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(71) Applicant: APLISENS S.A. [—/PL]; ul.Morelowa 7, PL-03-192 Warszawa (PL).

(72) Inventor; and

(71) Applicant : MAST Dr STRĄCZYŃSKI, Marian [—/PL]; ul.Dzika 38, Belchatów, 97-0400 (PL).

(72) Inventor: STRĄCZYŃSKI, Marian; ul.Dzika 38, PL-97-400 Belchatów (PL).

(74) Agent: ADAMCZYK, Piotr; Kancelaria Patentowa Piotr Adamczyk, ul.Wilcza 70/8, PL-00-670 Warszawa (PL).

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(54) Title: METHOD FOR CONDUCTING ON-GOING ANALYSIS OF THE CURRENT TECHNICAL CONDITION OF A SUBMERSIBLE PUMP SYSTEM AND A PROBE USED FOR EMPLOYING THIS METHOD

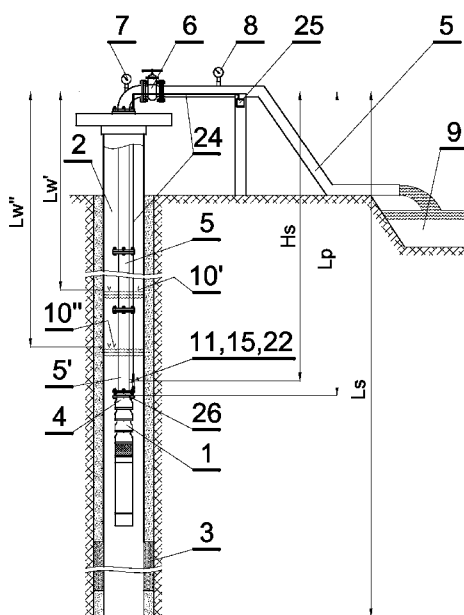


Fig. 1

(57) Abstract: The method concerns a pump system comprising a submersible pump (1) with a known lift as a function of capacity determined on a test stand, with the submersible pump immersed in a liquid contained in a deep well (2), and a pressure pipeline (5) with fittings, which discharges the pumped liquid, and is connected to the pressure port (4) of the same submersible pump (1). The method is characterised in that for a given capacity of the pump system measured at its downstream end, differential pressure is determined between the liquid pressure in the pipeline (5) near the pump (1) pressure port (4) and the hydrostatic pressure of the same liquid outside of the pump (1) at the pump pressure port (4). The differential pressure determined in this way is then compared against the lift (H), which results from the known lift as a function of capacity (Q), for the capacity value being the given capacity of the pump system for which the differential pressure has been determined. The probe comprises two pressure transducers (11, 15) of the forced liquid pressure provided with electrical outputs. One of the pressure transducers (15) measures the pressure of the liquid forced by the pump (1) to the pipeline (5) connected to its pressure port (4). The other pressure transducer (11) measures hydrostatic pressure of the liquid the pump (1) is immersed in. Each of the pressure transducers (11, 15) features a separate body (14, 16) and on one end of each body (14, 16) there is a metering orifice (12, 18). The pressure transducer (11, 15) bodies (14, 16) are installed generally perpendicularly to each other in a common coupling body (22).

Method for conducting on-going analysis of the current technical condition of a submersible pump system and a probe used for employing this method

Technical Field

The invention relates to method for conducting on-going analysis of the current technical condition of a submersible pump system installed in a deep well and to a probe to survey of the current technical condition of such system.

Background Art

The basic operating parameters of any submersible pump include its capacity (Q), which is the volume of liquid pumped out within a specific time unit, and lift (H), which is the pressure of pumped liquid provided in metres water column. The relationship between a pump's lift and its capacity is defined by the well-known pump flow characteristic $H=f(Q)$. The submersible pump operating parameters (Q,H) facilitate determination of other parameters, such as efficiency and power consumption of the pump. The existing method for conducting on-going analysis of the current technical condition of a submersible pump system with known capacity value (Q) involves approximate determination of pump lift (H_R) by adding the water surface height in the well to the pressure value measured upstream of the damper gate in a horizontal run of the pipeline which terminates the pump system. Since it is impossible to determine the linear flow loss in a vertical pressure line of a submersible pump, its estimate value is sometimes added, and in each such instance the actual pump lift of the pump system was estimated. The lack of a known actual lift of a submersible pump (H_R), operated in a pump set with a known capacity

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value (Q), precluded determination of actual distortions to the actual characteristic $H_R=f(Q)$ during operation of the pump against the reference $H=f(Q)$, determined on a test stand. This prevents exact diagnosis of the technical condition of a submersible pump system and of the actual pump. The reference characteristics $H=f(Q)$ determined on a test stand is evaluated by reference to the pump technical data sheet according to the approved standards, e.g. PN-EN ISO 9906:2012. Before installing the pump into the pumping system, the submersible pump is fully diagnosed, as well as it is in good technical condition and it is energy-efficient.

Disclosure of Invention

The purpose of the invention was to develop a method for conducting on-going analysis of the current technical condition of an assembled (integrated) and commissioned submersible pump system.

The purpose meets a method by which, for a given capacity of the pump system measured at its downstream end, differential pressure is determined between the liquid pressure in the pipeline near the pump pressure port and the hydrostatic pressure of the same liquid outside of the pump and near the pump pressure port. The differential pressure determined in this way is compared against the lift, which results from the known lift as a function of capacity, for the capacity value being the given capacity of the pump system for which the differential pressure has been determined.

In one of variants of the method according to the invention, comparison of the determined differential pressure to lift involves calculating the ratio of that differential pressure to that lift.

Another variant of the method according to the invention involves determining the differential pressure for pressure values measured at a distance to the pump pressure port equal or less than 0.15% of the pump installation depth but also equal or less than 4 meters.

Another variant of the method according to the invention involves determining the differential pressure by measuring the liquid pressure in the pipeline and the liquid hydrostatic pressure outside of the pump in two separate measurements in which two separate liquid electrical pressure transducers are applied and then determining the difference between the two obtained electric signals.

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In another variant of the method according to the invention the pressure transducers feature piezo-resistive silicon sensors, isolated from the liquid being measured by a separating membrane enclosing a manometer liquid.

Another variant of the method according to the invention involves measuring the liquid pressure in the pipeline by connecting a pressure transducer to a port located in an intermediate ring installed in line of the pipeline, advantageously between the pump pressure port and the pipeline start section.

Yet another variant of the method according to the invention involves determining the liquid differential pressure with a measurement probe which houses both of the said pressure transducers connected with each other by one common body. The common body is installed on the pipeline and the pressure transducer of the liquid hydrostatic pressure outside of the pump is oriented perpendicularly to flow direction in the pipeline.

A probe according to the invention consists of two liquid electrical pressure transducers. One of the pressure transducers measures the pressure of liquid forced by the pump into the pipeline connected to the pump pressure port. The other pressure transducer measures hydrostatic pressure of the liquid in which the pump is immersed. Each of the two pressure transducers is housed in a separate body which features a metering orifice on one end. The pressure transducer bodies are installed substantially in perpendicular against each other in a common coupling body.

In one of variants of the probe according to the invention both pressure transducers feature piezo-resistive silicon sensors isolated from the measured liquid with a separating membrane and a manometer liquid.

In another variant of the probe according to the invention, the probe also features an intermediate ring designed to be fastened between the pump pressure port and the starting section of the pipeline. The intermediate ring features a port connected by a line with the metering orifice of the pump-forced liquid pressure transducer

In yet another variant of the probe according to the invention, the probe also features a fixture for fastening the probe to the pipeline.

The advantage of the invention is that it facilitates conducting on-going analysis of the current technical condition of a submersible pump system, i.e. the actual submersible pump, its pressure pipeline, and its fittings. This fact considerably improves the quality of operation of submersible pumps and submersible pump systems. Only if damage to a pump operating in a deeply submerged assembly is detected soon enough, is it possible to predict and prevent problems which are always expensive to fix. According to the invention, the technical condition diagnosis allows the pump user to remove the damaged submersible pump immediately or stop leaks in the pressure pipeline. As a result, significant savings in electrical power consumption are made. The invention effectively optimises the use of submersible pump systems.

Brief Description of Drawings

Embodiment exemplifying the invention is described below and presented on the drawings. Fig. 1 shows schematically cross-section of a deep well with installed submersible pump and the probe according to the invention. Fig. 2 shows a magnification of vertical cross-section of the pipeline starting section which is provided with the probe according to the invention, and admits water from the pump. Fig. 3 shows a partial cross-section of a part of the first pressure transducer (the pipeline liquid pressure transducer) being a component of the probe according to the invention. Fig. 4 shows, in the same cross-section as provided in Fig. 3, a part of the second pressure transducer which is a component of the probe and measures hydrostatic pressure. Fig. 5 shows a diagram presenting the lift vs. capacity of the pump, which is implemented in the invention embodiment.

Mode for Carrying out Invention

The submersible pump (1) type GCA.6.12 manufactured by HYDRO VACUUM S.A., with nominal capacity of 1.42 m³/min and nominal lift of 219 meters was installed on a known test stand. Further, lift H was determined as a function of capacity Q, as shown in the diagram on Fig. 5. Next, the pump 1 was placed in a deep well 2 bored in an aquifer. The deep well 2 depth L_s was 250 meters and the deep well diameter was 16" (ca. 406 mm). The structural design of the deep well in question 2 resembled the well-known design of S5 submersibles

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and it included, among others, the filter 3. The pump 1 was installed in the deep well 2 at the depth L_p of 223 m. The pump 1 pressure port 4 was connected to the pipeline 5 with a diameter of 150 mm, featuring a throttle valve 6 installed on the pipeline surface and two pressure gauges 7 and 8 located on both sides of the throttle valve 6. The end of the pipeline 5 was located over a surface reservoir 9 into which the water from the deep well 2 was pumped. The water surface 10 in static conditions ($10'$), i.e. with non-operating submersible pump 1 was at the depth L_w' of 167 m. When the pump 1 was operating, the water surface depth was reduced ($10''$) to L_w'' of 199 m.

The measurement probe enabling the invention to be embodied was made of two measurement probes manufactured by APLISENS S.A. Smart depth probe type SG-25 Smart was used as hydrostatic pressure transducer 11. The probe had two metering orifices 12 made in the head 13, which closed the probe body 14 on one end. PC28 pressure transducer was used as the pressure transducer 15 for water forced by the pump 1 into the pipeline 5. The body 16 of the said pressure transducer 15 had a threaded head 17 with a metering orifice 18. Both pressure transducers 11 and 15 featured piezo-resistive silicon sensors 19 isolated from the measured liquid by a separating membrane 20 and a manometer liquid 21. The above-mentioned transducers 11 and 15 featured also digital electronic circuits (not shown) working with the sensors 18. The body 14 and 16 ends of the pressure transducers 11 and 15 were installed inside a common body 22 with a watertight seal. The common body 22 features known fixing assemblies 23 which facilitated fastening of the probe (11,15,22) to the pipeline 5 at the depth H_s of 228 m. A cable 24 was fed out of the common body 22 in order to transmit electrical outputs from the transducers 19 to a measurement instrument assembly 25. Between the pump 1 pressure port 4 and the pipeline 5 start section $5'$ there was an intermediate ring 26 installed with a port 27 on the side, which allows a user to use a tube 28 to connect the pipeline 5 interior to the metering orifice 18 of the pressure transducer 15. A water meter (not shown in the drawing) was also installed in line of the pipeline 5 in order to measure the actual water output from the pump 1. The water meter enabled the actual output of the pump 1 to be recorded at $1.36 \text{ m}^3/\text{min}$. During the use of the pump 1 the pressure transducer 15 recorded pipeline internal pressure of 256 m H_2O . At the same time, the

pressure transducer 11 recorded hydrostatic pressure of 29 m H₂O inside the well 2. The measurement instrument assembly 25 recorded the differential pressure of 227 m H₂O, which corresponded to the actual ongoing lift H_R of the pump system. With the Q_R capacity of 1.36 m³/m as established on the test stand, the pump 1 achieved the lift H of 228 m (Fig. 5), i.e. only 1 metre above the reference value. This results in drawing the conclusion that the pump 1 is in good technical condition and the entire pump system is leak-free. Due to determining, according to the above-mentioned procedure, the actual lift H_R for a submersible pump in a pump system it is possible to accurately track the current changes (run distortions) of the pump characteristics at any measured capacity Q. It is also possible to evaluate the optimum energy efficiency of the pump system. If we know the actual water pressure in the pipeline 5 upstream and downstream of the throttle valve 6 which is read e.g. from the pressure gauges 7 and 8, and if we know the actual lift as determined by the method according to the invention, it is possible to precisely evaluate pressure loss across the entire pipeline. The determination of actual lift with the electrical outputs from the pressure transducers 11 and 15 can be easily automated with any computer. This will greatly simplify remote monitoring of the submersible pump performance. One of ways of defining the technical condition of a pump system is calculating the ratio of a determined differential pressure to pump lift read from the pump characteristics and provided in percentage. This facilitates easy visualisation of the technical condition, with 100% being a brand-new pump system.

According to the invention, the internal pressure in the pipeline 5 can be measured with the probe also at the pump pressure port 4, provided that the pressure port 4 is provided with a suitable metering orifice similar to the aforementioned orifice 27 of the intermediate ring 26, or at the pipeline 5 start section, provided that the pumped liquid can access the pressure transducer 15 in a similar way. It is essential to take measurement within the following distance from the pump pressure port: equal to or less than 0.15% of the pump installation depth and also equal to or less than 4 meters.

Patent claims

1. A method for conducting on-going analysis of the current technical condition of a submersible pump system consisting of a submersible pump with a known lift as a function of capacity determined on a test stand, with the submersible pump immersed in a liquid contained in a deep well, and of a pressure pipeline complete with fittings to discharge the pumped liquid and connected to the pressure port of the same submersible pump, **characterised in that** for a given pump system capacity measured at its discharge end, a differential pressure is determined between the liquid in the pipeline (5) close to the pump (1) pressure port (4) and the hydrostatic pressure outside of the pump (1) measured in close proximity to the pressure port (4), and then the acquired value of the determined differential pressure is compared against the lift (H) resulting from its known value as a function of capacity (Q), being the given capacity of the pump system, for which that differential pressure is determined.
2. The method according to claim 1, **characterised in that** the comparing of the determined differential pressure to the lift involves calculating the ratio of that differential pressure to that lift.
3. The method according to claim 1 or 2, **characterised in that** the differential pressure is determined for the pressure values measured at a distance to the pump pressure port equal to or less than 0.15% of the pump installation depth (Lp) but also equal to or less than 4 meters.
4. The method according to claim 1 or 2 or, 3, **characterised in that** the differential pressure is determined by measuring the liquid pressure in the pipeline (5) and the liquid hydrostatic pressure outside of the pump (1) with two separate liquid electrical pressure transducers (11,15) separately, and then determining the difference between the two obtained electric signals.

5. The method according to claim 4, **characterised in that** the pressure transducers (11,15) feature piezo-resistive silicon sensors (19) isolated from the measured liquid by a separating membrane (20) and manometer liquid (21).
6. The method according to claim 4 or 5, **characterised in that** the liquid pressure in the pipeline (5) is measured by connecting the pressure transducer (15) to a port (27) located in an intermediate ring (26) installed in line of the pipeline (5), advantageously between the pump (1) pressure port (4) and the pipeline (5) starting section (5').
7. The method according to claim 4 or 5 or 6, **characterised in that** the liquid differential pressure is determined with a measurement probe, housing both of the said pressure transducers (11, 15) within the same common body (22) and where the common body (22) is installed on the pipeline (2), whereas the pressure transducer (11) of the liquid hydrostatic pressure outside of the pump (1) is oriented in perpendicular to the pipeline (5) liquid direction of flow.
8. A probe for conducting on-going analysis of the current technical condition of a submersible pump system comprising a submersible pump immersed in a deep well and a pressure pipeline discharging the pumped liquid and connected to the pressure port of the same submersible pump, **characterised in that** the probe comprises two pressure transducers (11,15) of the forced liquid pressure provided with electrical outputs, where one of the pressure transducers (15) measures the pressure of the liquid forced by the pump (1) to the pipeline (5) connected to its pressure port (4), whereas the other pressure transducer (11) measures hydrostatic pressure of the liquid the pump (1) is immersed in, each of the pressure transducers (11, 15) features a separate body (14,16) and on one end of each body (14, 16) there is a metering orifice (12, 18), while the pressure transducer (11, 15) bodies (14, 16) are installed substantially perpendicular to each other in a common coupling body (22).
9. The probe according to claim 8, is **characterised in that** the pressure transducers (11, 15) feature piezo-resistive silicon sensors (19) isolated from the measured liquid by a separating membrane (20) and manometer liquid (21).
10. The probe according to claim 8 or 9 is **characterised in that** it additionally features an intermediate ring (26), which is to be placed between the pump (1)

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pressure port (4) and the pipeline (5) starting section (5'), and the intermediate ring (26) is provided with a port (27) connected by a line (28) to the metering orifice (18) of the pressure transducer (15) of the liquid forced by the pump (1).

11. The probe according to claim 8 or 9 or 10, **characterised in that** it additionally features a fixture (23) for fastening the probe to the pipeline.

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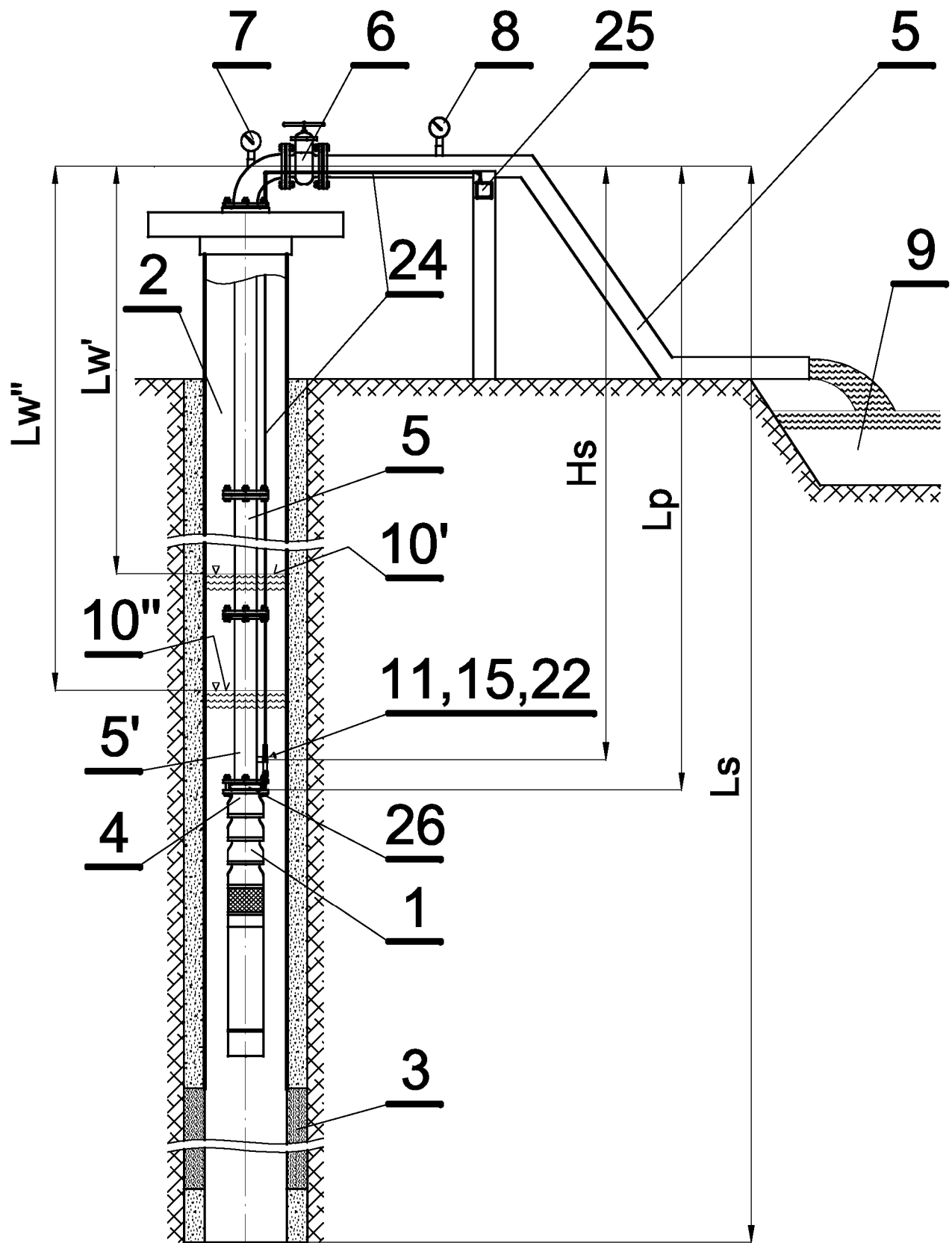


Fig. 1

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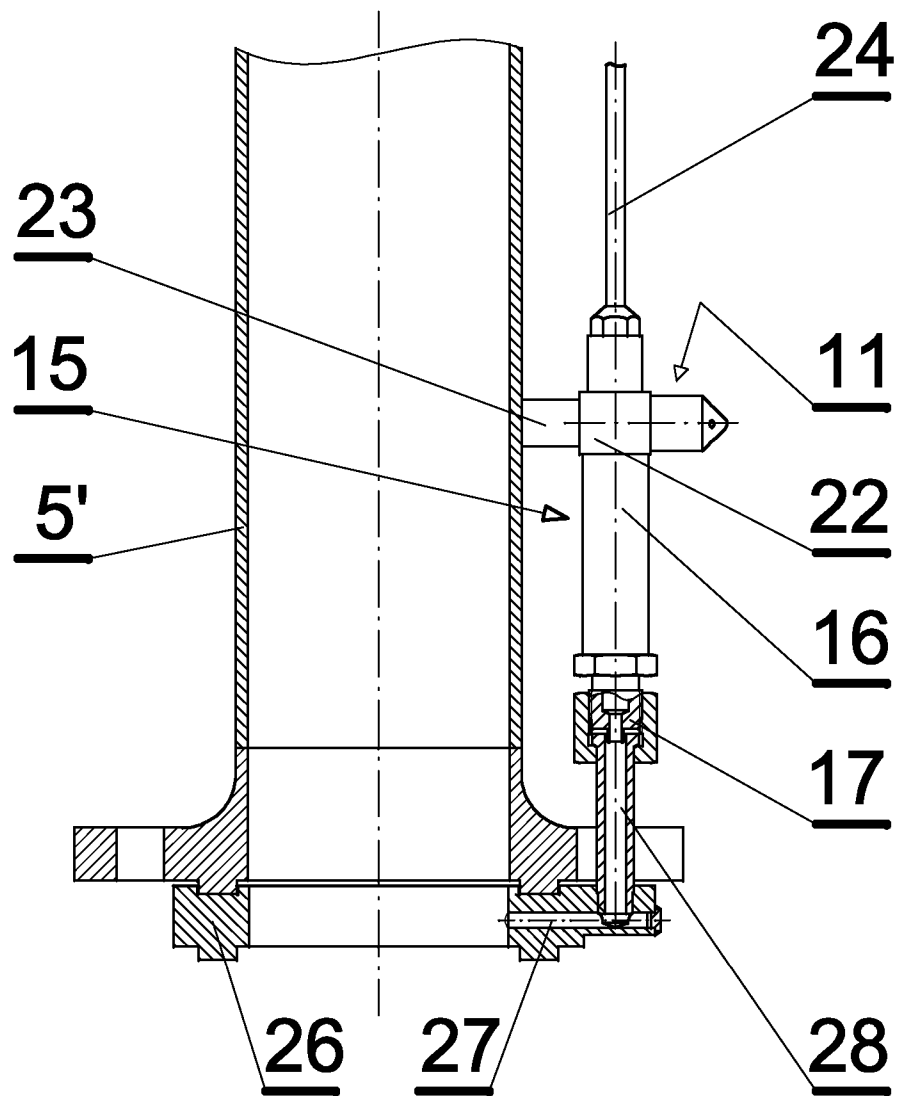


Fig. 2

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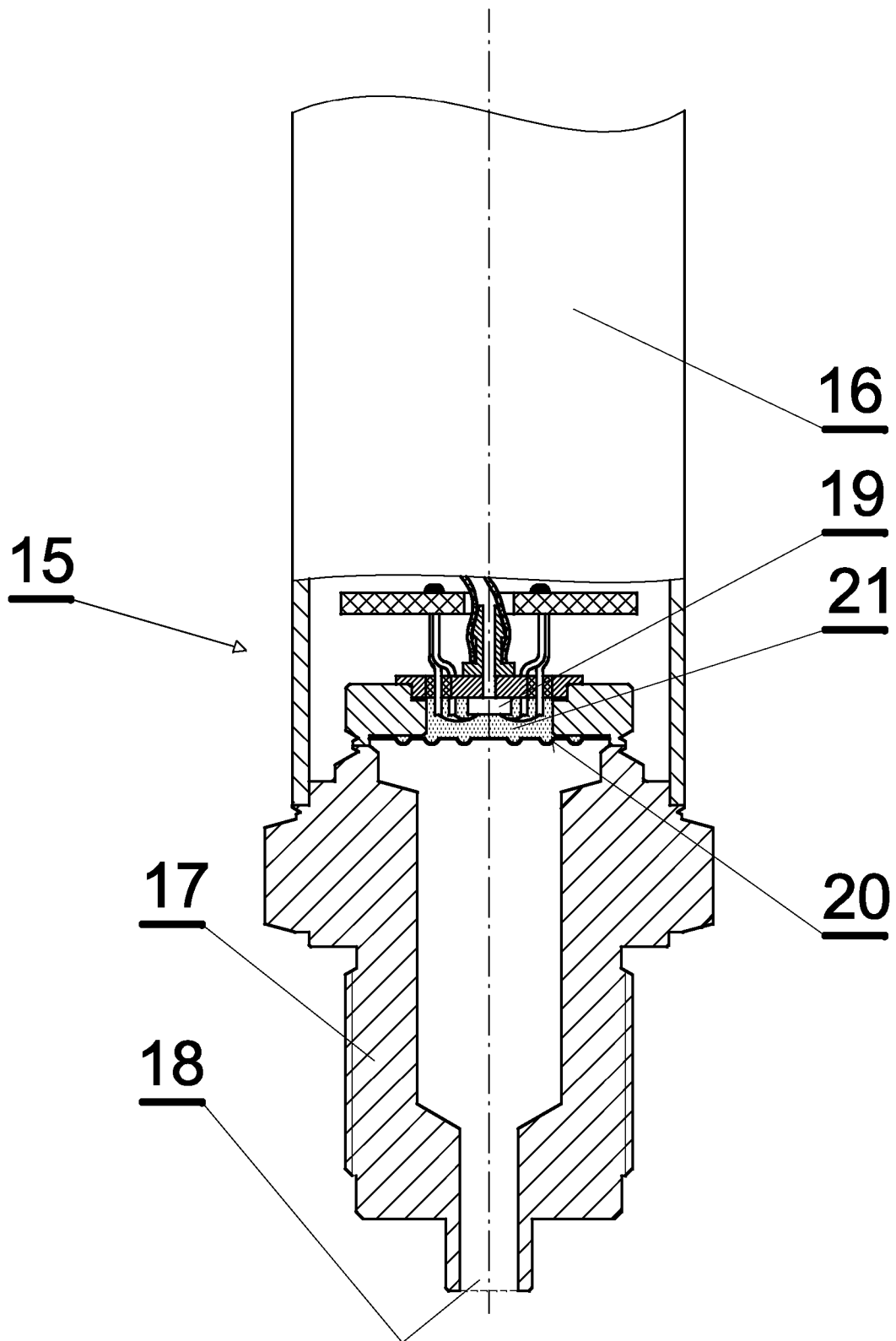


Fig. 3

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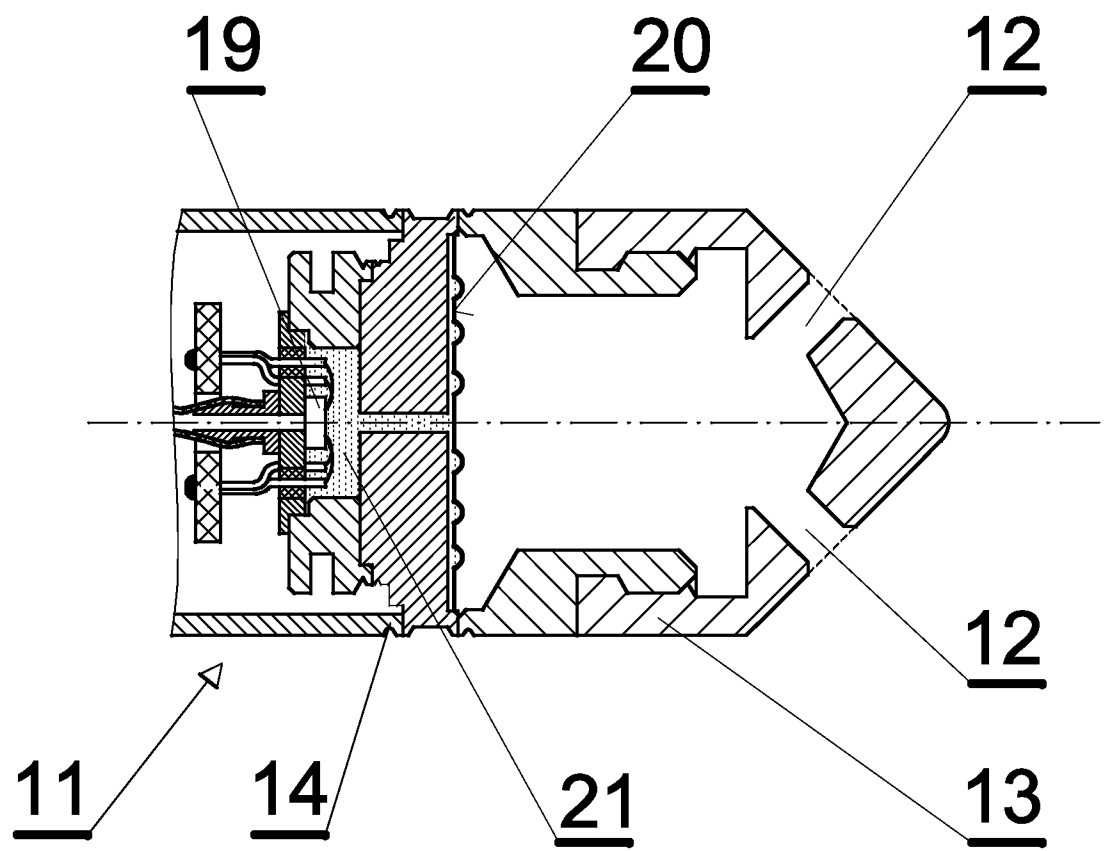


Fig. 4

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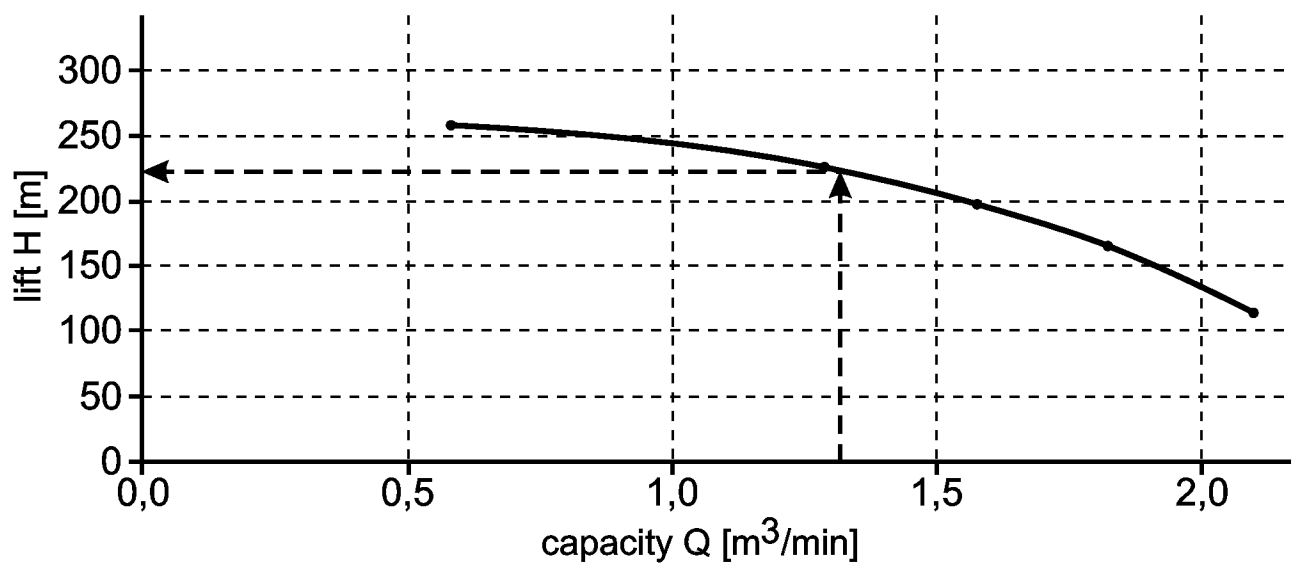


Fig.5

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B43/12
ADD. E21B43/128

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 5 634 522 A (HERSHBERGER MICHAEL D [US]) 3 June 1997 (1997-06-03) abstract column 4, paragraph 2 - column 4, paragraph 4 column 31, paragraph 2-3; figure 20 -----	1-11
A	WO 98/05848 A2 (CAMCO INT [US]) 12 February 1998 (1998-02-12) abstract page 14, paragraph 3 - page 15, paragraph 1; figure 1A figures 2-4 -----	1-11



Further documents are listed in the continuation of Box C.



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European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Wehland, Florian

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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