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54 Hydraulic air compressor.

57 Use is made of a descending column of water to compress air entrained with the water.

The water can be fed to an air inclusion chamber at the head of a down pipe from a source of stored water, such as a dam, or can be recycled by means of a pump.

The water is fed tangentially to the air inclusion chamber which has a conical shape.

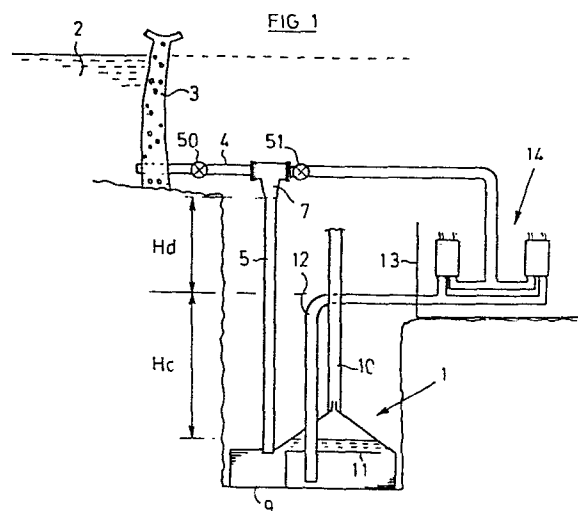
As a result of the tangential entry of the water, it is caused to swirl with a vortical motion.

In addition, the water stream is in turbulent flow.

A venturi effect is created at the narrow throat section of the air inclusion chamber.

A combination of these factors serves to enhance the entrainment of air. The inertia of the water as it leaves the orifice, or nozzle, and swirls into the venturi throat enables the inertia of the water in the down pipe to be overcome at the same time providing a blocking mechanism to prevent air rising into the air inclusion chamber.

At the bottom end of the down pipe, the compressed air is separated from the water, and the water is returned to a surge tank in which the pump is mounted, the pump is only used if the source of water is unable to supply water under sufficient head to the air inclusion chamber.



HYDRAULIC AIR COMPRESSOR

This invention relates to a hydraulic air compressor.

In particular, the invention relates to a hydraulic air compressor in which a gas can be compressed to a desired pressure at the temperature
5 of the water used in the compressor.

The energy of the compressed air can be put to a variety of uses.

Hydraulic air compressors are well known and have been used on a substantial scale in the past to compress air using the energy possessed by a head of water (under pressure).

10 Whilst the hydraulic air compressor has attractions, it was superceded by the internal combustion engine and cheap sources of other energy, at that time, mainly because of the inefficiencies of the velocity flow principle adopted by all to entrain the air. However in the modern world these alternatives are becoming less viable,
15 and the attractive features of the hydraulic air compressor are once again worth investigation.

One problem with the design of the conventional hydraulic air compressor was that the drive head of the compressor was regarded merely as that head of water existing between the inlet and tail race
20 of the compressor.

In fact, the excess of mass per unit volume of water in the down pipe of the compressor over the mass per unit volume of water in the tail race, or 'up pipe' is critical in the determination of the water velocity, since the drive head varies in accordance with the degree to
25 which air has been entrained in the falling column of water.

Different degrees of air entrainment result in variations in the mass of the column and therefore the height to which the drive column must be above the tail race outlet for the same velocity and pressure.

The invention provides a hydraulic air compressor having a drive
30 and compression down pipe, an air inclusion chamber at the head of the down pipe arranged to be fed with water from a water source, an air separating chamber at the bottom of the down pipe, an air pipe leading

from the separating chamber, an upwardly directed water return pipe leading from the separating chamber, means at the exit of the return pipe for pressurising water flowing from the return pipe and for directing the water into the air inclusion chamber when the air
5 inclusion chamber is not fed with water from the water source the air inclusion chamber being arranged so that water enters it in a vortex and so that a venturi effect is created in the water stream and having an air inlet arranged so that, in use, air is drawn into the air inclusion chamber as a result of the vortical motion of the water;
10 the venturi effect due to the velocity of the issuing jet, the inertia of which, permits the introduction of air into the air inclusion chamber at pressures higher than atmospheric.
Preferably, the air inclusion chamber tapers downwardly and includes a double wall with a gap between the walls, the gap being open at the
15 bottom of the chamber, air inlet communicating with the gap, and tangential inlet or inlets to the top of the chamber for the introduction of water flowing from the water source or from the pressurising means, as the case may be.

It is intended that the compressor will serve to provide a supply
20 of gas compressed by a liquid to the hydrostatic head at the point of separation when the temperatures of the gas will be that of the liquid. If the water source is not able to supply water at a sufficient head to maintain the supply of compressed air, then the pressurising means will be actuated to ensure that an adequate flow of water to the air
25 inclusion chamber is provided.

In one application of the hydraulic air compressor, the compressed air is fed directly to the combustion chamber of a gas turbine or ram jet, so that no filters or turbine powered compressor stage is required. In another application of the invention, the compressed air from the
30 hydraulic air compressor is fed to the chambers of a pneumatic displacement pump.

The pump may be arranged to inject water into the combustion chamber of a gas turbine.

In addition, the pump can be used for dosing water with chemicals such as chlorine or soda-ash, or for irrigation.

5 Another important feature of the hydraulic air compressor is that it compresses air isothermally.

If this isothermally compressed air is allowed to expand adiabatically in doing work, it will produce sub-zero temperatures which can be used to provide a freezer capability.

10 The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of a hydraulic air compressor installation.

15 The source of water being from behind a dam wall or the pneumatic displacement pump shown in the sump.

Figure 2 is an enlarged view of part of the installation shown in Figure 1.

Figure 3 shows a schematic view of a pneumatic displacement pump suitable for use with a hydraulic air
20 compressor of the invention.

The compressor shown in Figure 1 is indicated generally by reference numeral 1.

It is fed with water 2 retained behind a dam wall 3.

The water 2 passes out from behind the dam wall 3 through a feed pipe
25 4 to an air inclusion chamber 7 at the head of a drive and compression down pipe 5.

As can be seen in Figure 2, there are tangential inlets from the feed pipe 4 to the chamber 7.

The tangential inlets 6 serve to impart a swirl to the jet of water entering the chamber 7.

- 5 The water moved downwardly in this chamber and air enters through an inlet 8.

The air is entrained by the water stream in the form of bubbles, so that when the narrow cylindrical section of the pipe 5 is reached the water is impregnated with bubbles of air.

- 10 The air is carried to the bottom of the pipe 5 to an air/water separating chamber 9.

As the air/water mixture descends, the air is compressed.

When the descent of the air/water column is checked in the chamber 9, the direction of the flow is reversed.

- 15 The air separates from the water and passes upwardly via an air pipe 10.

The water passes around a baffle 11 and returns upwardly through a return pipe 12.

The pipe 12 feeds into a surge tank 13 in which is arranged a pump 14.

- 20 The pump 14 serves to raise water into the air inclusion chamber 7 via a tangential inlet 15 when there is an inadequate flow of water through the feed pipe 4.

When there is an inadequate flow of water through the pipe 4 under sufficient head, water will overflow from the chamber.

- 25 In this case, the valve 51 between the pump and the chamber is closed, and a valve in the feed pipe 4 can be operated to control inlet water pressure.

If there is an inadequate flow through the pipe 4, a valve 50 in the pipe 4 is closed and the pump 14 is actuated to raise water to
30 the air inclusion chamber 7.

A suitable design velocity can, therefore, be maintained at all times in the compressor so that a correct supply of compressed air is produced.

The pressure of water from the pump is controlled by operation of the valve 51 and this permits air at a pressure higher than atmospheric at the venturi throat.

The drive head of the compressor is determined by the excess of the mass of the water/air mixture per unit volume in the pipe 5 over that in the pipe 12.

This drive head must be sufficient to ensure that the velocity in the down pipe 5 is greater than the velocity at which air bubbles would rise in the water column if it were stationary.

The maximum drive head possible is designated in Figure 1 by the symbol H_d , which represents the elevation of the top of the pipe 5 over that

of the maximum hydrostatic height of the pipe 12.

The compression of the air is dependent on the hydrostatic head of the water in the return pipe 12, represented in Figure 1 by the symbol H_c .

The design and function of the air inclusion chamber 7 is of critical importance to the successful operation of the hydraulic air compressor of the invention.

There are a number of factors which contribute to the efficiency of air entrainment in the stream of water entering the chamber.

Firstly, the voluted entry of the water through the inlets 6 or 15 (depending on whether the water is supplied from storage behind the dam wall 3 or is supplied via the pump 14) causes a swirl in the water stream.

This swirling or vortical motion of the water serves to draw air into the water stream.

Also, the turbulent nature of the water as it enters the chamber 7 is conducive to the introduction of air.

In combination with these factors the venturi effect created as the water passes the throat section at the bottom of the chamber 7 acts to increase air entrainment.

As a result of the swirl and of the turbulent nature at speed of the flow, the water may form into droplets with the result that entrainment is enhanced since the air can enter the stream above zero gauge pressure assisted by the venturi effect for uniform distribution throughout the body of water.

In addition, the inertia of the issuing jet at the venturi throat enables the entrainment of air at pressure substantially above atmospheric pressure.

Air which has already been compressed can therefore be recycled via the hydraulic air compressor for further compression from a volume equal to that of the chamber from which liquid is being displaced.

The actual form of one type of air inclusion chamber 7 is shown in Figure 2.

The chamber has an upper cylindrical portion 40 and a lower frustro-conical portion 41.

Within the portion 41 there is a shorter member 42 of fustro-conical shape so that there is a gap between the walls of the portion 41 and the member 42.

The air inlet 8 is in communication with this gap 43.

A further important feature of the invention is the fact that the air can actually be cooled down while undergoing compression in the compressor.

The compression of the air can be considered to be sub-isothermal.

In one experiment which has been conducted, the water had an inlet temperature of $15,5^{\circ}\text{C}$ while ambient temperature was $21,1^{\circ}\text{C}$.

The air temperature was thus some $5,6^{\circ}\text{C}$ lower than the ambient or inlet air temperatures.

A modification to the compressor which is not shown in the drawings involves the use of a second air/water separating chamber part-way up the return pipe 12.

The air which separates from the water in the chamber 9 is oxygen
5 deficient, since oxygen will have become dissolved in the water at the high pressure involved in the operation of the hydraulic air compressor of the invention.

The inclusion of a second separating chamber allows for the separation of oxygen rich air at a pressure determined by the hydrostatic head
10 existing between the water level in the second separating chamber and the upper level of the return pipe 12.

In addition, it is proposed to provide an excess air relief pipe for the compression section of the pipe 5 so that uniform flow through the pipe will not be interrupted by blow back when volume of gas
15 compressed exceeds draw off.

The surplus could provide a freezer capability.

The particular advantage of having a pressurised feed to produce a constant drive head at the top of the pipe is that it is then possible to have a constant flow compressor in which the rate of flow
20 down the pipe 5 is maintained at a steady level.

Pressurised feed can be provided by a conventional centrifugal pump as shown in Figure 2.

Preferably however, the pressurisation is provided by a pump arrangement with twin pneumatic displacement chambers as shown
25 schematically in Figure 1.

In this arrangement, air displaced from the pneumatic chambers of the pump is fed to the air inclusion chamber 7.

The principle of operation of such an arrangement can be understood from the description of the application of the hydraulic compressor
30 to a pneumatic displacement pump which follows.

The capacity of the surge tank 13 as measured from the top of the pump 14 to the top of the tank should be at least 10% more than the total volume of the air pipe 10 and the excess air relief pipe between the chamber 9 and the top of the pump, or a separate relief
5 tank could be provided.

The hydraulic air compressor of the invention has a number of important applications:

HYDRAULIC AIR COMPRESSOR AND GAS TURBINE.

A conventional gas turbine drives its own adiabatic compressor
10 stage and the air must be filtered.

As a result, up to 70% of the turbine effort may be expended in powering the air compression stage, so that only 30 % of the effort is available for useful work.

In addition, the high temperatures encountered in a conventional
15 adiabatic compressor stage can have the effect of limiting the permissible compression ratio.

Also, the compressor stage represents a considerable bulk and weight factor.

It is therefore proposed to use a hydraulic air compressor to
20 provide a supply of filtered compressed air, so that the conventional compressor stage and filters can be done away with.

The pressure available from the hydraulic air compressor of the invention may be substantially greater than those available from the conventional compressor stage.

25 The compressed air from the hydraulic air compressor can be fed directly at exact pressure required by the combustion chamber of a ram jet or turbine, and can be fed to the combustion chamber, after passing through a heat exchanger, at the best temperature.

In the combustion chamber, fuel is burnt in the oxygen enriched
30 compressed air environment to produce hot compressed gases which are then expanded adiabatically through a turbine stage.

The resulting energy can be used for electrical generation or the operation of other devices.

Because the gas turbine proposed does not have to power its own compressor, there can be a considerable increase in efficiency over conventional turbines and a saving in first cost. Efficiency is further improved by regeneration.

5 It is anticipated that the amount of fuel necessary for the firing functions will be some 1.4 times that which would be expended in the standard designed output of the turbine. Nevertheless, it is anticipated that the power output from this turbine could be three times that achievable with the standard turbine.

10 Because the hydraulic air compressor can produce filtered air at very high pressures, it may be possible to expand this air to some extent through a turbine which would replace the conventional filter and adiabatic compressor in a gas turbine.

This should still further increase the efficiency of the turbine, and
15 could be carried out in a simple way merely by reversing the blades of the compressor.

The adiabatic expansion of the air through what was compressor blading producing extremely low temperatures which can be used for freezing purposes, due to the energy expended in assisting the gas turbine and
20 precipitated water could be drained off at appropriate stages of adiabatic expansion.

HYDRAULIC AIR COMPRESSOR AND PNEUMATIC DISPLACEMENT PUMP.

A typical pump is shown in Figure 3.

This has chambers 21 and 22 each of which has an inlet 23, 24 for
25 high pressure air, an outlet 25, 26 for water, a water feed pipe 27, 28 and an air evacuation pipe 29, 30.

Both the inlets 23 and 24 are connected to the air pipe 10 of the hydraulic air compressor, and a two-way valve 31 can be operated to feed the compressed air either to the inlet 23 or to the inlet 24.

30 The operation of the other valves will become clear from the following description of operation.

When compressed air is passed through the inlet 23 to the chamber 21, the outlet 25 is opened and valves in the pipes 27 and 29 are closed.

The compressed air in the upper part of the chamber 21 therefore pushes
5 the water out through the outlet 25, and to a common water line 32.

At the same time, the chamber 22, having exhausted to atmospheric pressure, or recycled is being recharged with water via the line 28.

The outlet 26 is closed, the inlet 24 is closed but the air pipe 30 is open.

10 Water enters at a relatively low pressure through the pipe 28 and displaces the air in the top of the chamber 22.

As stated previously, it is preferred to use a pump of this general nature to raise water from the surge tank 13 to the air inclusion chamber 7 with air displaced from the empty chamber also
15 returned to the air inclusion chamber 7.

In this case, the displacement of air can be aided by the suction generated in the air inclusion chamber 7 of the compressor which can serve to suck the air out of the upper part of the chamber 22.

In any case, the pressure of the air to the air mixing chamber 7
20 can be higher than atmospheric because of the inertia of the jet issuing from the venturi orifice.

When the chamber 21 is nearly empty, the chambers are switched over and compressed air is passed to the inlet 24 so that the chamber 22 which is now full of water, can be pumped out by the air.

25 Whilst this is happening the chamber 21 is being refilled.

One can therefore get a continuous feed of water under pressure through the line 32.

The pump can be used to pump irrigation water using eg. the overflow from surge tank 13 or to provide any sort of pumping facility
30 as pumping from mines, wells, boreholes, lakes or even shallow swamps, to any head.

The compressed air could also be used to inject water into the combustion chamber of a gas turbine or ram jet as described in the preceding section of this specification, to ensure atomisation and therefore to produce greater power from the turbine, or for the injection
5 of chemicals such as chlorine or soda-ash into water to make it potable. The air from the injector pump exhaust is at very low temperature.

An advantage of the use of pneumatic displacement pump for the pressurisation of a liquid is that the air is filtered and the liquid uncontaminated with oil etc.

10 In addition, the nature of the pressurisation which takes place is suitable for the production of liquid velocities for the transportation of solids in pipelines.

HYDRAULIC AIR COMPRESSOR TO PROVIDE FREEZER TEMPERATURES.

The isothermally compressed air from the hydraulic air compressor
15 can be used to supply freezer temperatures by allowing it to expand adiabatically while doing work.

Depending on the pressures before and after expansion, extremely low temperatures are obtainable in accordance with the conventional gas laws, ie. with an expansion ratio of 1 to 3 and ambient of plus
20 40°C, (104°F) by the gas expansion formula $T_2 = T_1 (P_2/P_1)^{0.283}$

$$\begin{aligned} T_2 &= 313 \left(\frac{1}{3}\right)^{0.283} \\ &= 313 \times 0.7327818 \\ &= 229.36 \text{ K} \end{aligned}$$

$T_2 = -43.64^\circ\text{C}$
25 Gases such as NH_3 (anhydrous ammonia) can be delivered to distant points from any remote source by condensing the gas to liquid wherever required.

CLAIMS

1. A hydraulic air compressor having a drive and compression down
pipe, an air inclusion chamber at the head of the down pipe arranged
to be fed with water from a water source, an air separating chamber
5 at the bottom of the down pipe, an air pipe leading from the
separating chamber, an upwardly directed water return pipe leading
from the separating chamber, means at the top of the return pipe for
pressurising water flowing from the return pipe and for directing
the water into the air inclusion chamber when the air inclusion
10 chamber is not fed with water from the water source, the air
inclusion chamber being arranged so that water enters it in a
vortex and a venturi effect is created in the water stream and having
an air inlet arranged so that, in use, air is drawn into the air
inclusion chamber as a result of the vortical motion of the water
15 and the venturi effect created by the velocity of the issuing jet
and also the blocking effect at the nozzle (orifice) because of the
inertia of the issuing jet which permits entry of air at pressures
well above atmospheric.
2. A hydraulic air compressor according to Claim 1, in which the
20 air inclusion chamber tapers downwardly and includes a double wall
with a gap between the walls, the gap being open at the bottom of
the chamber, an air inlet communicating with the gap, and
tangential inlets to the top of the chamber for the introduction
of water flowing from the water source or from the pressurising
25 means, as the case may be.
3. A hydraulic air compressor according to either one of the
preceding claims, including a further separating chamber arranged
in the path of the upwardly directed return pipe.

4. A hydraulic air compressor according to any one of the preceding claims, including an excess air relief pipe which is designed to spill water from the relief pipe into a relief water tank; if the relieved air is cut off to achieve an expansion ratio of 1 to 6
5 from air at 15°C in the air/water chamber then a temperature of minus 100°C can be obtained.
5. A hydraulic air compressor according to any one of the preceding claims, in which the pressurising means includes a pneumatic displacement pump arranged at the exit of the water return pipe.
- 10 6. A hydraulic air compressor according to Claim 5, including means for directing air displaced from the pneumatic displacement pump to the air inlet of the air inclusion chamber.
7. A hydraulic air compressor according to any one of Claims 1 to 4 in which the pressurising means includes a pump arranged at the exit
15 of the water return pipe.
8. A hydraulic air compressor according to any one of the preceding claims, including valves for controlling the flow of water from the pressurising means to the air inclusion chamber or from the water source to the air inclusion chamber.
- 20 9. A hydraulic air compressor according to any one of the preceding claims, arranged in combination with a gas turbine or ram jet to provide compressed air to the combustion chamber of the turbine or to the combustion chamber or a ram jet for heating or producing steam for whatever purpose or high temperature gas for gas turbines.
- 25 10. A hydraulic air compressor according to Claim 9, in which the gas turbine is arranged to power a generator of electricity or similar devices.

11. A hydraulic air compressor according to any one of Claims 1 to 8 in combination with a pneumatic displacement pump having two chambers arranged to be filled alternatively with liquid and having means for the introduction of compressed air selectively from the hydraulic air compressor to each chamber in turn to expel liquid in the chamber.
12. A hydraulic air compressor according to Claim 11, in which water separated from the air in the hydraulic air compressor is fed to the air inclusion chamber from the water source alternatively by the chambers of the pneumatic displacement pump.
13. A hydraulic air compressor according to either one of Claims 11 or 12, including means for directing water expelled from the chambers of the pneumatic displacement pump into the combustion chamber of a gas turbine.
14. A hydraulic air compressor according to Claim 11 in which the liquid is dosing chemicals for water treatment and the pump is arranged to inject the chemical into the water.
15. A hydraulic air compressor according to either one of Claims 11, 12 or 13 including means for directing water into a water main.

FIG 1

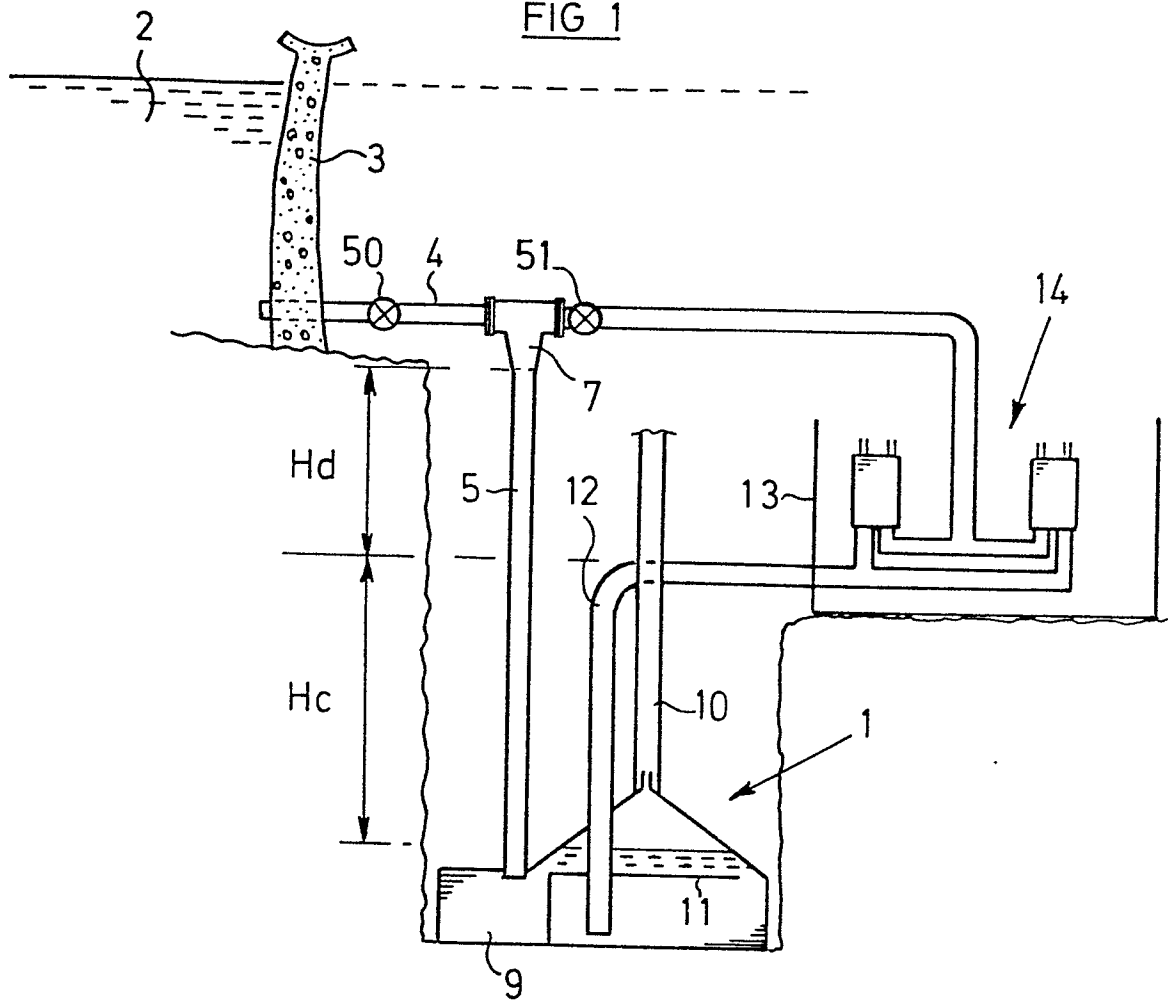


FIG 3

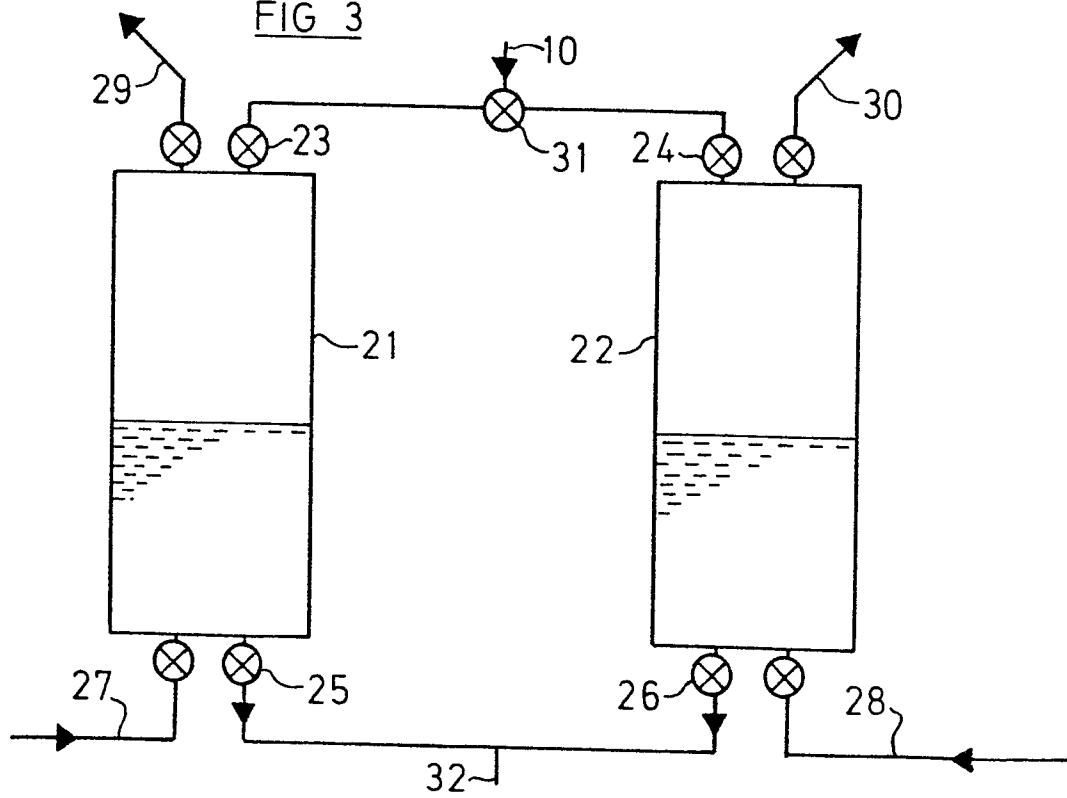
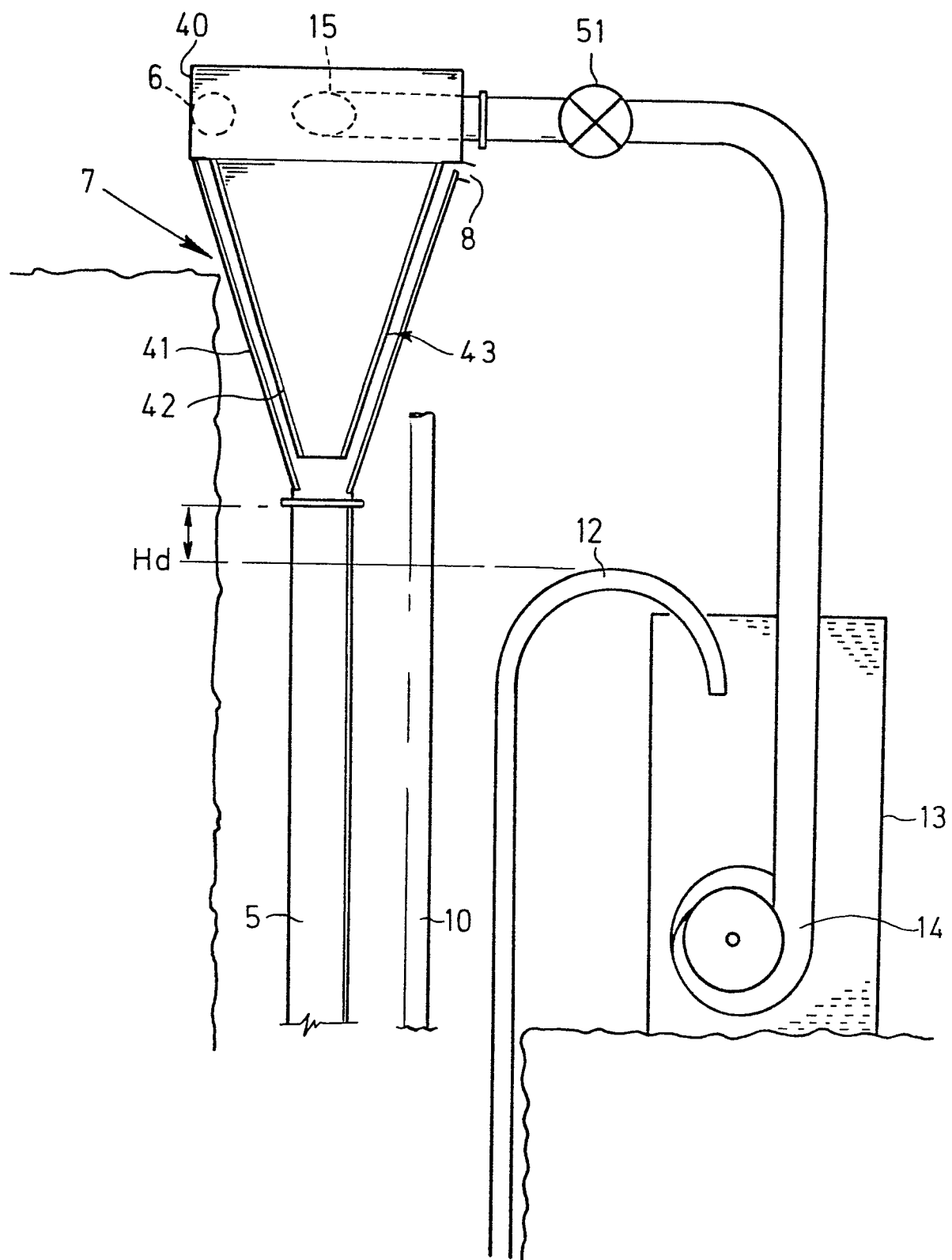


FIG 2





DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
A	GB-A-2 001 395 (NORTON) * Page 1, line 62 - page 3, line 35 *	1,7-10	F 03 B 17/00 F 02 C 6/16
A	--- US-A-3 754 147 (HANCOCK) * Column 5, line 8 - column 9, line 45 *	1,2	
A	--- US-A-4 110 980 (FOULKE) * Column 3, line 1 - column 6, line 14 *	5,7,11 ,15	
A	--- US-A-3 939 356 (LOANE) * Column 3, line 28 - column 5, line 24 *	1,8-10	
A	--- FR-A-1 081 853 (E.D.F.) * Page 2, lines 16-32 *	1,9	TECHNICAL FIELDS SEARCHED (Int. Cl. ³) F 03 B F 02 C
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 20-04-1983	Examiner DE WINTER P.E.F.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			