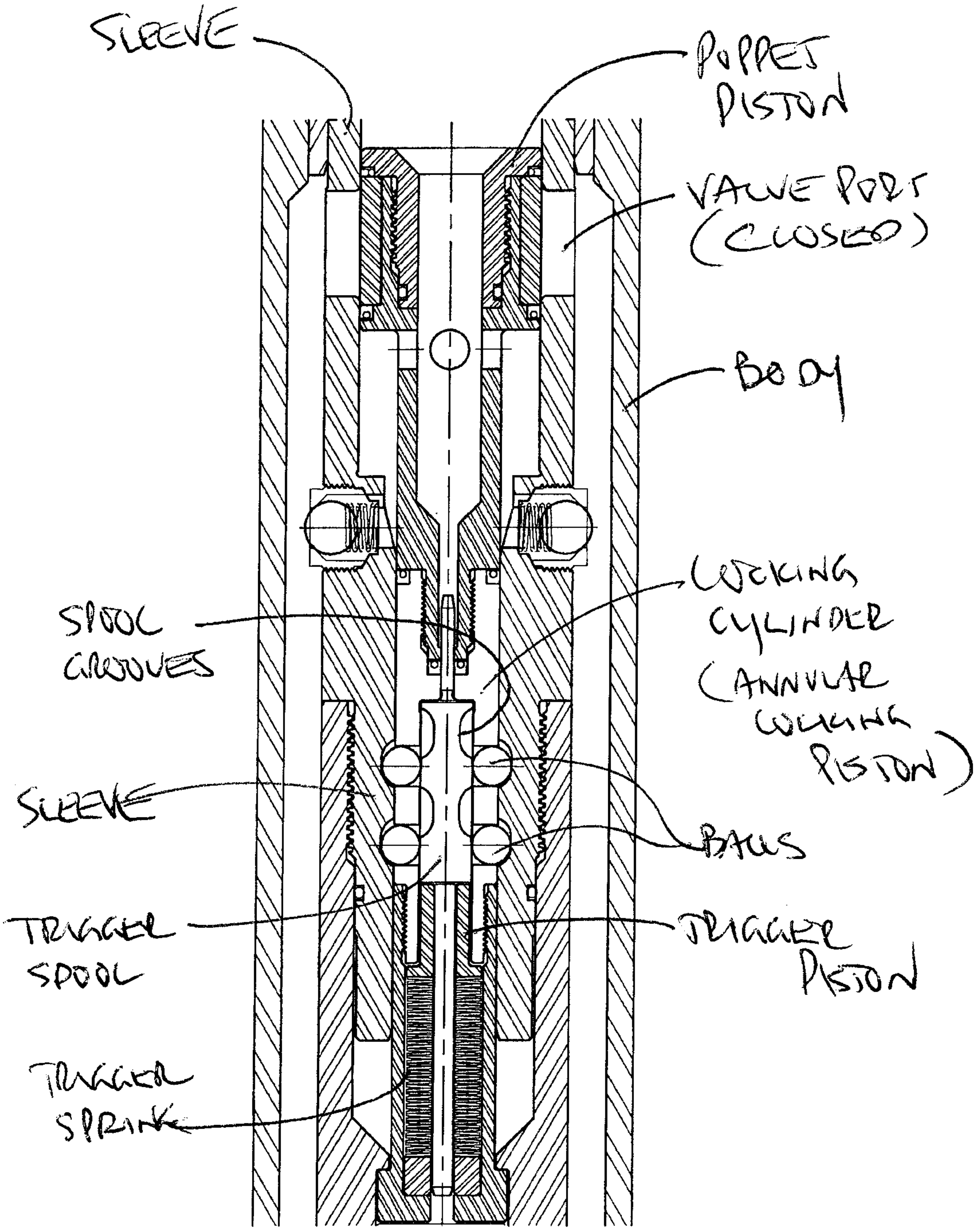

SLEEVE
POPPET PISTON
VALVE PORT (CLOSED)
BODY
LOCKING CYLINDER (ANNULAR LOCKING PISTON)
SPOOL GROOVES
SLEEVE
BALLS
TRIGGER SPOOL
TRIGGER PISTON
TRIGGER SPRING

Fig. 3

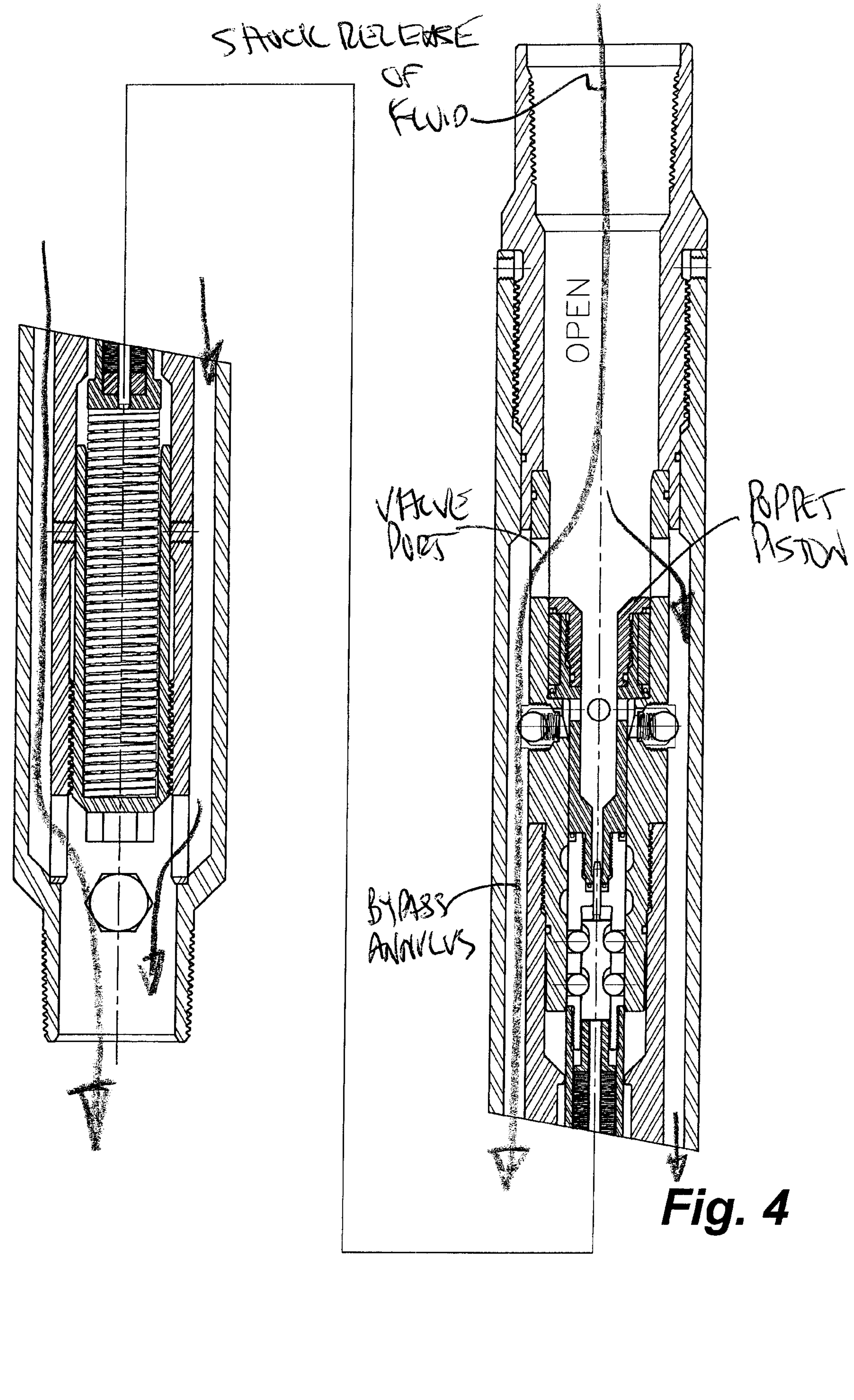

SHOCK RELEASE
OF
FLUID
OPEN
VALVE
PORTS
POPPET
PISTON
BYPASS
ANNULUS

Fig. 4

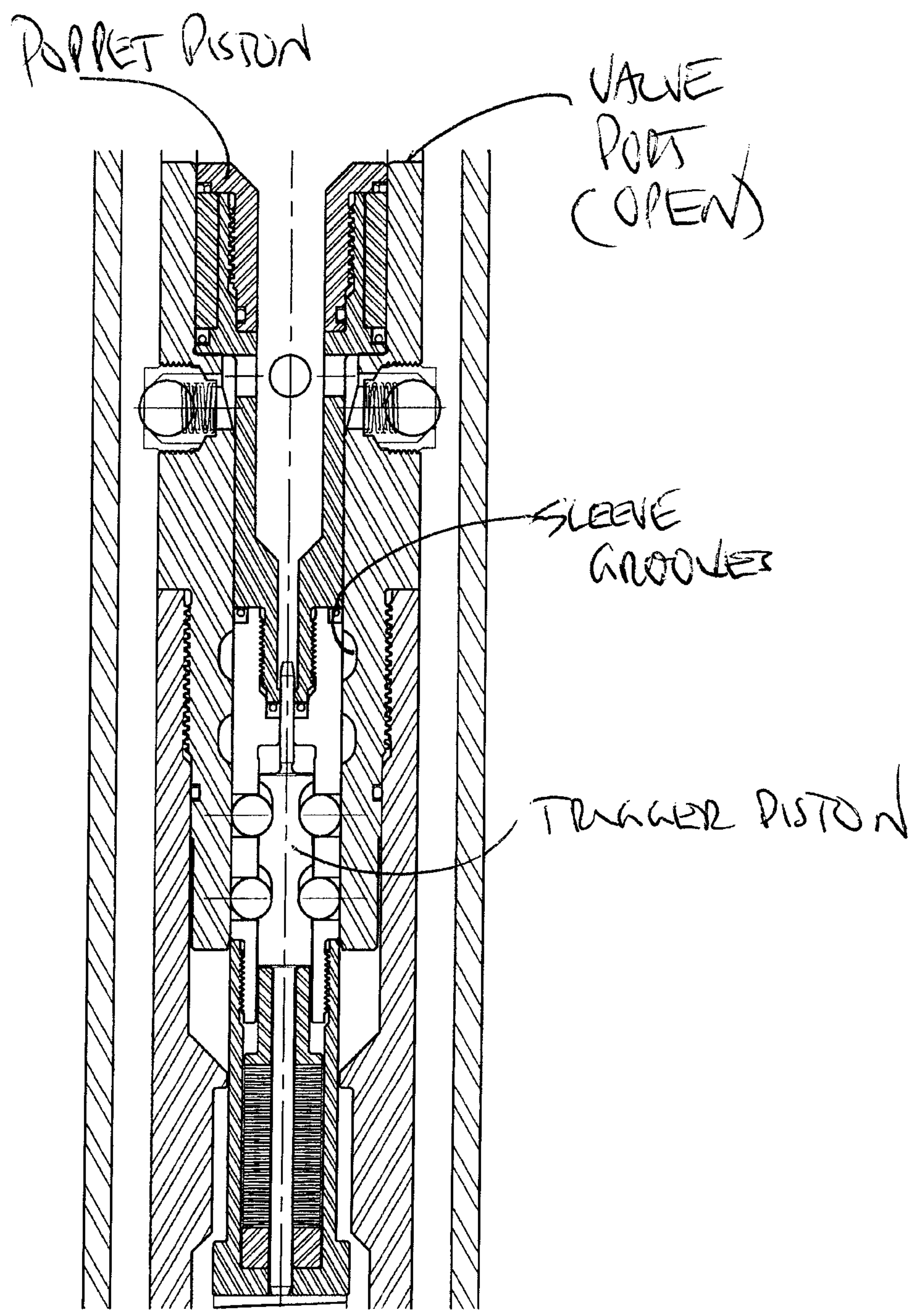

POPPET PISTON
VALVE
PORTS
(OPEN)
SLEEVE
GROOVES
TRIGGER PISTON

Fig. 5

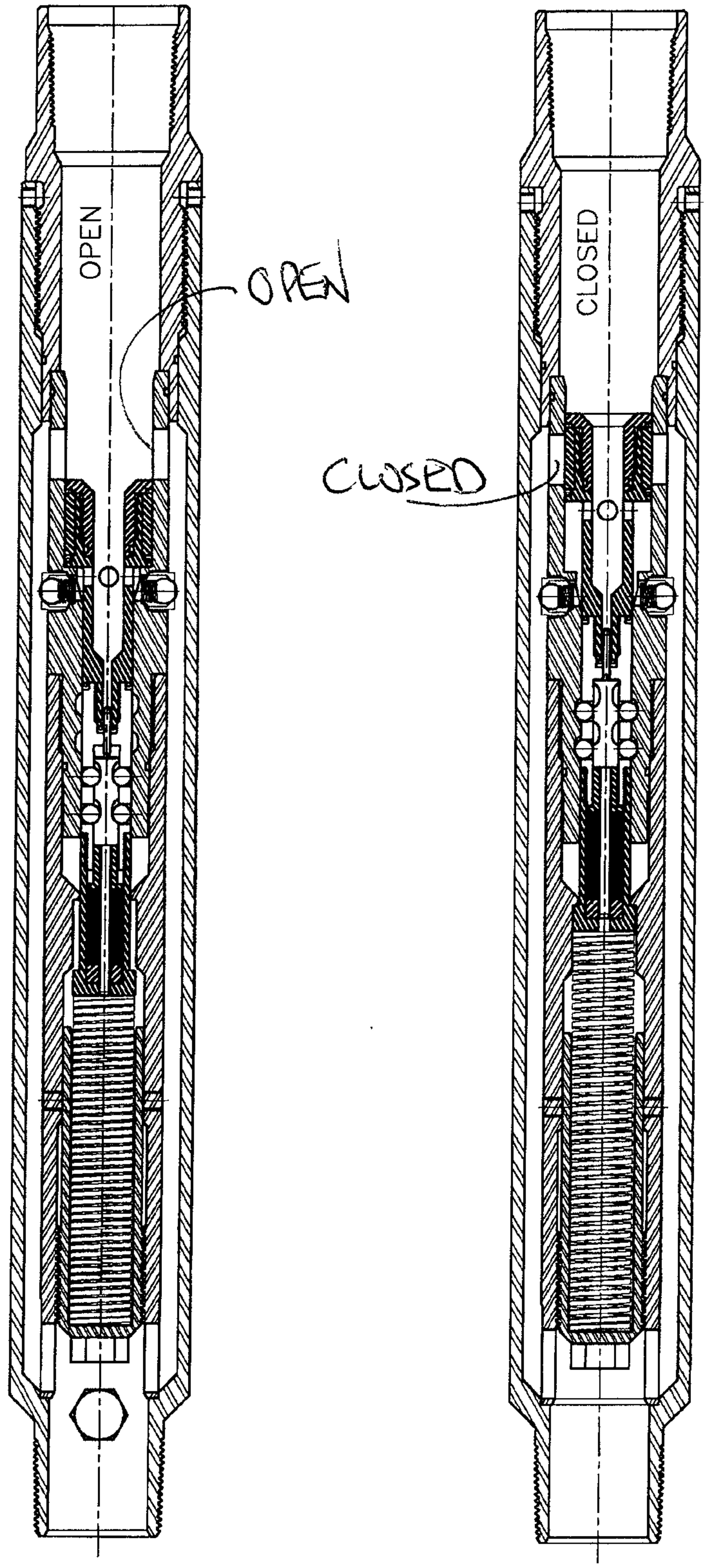


Fig. 6

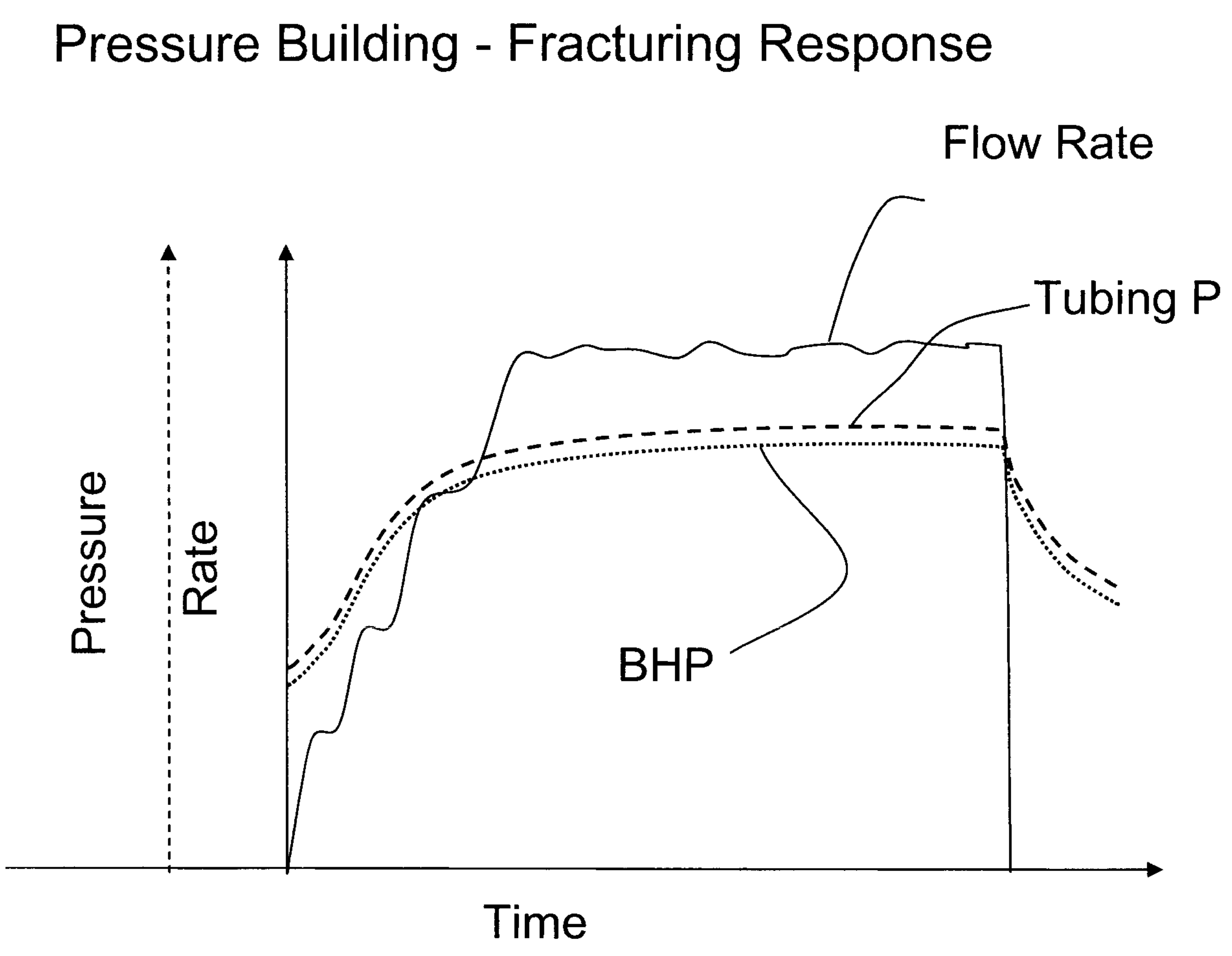


Fig. 7A Prior Art

Single Fire Shock Release Simulated Response

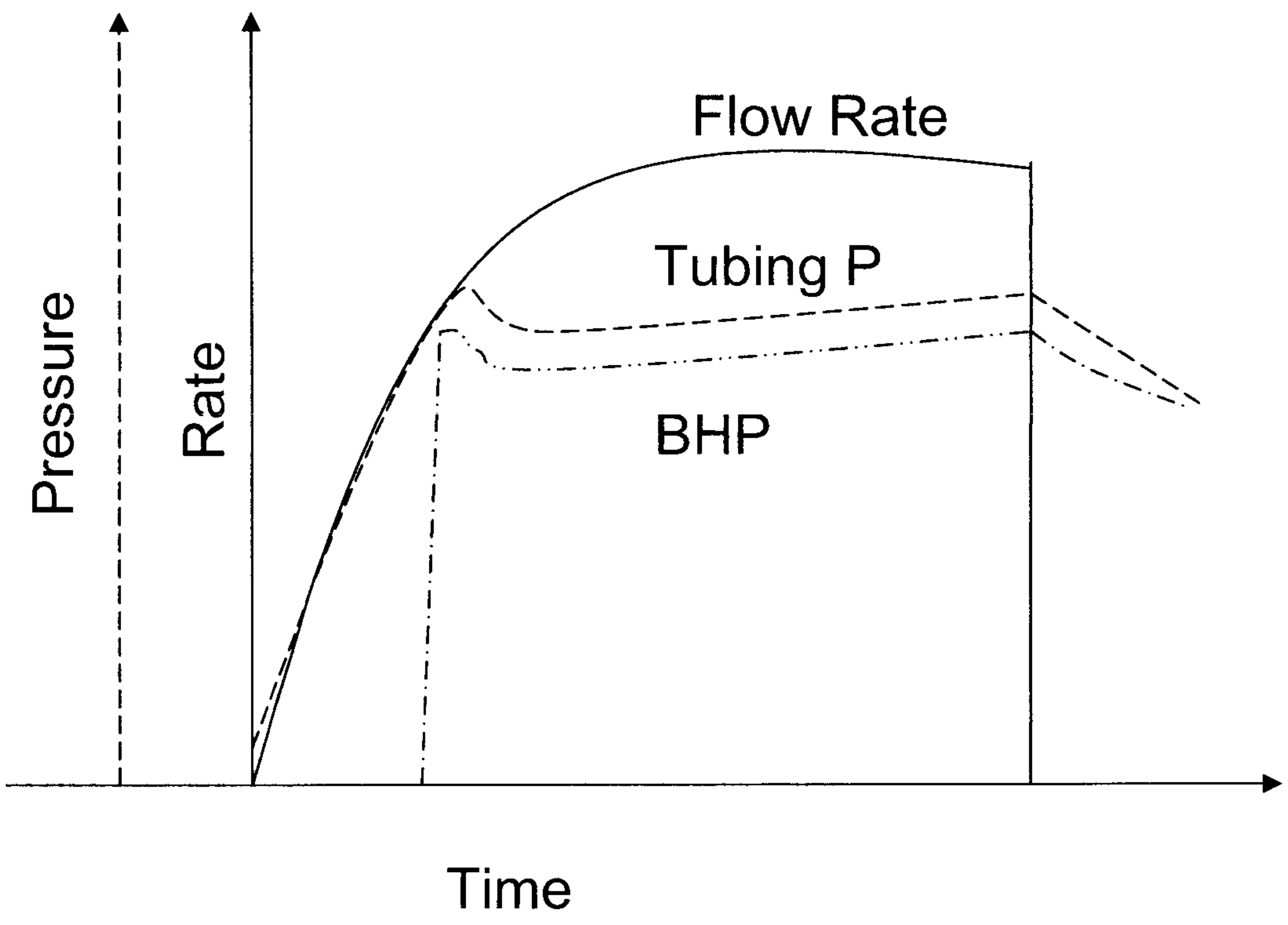


Fig. 7B

Multi-Fire Shock Release Simulated Response

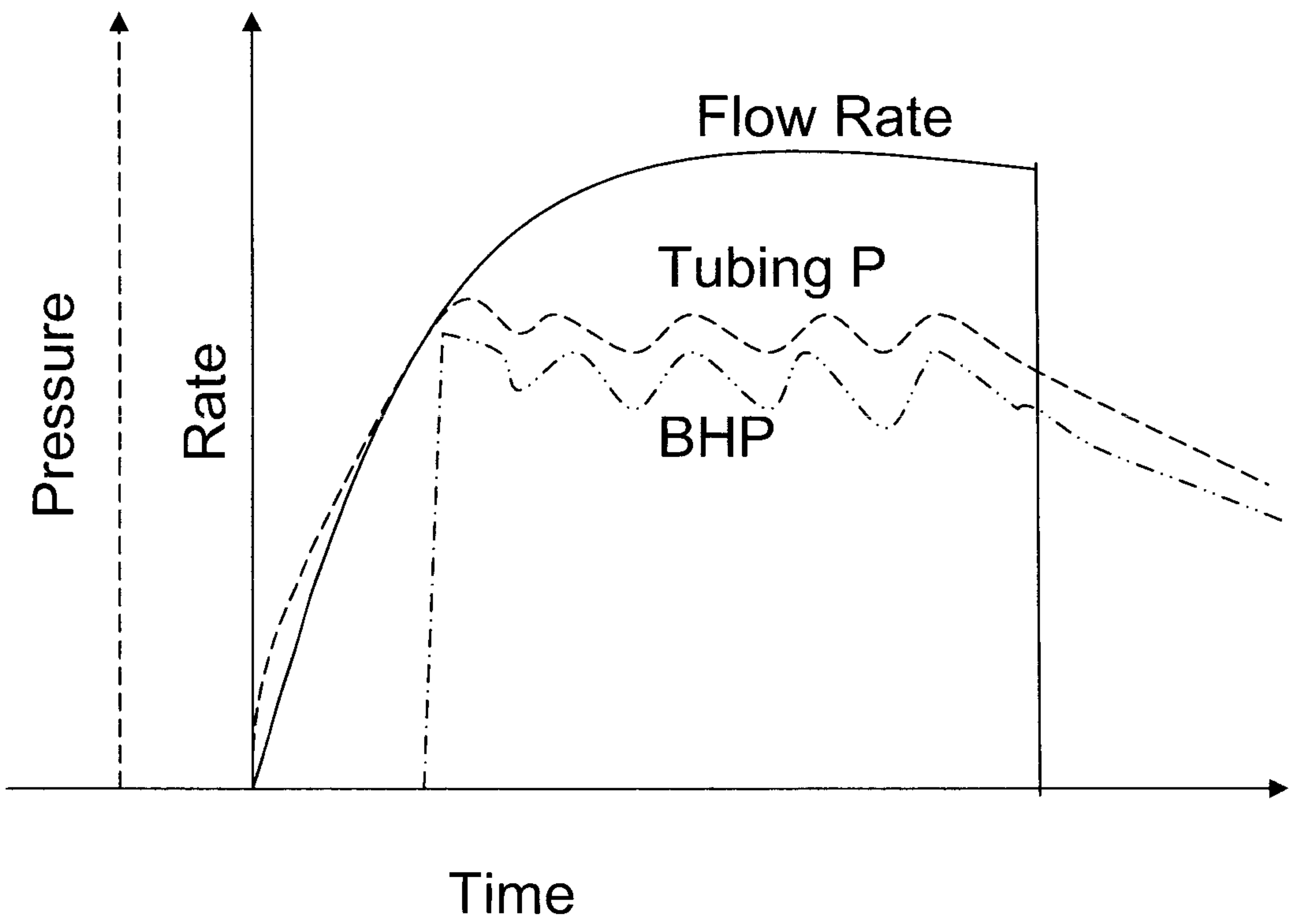


Fig. 7C

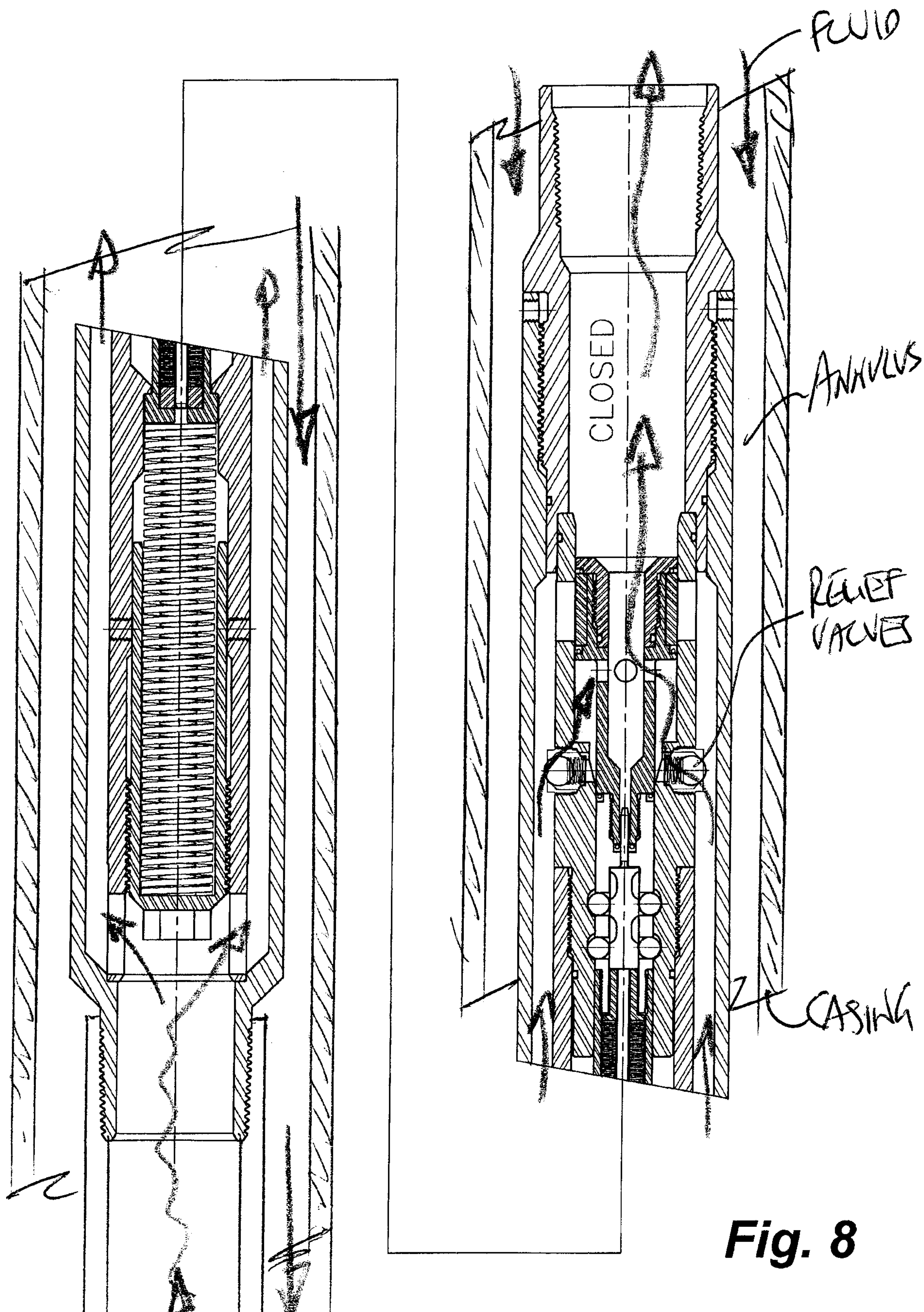


Fig. 8

Single Fire Shock Release Simulated Response