

GEOHERMAL POWER GENERATING SYSTEM

The present invention relates to a natural geothermal power generating system and, more particularly, to a geothermal power station.

It is well known to use geothermal energy to produce power. However, existing geothermal power stations are only located in regions where there are weaknesses in the Earth's crust. These power stations tend only to produce sufficient power for local use.

It is therefore an object of the present invention to provide an improved geothermal power generating system.

According to one aspect of the present invention there is provided a natural geothermal power generating system, characterized by heat exchanging means being arranged to receive water, the heat exchanging means comprising a plurality of heat exchangers connected in series, each successive heat exchanger being located in rock at a greater predetermined depth below the surface of the Earth than the previous heat exchanger, turbine means located above the heat exchanger closest to the surface of the Earth, and a riser passage extending from the lowest heat exchanger up to the turbine means, whereby naturally generated heat from the rock surrounding the heat exchanging means converts the water in the heat exchanging means into steam which rises up the riser passage at a pressure capable of driving the turbine means.

Such a geothermal power station is preferably built in regions where the Earth's crust is relatively stable. It is well known that rock increases in temperature in relation to its depth from the Earth's surface and the power station gains its power from the heat of the rock. Thus, the power station does not rely on weaknesses in the Earth's crust to gain its power.

Preferably, the riser passage is substantially vertical.

The water for the heat exchanging means may be supplied from the Earth's surface.

The system may include condensing means for condensing steam exhausted from the turbine means into water.

Desirably, the system includes underground reservoir means for storing water for the heat exchanging means. The underground reservoir means is preferably adapted to receive water from the condensing means.

The system may include flow control means for controlling the flow of water or steam in the system. The system may include pressure control means for controlling pressure of water in the system.

At least one heat exchanger may have an associated reservoir. The plurality of heat exchangers may be arranged in a helix formation to form a shaft pillar. Each heat exchanger may have associated vent valve means, each vent valve means being connected to the riser passage by a vent slightly inclined towards the surface to aid venting.

The riser passage may be vented to the surface via valve means.

A geothermal power station may comprise a plurality of arms, each arm comprising a natural geothermal power generating system as described above.

According to another aspect of the present invention there is provided a method for operating a natural geothermal power generating system including turbine means, characterized by the steps of:

feeding water into heat exchanging means comprising a plurality of heat exchangers connected in series, each successive heat exchanger being located in rock at a greater predetermined depth below the surface of the Earth than the previous heat exchanger;

using the natural heat of the rock surrounding the heat exchanging means to generate steam from the water in the heat exchanging means; and constraining the generated steam so that it rises at a pressure capable of driving the turbine means.

The method may include the steps of condensing steam exhausted from the turbine means into water, and feeding said water back into the heat exchanging means.

In order that the present invention may be more readily understood, reference will now be made, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a schematic plan view of a geothermal power station
5 according to one embodiment of the invention;

Figure 2 is a sectional view of one arm of the geothermal power station of Figure 1;

Figure 3 is a plan of a heat exchanger for the arm of Figure 2;

Figure 4 is a section taken along lines 4-4 of Figure 3;

10 Figure 5 is a plan section of two pipes of the heat exchanger;

Figure 6 is a section taken along lines 6-6 of Figure 5;

Figures 7 to 12 are details of parts of the arm; and

Figure 13 is a schematic view of an arrangement of heat exchangers for a modified arm.

15 Referring to Figure 1 of the accompanying drawings, in a preferred embodiment, a geothermal power station 1, which is substantially underground, comprises four arms 2, each arm 2 including a chamber 3 holding turbines and connected generators, a chamber 4 for a condenser, a main reservoir 5 and heat exchangers (not shown). Each arm is connected to
20 a coastal desalination or demineralisation plant (not shown).

Referring to Figure 2, one arm 2 will be described in detail. The turbine and generator chamber 3 is at a depth of 2 km below ground. The chamber, like all other underground excavations for the arm 2, such as shafts and tunnels, is sealed with a rock stabilisation material which stabilises the rock
25 surface of the chamber and prevents oxidation taking place and unravelling. The chamber 3, also like all other underground excavations for the arm 2, is further lined with a non-corrosive material such as stainless steel. All non-corrosive linings have ceramic wool joints to accommodate expansion and the lining permanently seals the underground excavation. The chamber 3 houses
30 conventional steam turbines 6 connected to generators (not shown), as well

as a generator control room and maintenance equipment (not shown). Each steam turbine also has an associated turbine condenser 7.

A main feed discharge tunnel 10, 300 m long and 6 m in diameter, connects the chamber 3 to the dump condenser chamber 4. The tunnel 10 has an additional lining, between the rock stabilisation and non-corrosive linings, for preventing heat transfer from the surrounding rock.

The dump condenser chamber 4 contains dump condensers 11, a dump condenser reservoir 12 which is able to hold approximately 450,000 tonnes of demineralised water. The chamber 4 also contains a seawater cooling reservoir 13 and high pressure pumps (not shown) for pumping seawater from the reservoir 13 around the dump condensers 11 and the turbine condensers 7. The main feed discharge tunnel 10 connects the steam turbines condensers 7 to the dump condenser reservoir 11.

Five substantially vertical shafts 15,16,17,18,19 connect the dump condenser chamber 4 to the surface. The first shaft 15 is a seawater inlet to the seawater reservoir 13 and the second shaft 16 is the seawater outlet for seawater pumped around the dump condensers 11 and the turbine condensers 7. The third shaft 17 is connected to the coastal desalination or demineralisation plant and is the main feed inlet to the arm 2. The fourth shaft 18 is an outlet from the dump condenser reservoir 12 and the fifth shaft 19 is a vent to the atmosphere from the dump condenser reservoir 12 and the main reservoir 5.

A main feed tunnel 20, about 8 km long and 8 m in diameter, connected to the dump condensers 11 and the dump condenser reservoir 12, exits from the dump condenser chamber 4 via a shut off valve 21, the tunnel having a downward incline of about 2.5° . The tunnel subsequently descends as a substantially vertical shaft to the main reservoir 5 at a depth of 4 km from the Earth's surface via an inlet valve 22 which is capable of allowing a maximum flow rate of 30 tonnes per second of water but in normal operation allows a flow rate of 10 tonnes per second when open. The main reservoir 5

is able to hold 30 million tonnes of water.

A main feed tunnel 23a, 8 m in diameter, exits the main reservoir 5 via a first pressure reducer and flow control valve 24a with a vent valve 35a immediately downstream from the valve 24a. The tunnel 23a descends as a substantially vertical shaft until it enters a heat exchanger 26a at a depth of 5.75 km.

Referring to Figures 3 to 6, the heat exchanger 26a comprises a top header 27 and a bottom header 28, each having a volume of 1.2 million cubic metres. The top header 27 is connected to the main feed tunnel 23a. The headers are connected together by one hundred substantially parallel pipes 29, each pipe being 3 km long and 2 m in diameter. The top header 27 has a flow distributor (not shown) to distribute an equal flow of water to all parts of the header in order to eliminate thermals and hence provide an even heat distribution for water or steam passing through. The pipes are contained in an upper layer 30 and a lower layer 31 with fifty pipes in each. The pipes in the lower layer are spaced between the pipes in the upper layer and each pipe 29 is 20 metres from adjacent pipes. The top and bottom headers 27,28 and the pipes 29 all have a downward gradient of 2.5° . A door frame 32 and an associated 10 to 15 cm thick steel plate door 33, each with a plurality of apertures 34, are spaced along at intervals of 100m along the inside of each pipe 29. The door and frame apertures 34 create a small amount of turbulence to help prevent thermals occurring in the pipe 29 and the doors are designed to open in the opposite direction to flow in the pipe. The door frame comes in two parts and fits into a 25 cm groove in the pipe 29 providing space for expansion of the door frame.

Referring back to Figure 2, a second main feed tunnel 23b, 8 m in diameter, exits from the bottom header 28 (see Fig. 3) of the first heat exchanger 26a via a second pressure reducer and flow control valve 24b, with a second vent valve 35b immediately downstream from the valve 24b. The tunnel 23b descends as a substantially vertical shaft until it enters a second

heat exchanger 26b at a depth of 7.5 km. This construction is repeated until there are six heat exchangers connected in series, each successive heat exchanger being 1.75 km below the previous heat exchanger.

5 A seventh main feed tunnel 23g, 8 m in diameter, exits the sixth heat exchanger 26f via a seventh pressure reducer and flow control valve 24g, with a seventh vent valve 35g immediately downstream from the valve 24g. The tunnel 23g descends as a substantially vertical shaft until it enters a reservoir 36 at a depth of 16.25 km. The reservoir 36 (see also Figures 7 and 8) has a volume of about 2.4 million cubic metres and contains a flow
10 distributor (not shown) connected to the main feed shaft 23g to distribute and even the flow of water throughout the reservoir. Ten parallel feed pipes 37, each 2 metres in diameter and 300 to 500 metres long, connects the reservoir 36 to a seventh heat exchanger 23g. Each pipe 37 has a pressure reducer and flow control valve 38 which is capable of allowing a maximum flow rate
15 of 3 tonnes per second but in normal operation allows a flow rate of 1 tonne per second when open. The pipes are in a layer and spaced apart every 200 metres.

The seventh heat exchanger 26g is similar to the first six heat exchangers 26a...f except that the seventh heat exchanger 26g has two
20 hundred parallel pipes 29 and that the top and bottom headers each have a volume of 1.6 million cubic metres.

These pipes are also in two layers except that there are a hundred pipes in each layer. The pipes have the same dimensions and spacings as in the first six heat exchangers.

25 An eighth main feed tunnel 23h, 8 m in diameter, exits the seventh heat exchanger 26g via an eighth pressure reducer and flow control valve 24h, with an eighth vent valve 35h immediately downstream from the valve 24h. The tunnel 23h descends as a substantially vertical shaft until it enters an eighth heat exchanger 26h at a depth of about 18 km.

30 The eighth heat exchanger 26h is the same as the seventh heat

exchanger 26g except that the eighth heat exchanger 26h, which is the lowest one, has an upward gradient of 2.5° from its top header 27.

A tunnel 39, exiting from the eighth heat exchanger 26h via a ninth pressure reducer and flow control valve 24i with a vent valve 35i immediately before the valve 24i. The tunnel becomes a substantially vertical riser shaft 40, 6 m in diameter, which rises up to a depth of about 2 km. The shaft is constructed by raise boring from the tunnel 39 exiting the eighth heat exchanger 26h. Above a certain depth, the riser shaft is additionally lined between its rock stabilisation and non-corrosive linings to prevent heat transfer.

When the riser shaft 40 reaches the level of a depth of 2 km, there is a junction 41 to which are connected two branches 42,43. The first branch 42 continues from the junction 41 to the steam turbines 6 in the turbine and generator chamber 3 via a shut-off valve 44 close to the junction and an inlet valve 45 at the entrance to the chamber 3. The second branch 43 is a vent shaft for flashing up and for use in dewatering the system. The second branch 43 is 2m in diameter and vents to the atmosphere via a shut off valve 46.

Referring to Figures 9 and 10, at the junction 41, there is an inclined roof 47 inclining upwards from the first branch 42 at an angle of 30° to the second branch 43 for about 30 m. The second branch vent valve 46 is positioned immediately after the inclined roof 47 joins the second branch 43.

Referring back to Figure 2, a tunnel 48, 1.4 km long and 6 m in diameter, subsequently branches off the first branch 42 via an inlet valve 49 and joins the dump condenser chamber 4 via a shut-off valve 50, bypassing the turbine and generator chamber 3. The bypass tunnel 48 is connected to the dump condensers 11 in the dump condenser chamber 4.

Maintenance lift shafts 51 and maintenance tunnels 52 provide access to all the relevant parts of the geothermal power station 1 from the Earth's surface. A maintenance tunnel 52 is provided between the outlet from the

main reservoir 5, the reservoir 36, each of the first seven heat exchangers 26a...g and the riser shaft 40, the tunnels being inclined upwards at 2.5° from the reservoirs/heat exchangers. The eighth heat exchanger 26h is linked to the maintenance tunnel 52 to the seventh heat exchanger 26g by a lift shaft 51.

5 The pressure reducer and flow control valves 38 are each connected by a shaft 66 (see Figure 8) with airlock doors 67 to a maintenance tunnel 52. Below a depth of about 3 km these shafts 51,66 and tunnels 52 have a lining, between the rock stabilising and the non-corrosive linings, to prevent heat transfer.

10 Referring to Figures 11 and 12, a maintenance tunnel 52 between the main reservoir/heat exchanger 26a...g and the riser shaft 40 is separated into a series of machinery spaces 53 by airlock doors 54 in the portions of the tunnel adjacent the main reservoir/heat exchanger and the riser shaft. In the portion adjacent the main reservoir/heat exchanger, the doors 54 open
15 towards the main reservoir/heat exchanger 26a...g and in the portion adjacent the riser shaft, the doors 54 open towards the riser shaft 40. A vent line or piping 55 in the tunnel 52 is used to connect the vent valve 35a...i, adjacent the outlet from the main reservoir/heat exchanger 26a...h, to the riser shaft 40 and on to the atmosphere by the second branch vent 43 (see Fig. 2). The
20 vent line 55 has a vent safety valve 56 in each machinery space 53 that it passes through. When a vent valve 35a...i is opened to enable venting all the vent safety valves 56 in the vent line 55 are also opened. The maintenance tunnels 52 are inclined upwards at 2.5° from the heat exchangers to assist venting.

25 In a machinery space 53a, adjacent the main feed outlet from the heat exchangers 26a...g, there are two to four electric motors 57 for driving propellers 58 in the bottom header 28 of the heat exchanger 26a...g. The propellers 58 are used to agitate water or steam to prevent thermals occurring. This machinery space 53a also contains the control machinery 59
30 for operating the pressure reducer and flow control valves 35a...g, the control

machinery having two back-up motors (not shown).

A similar machinery space is provided adjacent the tunnel outlet 39 from the eighth heat exchanger 26h and also contains propeller motors 57 and valve control machinery 59. This machinery space is connected by a maintenance lift shaft 51 to the maintenance tunnel 52 for the seventh heat exchanger 26g and the vent line for the ninth vent valve 35i also uses this shaft.

There is also a similar machinery space adjacent the main feed outlet from the main reservoir 5 which contains valve control machinery 59, the machinery space being connected by a maintenance tunnel 52 to the riser shaft 40.

Referring back to Figure 2, a high pressure air reservoir 60 is provided and is pumped to a pressure of 40 million Pa (400 bar) by means of pumps 61 at ground level which are connected to it by a shaft 62. Air lines 63 (see Figures 11 and 12) connect the air reservoir 60 to all the machinery spaces 53,53a via the maintenance lift shafts 51 and tunnels 52. Air is pumped into the machinery in the machinery spaces at a pressure of 0.5 bars below the water or steam pressure passing around the machinery in the machinery space. This guards against high pressure water or steam leaks. Where an air line 63 passes through a machinery space 53,53a the air line is provided with an airlock valve 64.

All underground chambers, shafts and tunnels are built to mining standards.

All pressure reducer and flow control valves 24a...i,38 are sprayed with a ceramic lining to guard against erosion from any water or steam. The pressure reducer and flow control valves 24a...i are each capable of allowing a maximum flow rate of 30 tonnes per second of water/steam but in normal operation they each allow a flow rate of 10 tonnes per second when open. For each pressure reducer and flow control valve there is provided two back up valves.

Each vent valve 24a...i is connected to an aperture at substantially the crown of the tunnel exiting the main reservoir 5 / heat exchanger 26a...h.

Before the geothermal power station 1 is constructed a borehole, 18 km deep, is drilled. This borehole is used to test if the proposed site is
5 actually suitable for building the geothermal power station 1. Temperature readings are taken at regular intervals during the drilling so as to more accurately calculate the depths between successive heat exchangers. The maximum depth between successive heat exchangers is about 2 km and is governed by crane construction restraints. The borehole could be drilled to
10 a maximum depth of 20 km as this is considered the maximum depth for the lowest heat exchanger.

The maintenance lift shafts 51 and tunnels 52 would be built before the riser shaft 40 so that they can be used in the raised bore construction of the riser shaft.

15 To commission the geothermal power station 1, all the pressure reducer and flow control valves 24a...i,38 are closed. The coastal demineralisation plant receives seawater from the sea and demineralises it. The demineralised water fills the dump condenser reservoir 12 via the main feed inlet shaft 17, the reservoir being vented via the vent shaft 19. The valves 21,22 are then
20 opened enabling demineralised water to flow from the dump condenser reservoir 11 to fill the main reservoir 5, the dump condenser reservoir being continually filled. The main feed tunnel 20, by being inclined at an angle of 2.5° , enables air in the main reservoir 5 displaced by the filling of the reservoir, to be vented via vent shaft 19. It will take about 2 to 3 months to fill the
25 main reservoir 5.

The first branch shut off valve 44, the turbine and generator chamber inlet valve 45 and the turbine and generator chamber bypass inlet valve 49 are all closed and the second branch vent shut off valve 46 is opened. The first vent valve 35a is opened venting the first heat exchanger 26a below via the
30 vent line 55 in a maintenance tunnel 52 and the riser shaft 40. Demineralised

water in the main reservoir 5, immediately upstream of the first pressure reducer and flow control valve 24a, is at a pressure of 20 million Pa (200 bar), caused by the head of water from the dump condenser reservoir 12. The first pressure reducer and flow control valve 24a is opened and water flows
5 through. The water enters the first main feed shaft 23a and fills the pipes 29 in the first heat exchanger 26a, air displaced by the filling of the first heat exchanger 26a being vented via the first vent valve 35a. The water cannot flow any further because of the closed second pressure reducer and flow control valve 24b. When the water has filled the arm 2 up to and including
10 the first heat exchanger 26a, the pressure of water by the open pressure reducer and flow control valve 24a, caused by the valve 24a being open, is at a pressure of 10 million Pa (100 bar) and the pressure of water in the first heat exchanger 26a, because of the head of water from the main reservoir 5, is at a pressure of about 27.5 million Pa (275 bar).

15 The second vent valve 35b is opened venting the second heat exchanger 26b below. The second pressure reducer and flow control valve 24b is opened and water flows through. The water enters the second main feed shaft 23b and fills the pipes 29 in the second heat exchanger 26b, air displaced by the filling of the second heat exchanger 26b being vented via the
20 second vent valve 35b. The water cannot flow any further because of the closed third pressure reducer and flow control valve 24c. When the water has filled the arm 2 up to and including the second heat exchanger 26b, the pressure of water by the open second pressure reducer and flow control valve 24b, caused by the valve 24b being open, is at a pressure of 10 million Pa
25 (100 bar) and the pressure of water in the second heat exchanger 26b is at a pressure of about 27.5 million Pa (275 bar).

The third vent valve 35c is then opened and the process is repeated for each heat exchanger until the seventh vent valve 35g and the seventh pressure reducer and flow control valve 24g are opened so that water
30 proceeds to fill the reservoir 36 which is at substantially at the same depth as

the seventh heat exchanger 26g and is thus associated with it.

When the reservoir 36 is filled, the pressure of water in the reservoir is about 32.5 million Pa (325 bar). All the vent valves and all the pressure reducer and control valves previously opened are then closed and the main
5 reservoir 5 is refilled. The pressure is kept monitored in the arm 2 and if pressure needs to be relieved the appropriate pressure reducer and flow control valves can be opened to varying degrees and, if necessary, appropriate vent valves can also be opened.

The water in the first six heat exchangers 26a...f is left to absorb heat
10 from the surrounding rock. The deeper below the surface the heat exchangers are, the greater the temperature of the surrounding rock. The water in the pipes 29 in the first heat exchanger 26a is heated to about 100°C by the surrounding rock which is at a temperature of about 200°C. The pressure of the water prevents it from turning into steam. The water in the pipes 29 in
15 each successive heat exchanger should be successively increased in temperature by 50°C by the surrounding rock which is approximately 100°C higher. Thus, the water in the sixth heat exchanger should be heated to a temperature of about 350°C by surrounding rock at a temperature of about 450°C. When this occurs, one pressure reducer and flow control valve 38 is
20 opened to allow a flow of about one tonne per second and water fills the seventh heat exchanger 26g, the pressure of the water being 18 million Pa (180 bar) because of the open valve 38.

The water in the seventh heat exchanger 26g is surrounded by rock at a temperature of 500°C and when the water there is heated to above the
25 supercritical steam temperature the water is changed into superheated or dry steam, the seventh heat exchanger 26g being an evaporator section. The eighth and ninth vent valves 36h,36i are opened and the eighth pressure reducer and flow control valve 24h is opened when the steam, at a pressure of 18 million Pa (180 bar), has reached a temperature of 400°C. The
30 superheated steam then enters the eighth heat exchanger 26h, the open valve

24h causing pressure to be reduced to 16 million Pa (160 bar). When this heat exchanger 26h is filled with enough steam, the eighth pressure reducer and flow control valve 26g and the eighth and ninth vent valves 36h,36i are closed and the steam is then left to be heated in the heat exchanger to a temperature of 450°C, the eighth heat exchanger 26h being a superheater section.

All the vent valves 35a...i are now closed and the pressure reducer and flow control valves 24a...h are opened. The second branch vent shut off valve 46 and the turbine and generator chamber inlet valve 45 are closed and the first branch shut off valve 44, the turbine and generator chamber bypass inlet valve 49 and the bypass shut off valve 50 are opened, and the dump condenser chamber shut-off valve 21 and the main reservoir inlet valve 22 remain open. The ninth pressure reducer and flow control valve 24i is opened and the superheated steam, reducing to a pressure of 14 million Pa (140 bar) because of the open valve 24i, flows from the eighth heat exchanger 26h and rises up the riser shaft 40, the rising steam reducing in pressure to about 5 million (50 bar) at the top of the riser shaft 40. The steam bypasses the turbines 6 and generators via the bypass tunnel 48 and enters the dump condensers 11. The seawater flowing around the dump condensers 11 causes the steam to be converted into water which re-enters the main reservoir 5.

Water in the main reservoir 5, immediately upstream of the first pressure reducer and flow control valve 24a, is at a pressure of 20 million Pa (200 bar), caused by the head of water from the dump condenser reservoir 12. The open first pressure reducer and flow control valve 24a causes the water flowing through to be reduced to 10 million Pa (100 bar). The water flows through the first heat exchanger 26a where it is heated to a temperature of 100°C. The pressure of water in the first heat exchanger 26a, because of the head of water from the main reservoir 5, is at a pressure of about 27.5 million Pa (275 bar).

The water then flows through the open second pressure reducer and flow control valve 24b causing the water to be reduced to 10 million Pa (100 bar). The water then flows through the second heat exchanger 26b where it is heated to a temperature of 150°C. The pressure of water in the second
5 heat exchanger 26b, because of the head of water from the first heat exchanger 26a, is at a pressure of about 27.5 million Pa (275 bar).

This is repeated for each successive heat exchanger, the water being increased in temperature by about 50°C in each successive heat exchanger. Thus, the water flowing through the sixth heat exchanger 26f is heated to a
10 temperature of 350°C. In the seventh heat exchanger 26g (the evaporator section), the water is converted into steam and is heated to a temperature of 400°C, the pressure of steam being 18 million Pa (180 bar). In the eighth heat exchanger 26h (the superheater section), the steam is heated to a temperature of 450°C, the pressure of steam being 16 million Pa (160 bar).

15 The superheated steam leaving the eighth heat exchanger 26h at a pressure of 14 million Pa (140 bar) rises up the riser shaft 40, reducing in pressure to 5 million Pa (50 bar). The steam bypasses the turbines 6 and generators via the bypass tunnel 48 and is converted into water by the dump condensers 11, the water re-entering the main reservoir 5.

20 Thus a flow is established around the arm 2. The initial flow is about one tonne per second and this is increased to about ten tonnes per second by successively opening the remaining closed pressure reducer and flow control valves 38 in the feed pipes 37 to the seventh heat exchanger 26g. Water completes one cycle around the arm 2 in about 50 days.

25 When all ten pressure reducer and flow control valves 38 have been opened and all the required pressures and temperatures have been reached, the turbines and associated plant are commissioned in a conventional manner and the turbine and generator chamber inlet valve 45 is opened. Hence, the steam enters the turbine and generator chamber at a pressure of 50 bar and
30 drives the steam turbines 6 ultimately causing the generators to produce

electricity. Exhaust steam from the turbines 6 is condensed into water by the turbine condensers 7, the water passing into the main reservoir 5 via the dump condenser reservoir 12.

When the steam turbines 6 have warmed up, they are run up to their
5 operating speed and synchronised. Loading of the turbines 6 is completed by closing the bypass inlet and shut off valves 49,50.

The reservoir 36 is provided to enable water to be converted into steam which will be at a sufficient pressure to drive the steam turbines 6, the reservoir being used to increase the pressure of water from the sixth heat
10 exchanger 26f as when steam is produced in the arm 2, it cannot then be further increased in pressure.

The commissioning process would take about one to three years.

In normal running, water from the main reservoir 5 passes through the heat exchangers 26a...h so that superheated steam at a temperature of 450°C
15 emerges from the eighth heat exchanger 26h via the ninth pressure reducer and flow control valve 24i at a pressure of 14 million Pa (140 bar). The steam rises up the riser where it is reduced in pressure to 5 million Pa (50 bar). The steam drives the steam turbines 6 causing electricity to be produced by the connected generators and the exhaust steam is converted into water by the
20 steam turbine condensers 7. This water flows into the main reservoir 5 via the dump condenser reservoir 12.

In normal running, about one to two percent of the fluid in the arm 2 is steam.

The pressures in the arm are kept monitored, particularly in all the heat
25 exchangers 26a...h to avoid excess pressure. Pressure is controlled by the pressure reducer and flow control valves 24a...i being varied from being in a partially and a fully opened position. In an emergency, pressure can also be controlled by opening any of the vent valves 35a...i.

The above described process is repeated for all four arms 2 with each
30 arm 2 estimated to generate about 5 plus giga watts. The geothermal power

station 1 is estimated to turn 10 tonnes of water into dry steam per second which is used to generate the power.

The fourth shaft 18 from the dump condenser chamber 4 may be used to remove water from the arm when the arm is running and more water may be entered into the arm via the main feed inlet shaft 17. The water removed is demineralised and can be added to freshwater. The removed water may be aerated before being added to freshwater for rivers or reservoirs. Each arm 2 may be drained via the fourth shaft 18 and as part of the dewatering process the vent shaft 43 would be opened.

The geothermal power station operating with the above parameters would be operating at less than its full potential.

The invention is not restricted to the parameters given above, but they are given as one example of how to obtain the required geothermal power. For example, the depth underground and the dimensions of the components of the power station could be varied. The flow rates, pressures and temperature given are estimates for one embodiment and can be varied.

The use of a demineralisation plant ensures that freshwater supplies are not depleted. By-products of the plant include salt and any excess freshwater.

If salt water was used in the arms of the power station, parts of the arms would be liable to scale up and salt in the steam would damage the turbines 6.

The geothermal power station 1 should be built in regions where the land mass is relatively stable such as in the East coast of the United States, the East coast of the United Kingdom, and Northern Russia.

Referring to Figure 13, in a modification, the successive heat exchangers 26a...h are arranged in a helix bounded within a virtual cylinder 65 (shown in dotted line) wherein each heat exchanger and main feed pipe 23a..h is located along the outer face of the cylinder. This arrangement produces a shaft pillar which forms a stable underground structure providing a structure which is more resistant to earth movement.

Whilst a particular embodiment has been described, it will be

understood that various modifications may be made without departing from the scope of the invention. For example, the geothermal power station could have any number of arms. The number of heat exchangers could be varied. Reservoirs, similar to the reservoir 36 associated with the seventh heat
5 exchanger, could also be added to the fifth and/or sixth heat exchangers 26e,26f.

CLAIMS:

1. A natural geothermal power generating system, characterized by heat exchanging means being arranged to receive water, the heat exchanging.
5 means comprising a plurality of heat exchangers (26a...h) connected in series, each successive heat exchanger being located in rock at a greater predetermined depth below the surface of the Earth than the previous heat exchanger, turbine means (6) located above the heat exchanger closest to the surface of the Earth, and a riser passage (40) extending from the lowest heat
10 exchanger up to the turbine means, whereby naturally generated heat from the rock surrounding the heat exchanging means converts the water in the heat exchanging means into steam which rises up the riser passage at a pressure capable of driving the turbine means.
- 15 2. A system as claimed in claim 1, wherein the riser passage (40) is substantially vertical.
3. A system as claimed in claim 1, wherein the water for the heat exchanging means (26a...h) is supplied from the Earth's surface.
20
4. A system as claimed in claim 1, 2 or 3, including condensing means (11) for condensing steam exhausted from the turbine means (6) into water.
5. A system as claimed in and preceding claim, including underground
25 reservoir means (5) for storing water for the heat exchanging means (26a...h).
6. A system as claimed in claims 4 and 5, wherein the underground reservoir means (5) is adapted to receive water from the condensing means (11).

7. A system as claimed in any preceding claim, including flow control means (24a...i) for controlling the flow of water or steam in the system.

8. A system as claimed in any preceding claim, including pressure control means (24a...i) for controlling pressure of water in the system.

9. A system as claimed in any preceding claim, wherein at least one heat exchanger (26g) has an associated reservoir (36) for increasing water pressure into the heat exchanger.

10. A system as claimed in any preceding claim, wherein the plurality of heat exchangers (26a...h) are arranged in a helix formation to form a shaft pillar.

11. A system as claimed in any preceding claim, wherein each heat exchanger (26a...h) has associated vent valve means (35a...h), each vent valve means being connected to the riser passage (40) by a vent (55) slightly inclined towards the surface to aid venting.

12. A system as claimed in any preceding claim, wherein the riser passage (40) is vented to the surface via valve means.

13. A geothermal power station (1) comprising a plurality of arms (2), each arm comprising a natural geothermal power generating system as claimed in any preceding claim.

14. A method for operating a natural geothermal power generating system including turbine means (6), characterized by the steps of:

feeding water into heat exchanging means comprising a plurality of heat exchangers (26a...h) connected in series, each successive heat exchanger

being located in rock at a greater predetermined depth below the surface of the Earth than the previous heat exchanger;

using the natural heat of the rock surrounding the heat exchanging means to generate steam from the water in the heat exchanging means; and

5 constraining the generated steam so that it rises at a pressure capable of driving the turbine means.

15. A method as claimed in claim 14, including the steps of condensing steam exhausted from the turbine means (6) into water, and feeding said
10 water back into the heat exchanging means (26a...h).

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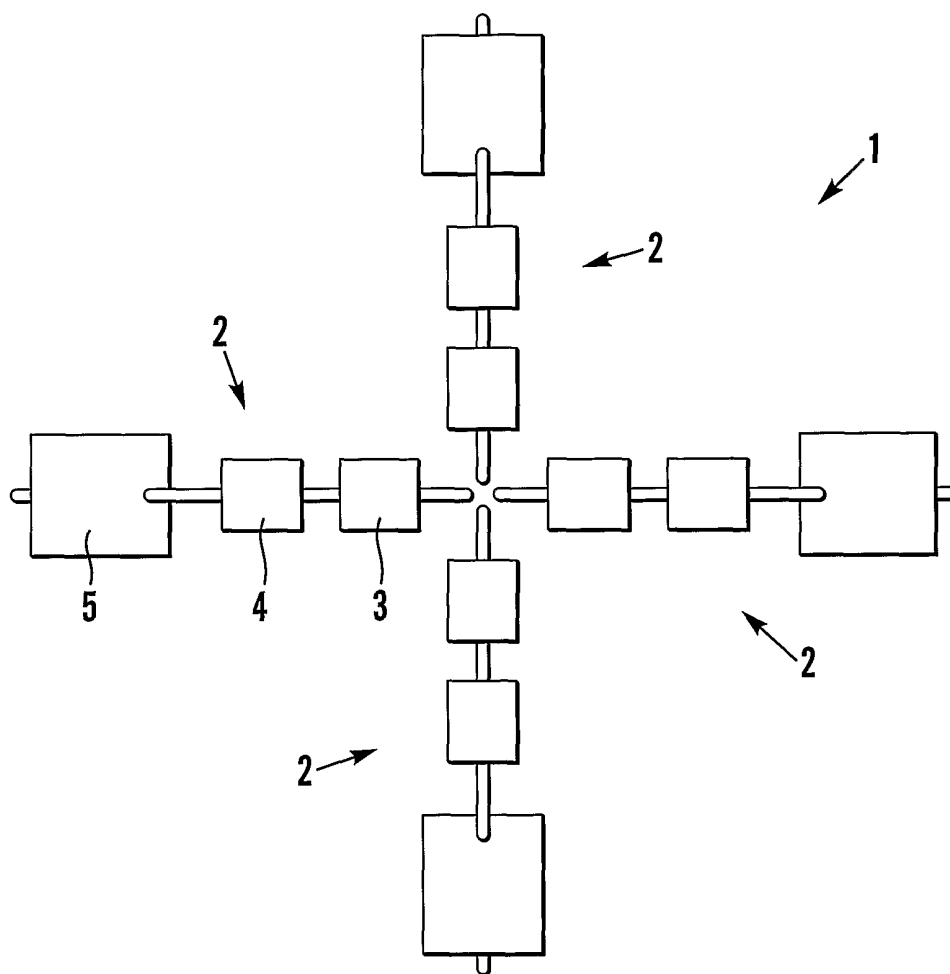


Fig. 1

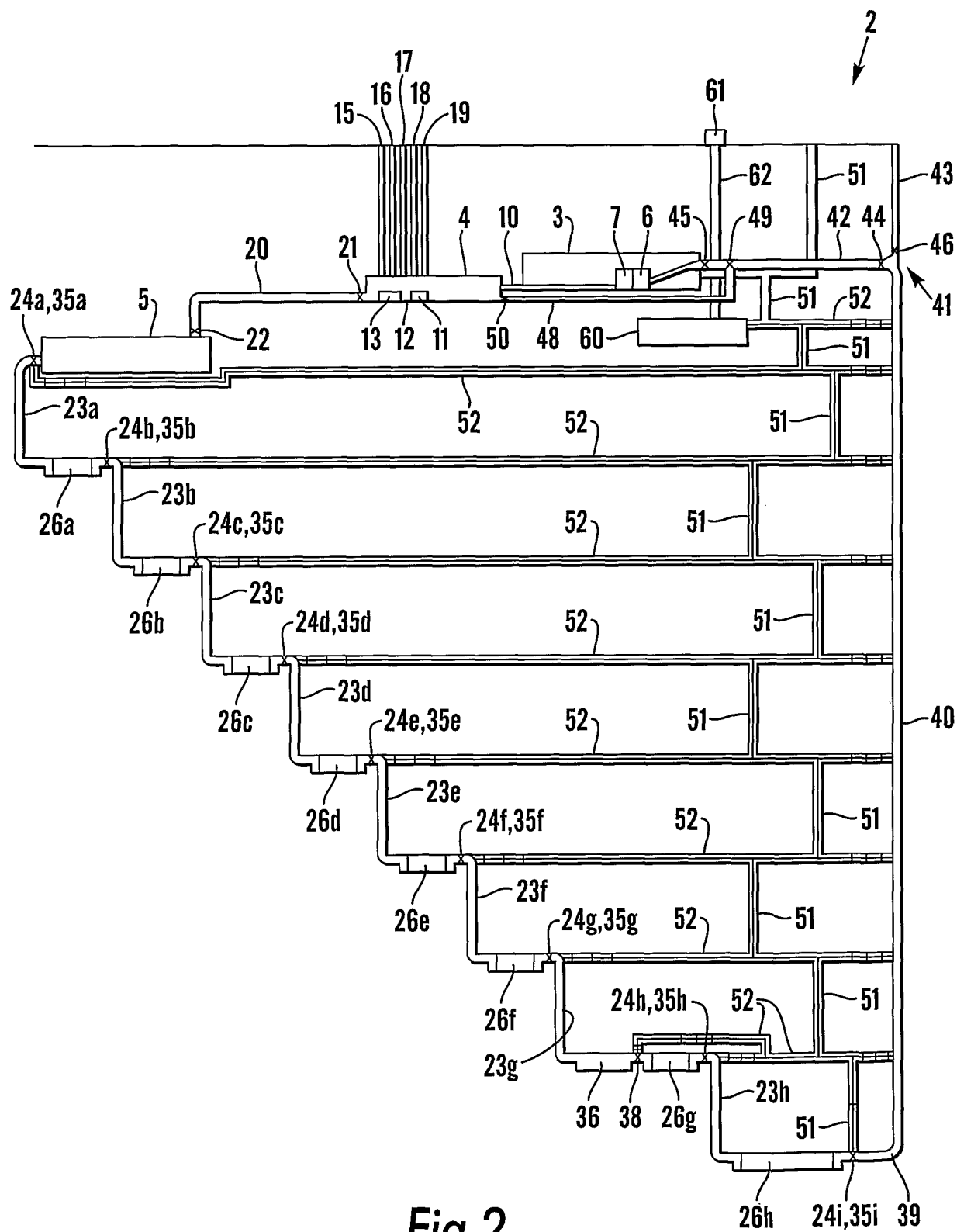
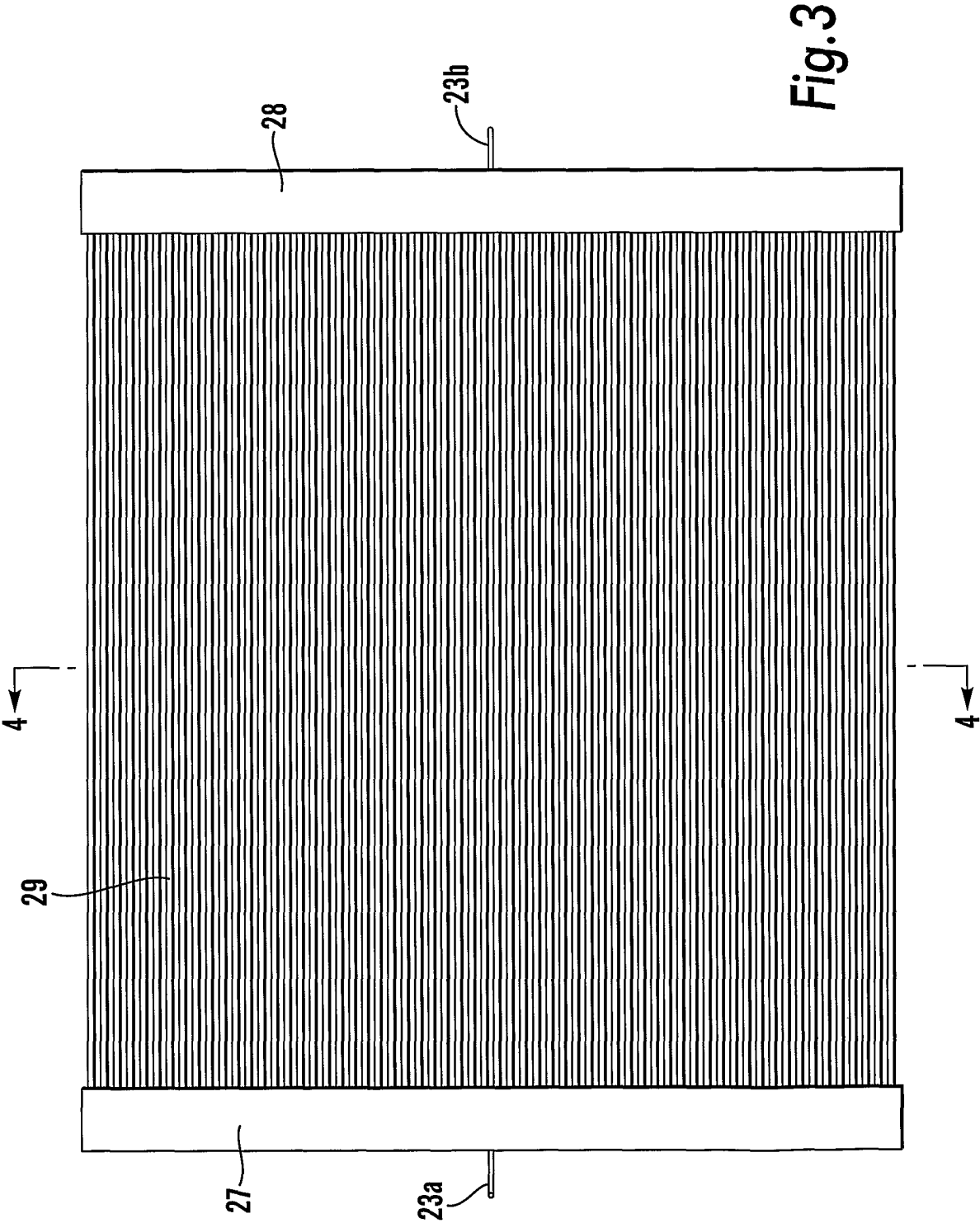


Fig.2



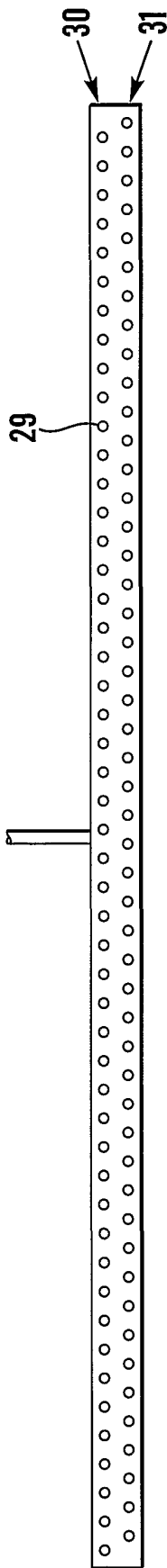


Fig. 4

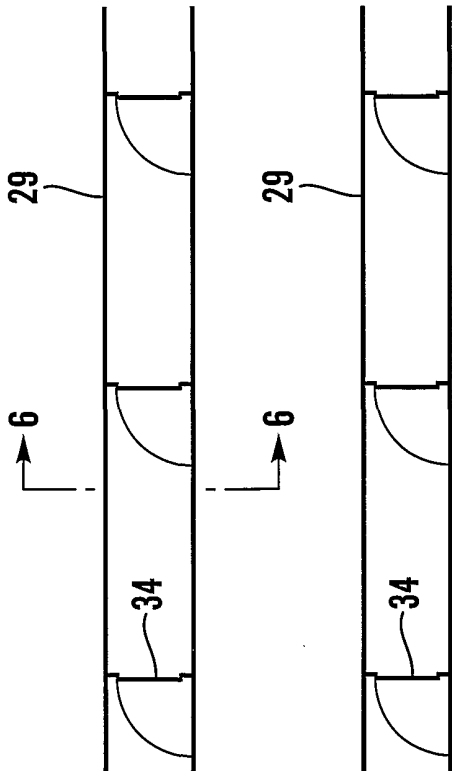


Fig. 5

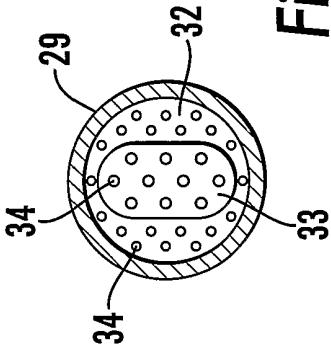


Fig. 6

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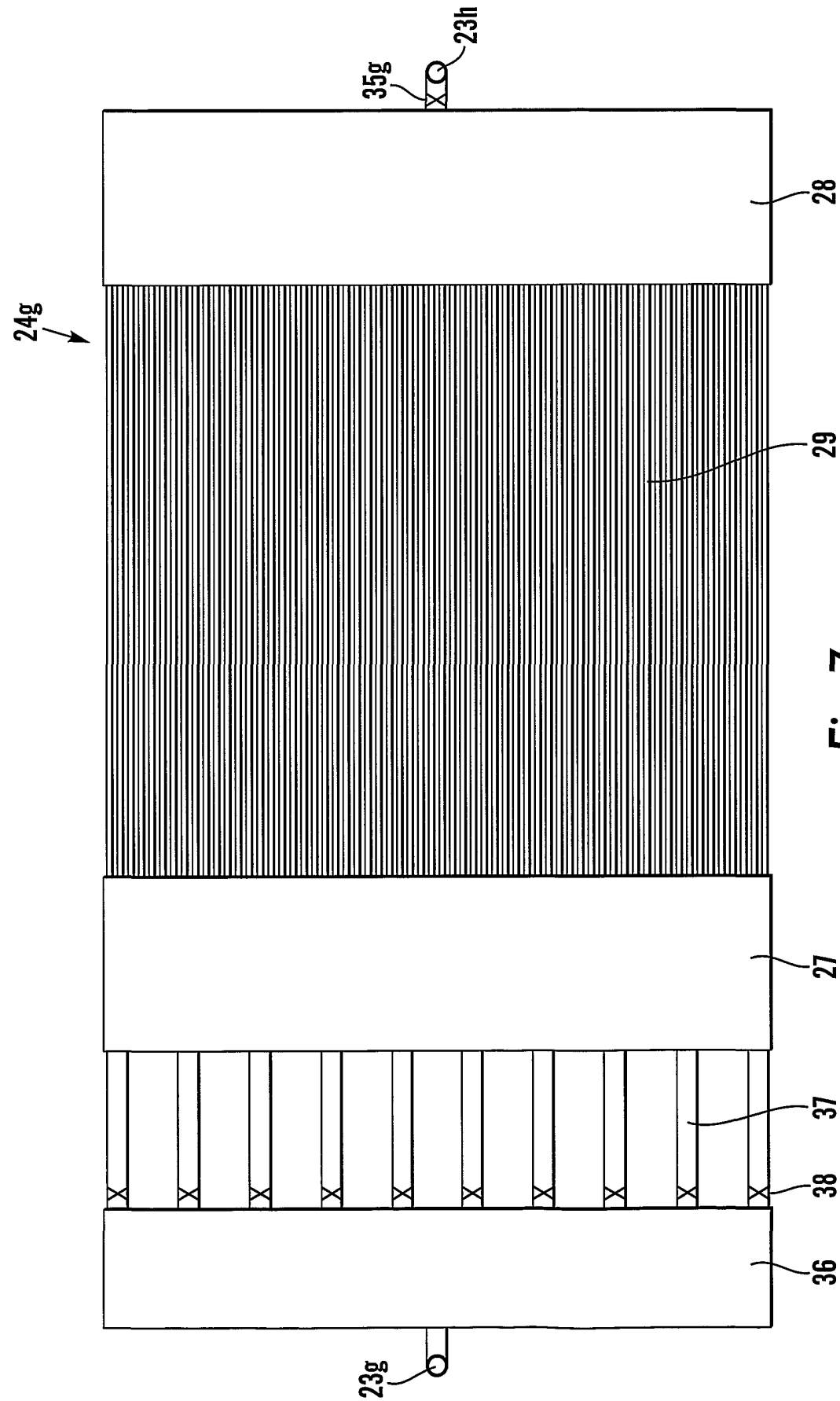


Fig.7

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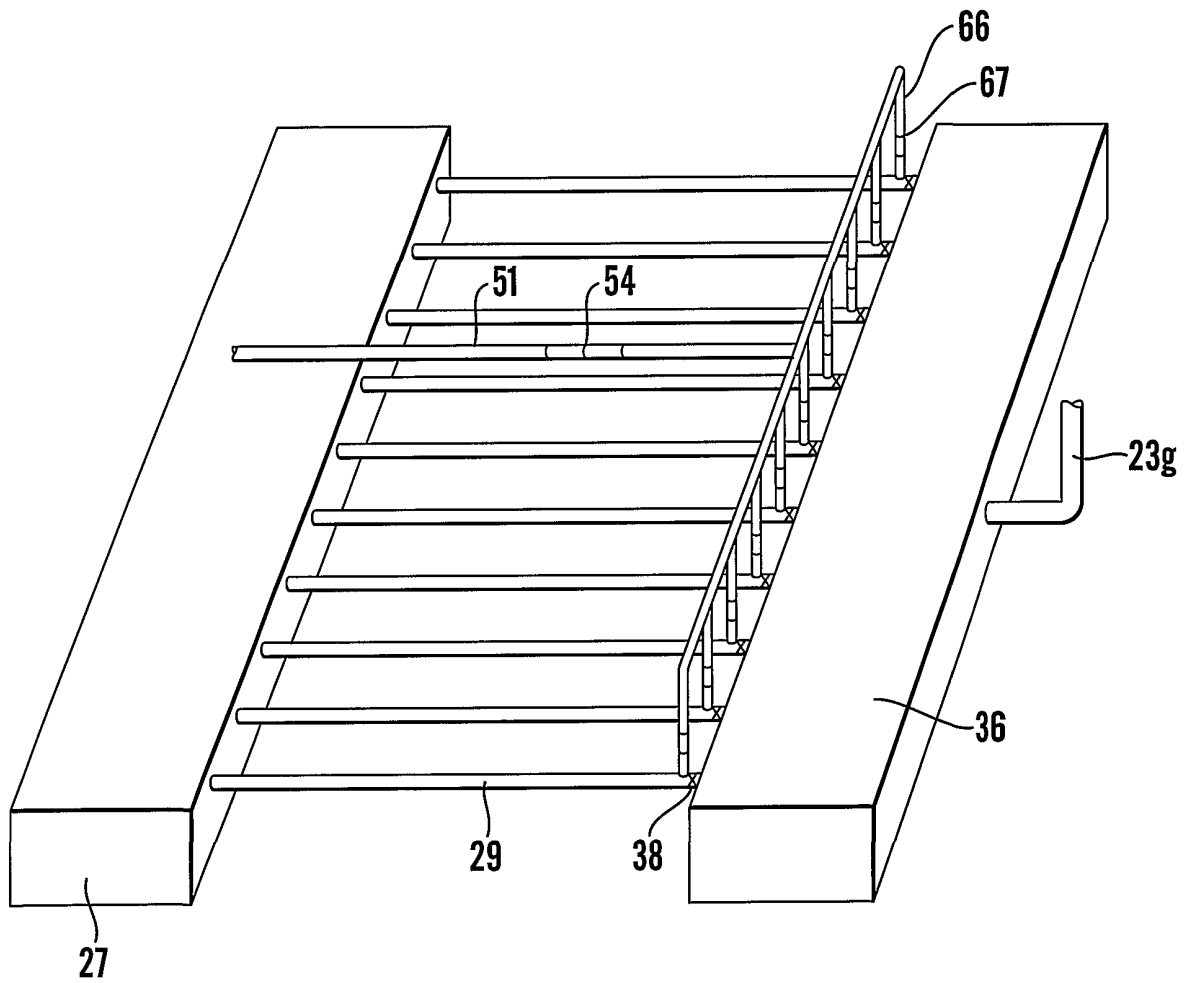


Fig. 8

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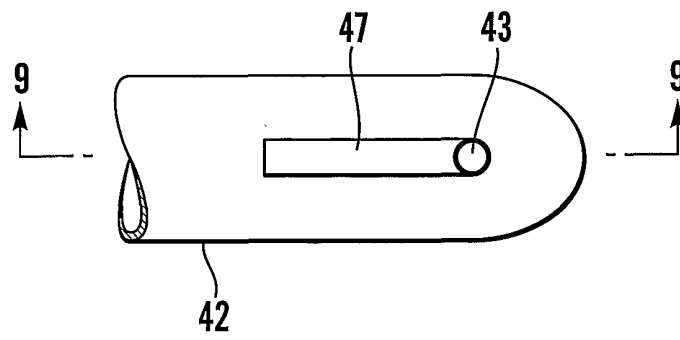


Fig. 9

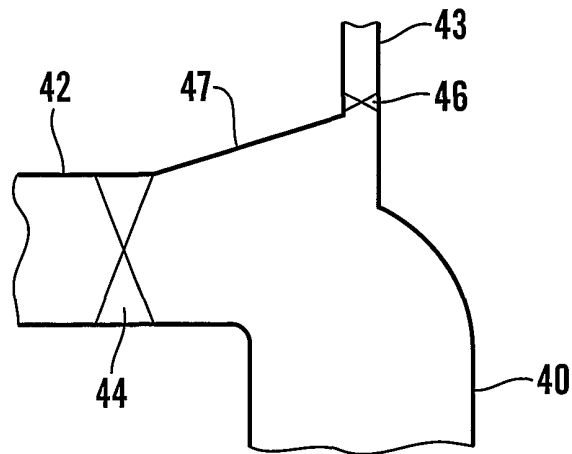
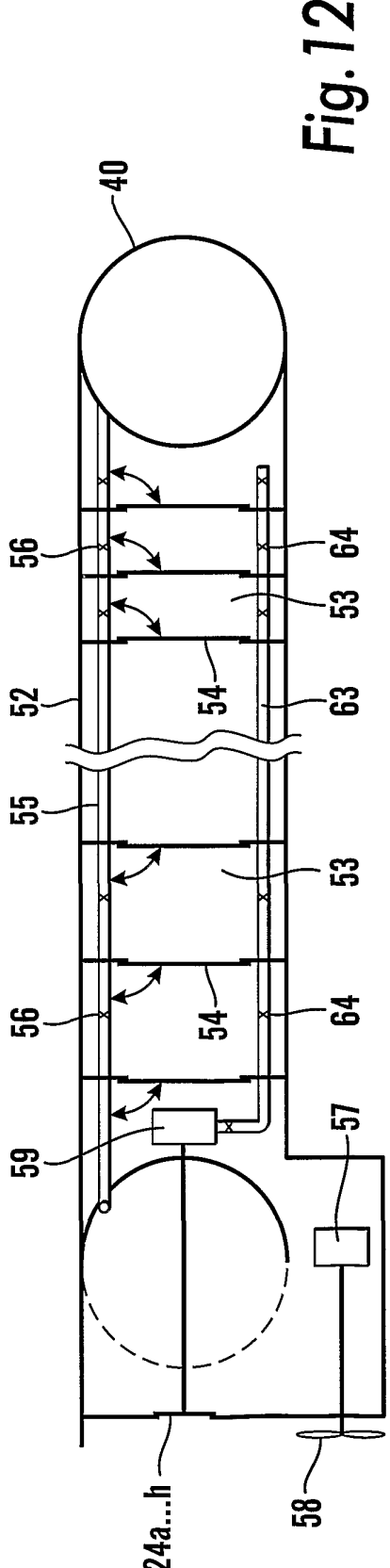
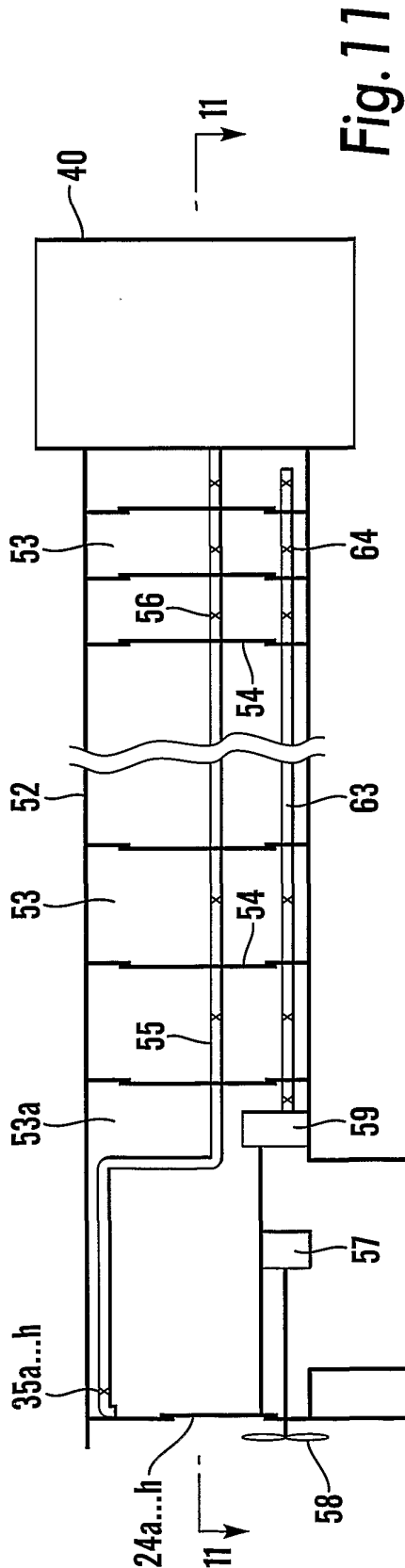


Fig. 10



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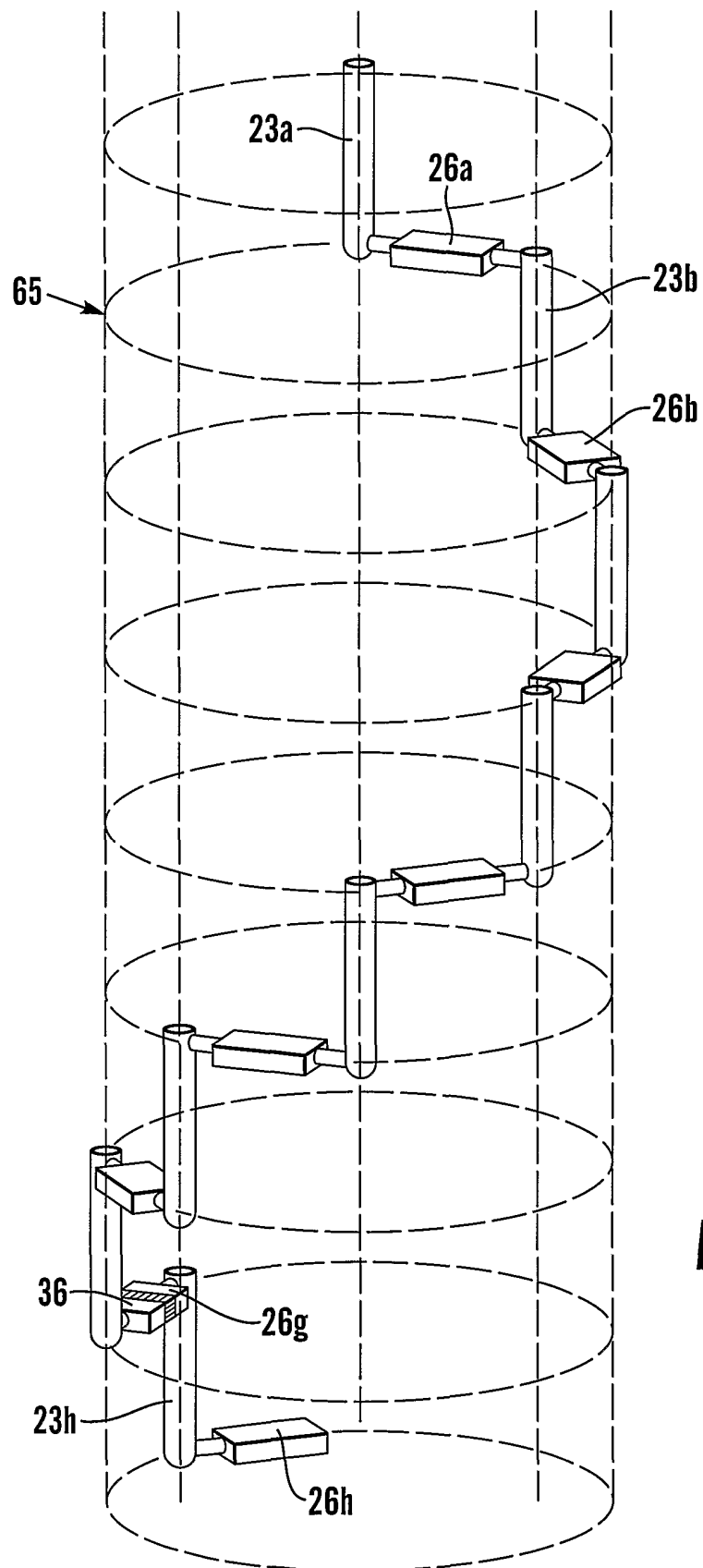


Fig. 13

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 00/02675

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F03G7/04

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)

IPC 7 F03G

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 practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 073 448 A (LOZADA VINCE M) 13 June 2000 (2000-06-13) column 6, line 45 -column 9, line 29; figures 4-5B ---	1-4, 7-9, 14, 15
A	DE 199 19 555 C (FLOWTEX TECHNOLOGIE GMBH & CO) 15 June 2000 (2000-06-15) column 6, line 23 -column 8, line 10; figure 1 ---	1, 14
A	US 6 000 471 A (LANGSET EINAR) 14 December 1999 (1999-12-14) column 1, line 53 -column 2, line 28; figure 1 --- -/--	1, 14

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

2 March 2001

Date of mailing of the international search report

09/03/2001

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INTERNATIONAL SEARCH REPORT

Intel^l nal Application No

PCT/GB 00/02675

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 644 750 A (LOCKETT GEORGE E ET AL) 24 February 1987 (1987-02-24) column 3, line 50 -column 4, line 52; figure -----	1,14
A	US 4 492 083 A (MCCABE BARKMAN C ET AL) 8 January 1985 (1985-01-08) column 5, line 55 -column 9, line 39; figure 1 -----	1,14

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 00/02675

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6073448 A	13-06-2000	NONE	
DE 19919555 C	15-06-2000	EP 1048820 A	02-11-2000
US 6000471 A	14-12-1999	NO 950306 A	29-07-1996
		AU 4635396 A	14-08-1996
		CA 2211366 A	01-08-1996
		DK 804709 T	22-11-1999
		EP 0804709 A	05-11-1997
		WO 9623181 A	01-08-1996
US 4644750 A	24-02-1987	GB 2160306 A	18-12-1985
		AU 4439585 A	10-01-1986
		BR 8506782 A	25-11-1986
		EP 0190161 A	13-08-1986
		FI 860615 A	11-02-1986
		WO 8600124 A	03-01-1986
		HU 47726 A,B	28-03-1989
		JP 61502412 T	23-10-1986
		NO 860526 A	13-02-1986
US 4492083 A	08-01-1985	NONE	