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CA 2330094 C 2006/04/18

(11)(21) 2 330 094

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(22) Date de dépôt/Filing Date: 2001/01/03
(41) Mise à la disp. pub./Open to Public Insp.: 2002/07/03
(45) Date de délivrance/Issue Date: 2006/04/18

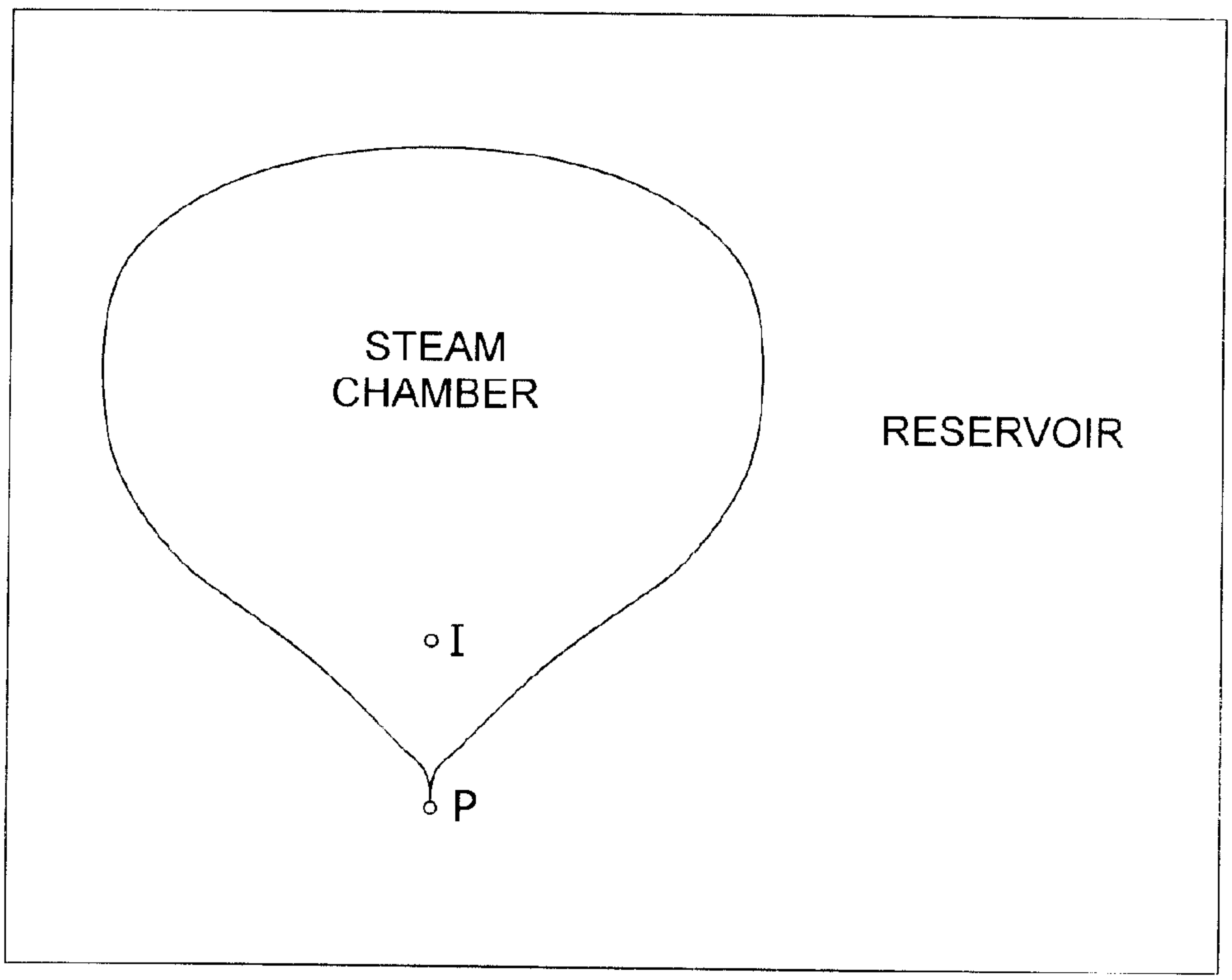
(51) Cl.Int./Int.Cl. *E21B 43/24* (2006.01)

(72) Inventeur/Inventor:
ITO, YOSHIAKI, CA

(73) Propriétaire/Owner:
JAPAN CANADA OIL SANDS LIMITED, CA

(74) Agent: JOHNSON, ERNEST PETER

(54) Titre : PROCEDE DE DRAINAGE PAR GRAVITE AU MOYEN DE LA VAPEUR
(54) Title: STEAM-ASSISTED GRAVITY DRAINAGE PROCESS



(57) Abrégé/Abstract:
Following second phase steam assisted gravity drainage operation using a co-operating pair of steam injection and fluid production wells, steam injection is terminated while flowing fluid production is continued, to draw down the reservoir pressure and flash steam in situ. Then a downhole pump is actuated to produce reservoir fluid and further reduce the reservoir pressure, thereby generating additional steam in situ. As a result of these steps, an additional recovery of oil is realized, using residual heat remaining in the reservoir at the end of steam injection and incremental steam generated in situ by pressure reduction obtained by pumping.

"STEAM-ASSISTED GRAVITY DRAINAGE PROCESS"

ABSTRACT OF THE DISCLOSURE

Following second phase steam assisted gravity drainage operation using a co-operating pair of steam injection and fluid production wells, steam injection is terminated while flowing fluid production is continued, to draw down the reservoir pressure and flash steam in situ. Then a downhole pump is actuated to produce reservoir fluid and further reduce the reservoir pressure, thereby generating additional steam in situ. As a result of these steps, an additional recovery of oil is realized, using residual heat remaining in the reservoir at the end of steam injection and incremental steam generated in situ by pressure reduction obtained by pumping.

BACKGROUND OF THE INVENTION

"Steam-assisted gravity drainage" and "SAGD" are a phrase and acronym used to identify a known oilfield thermal process. This SAGD process is now being used in Western Canada to recover heavy oil from shallow subterranean reservoirs.

The SAGD process typically involves:

- Providing a number of parallel co-operating pairs of horizontal wells located at spaced points across the reservoir. The wells are positioned close to the reservoir base (see Figure 1);
- Each co-operating pair comprises an upper injection well and a lower production well. The wells usually extend co-extensively, in parallel, with the injection well located directly above the production well in closely spaced relationship;
- The wells are suitably equipped for thermal operation;
- In the first phase of the process, fluid transmissibility is established between the wells of each pair. For example, steam may be circulated down to the toe of each well through a production tubing string and back through the annulus formed between the production tubing and the string comprising a sand exclusion liner and production casing. In effect, circulation of steam through the two wells creates two "hot fingers" which conductively heat the span of formation extending between the wells. Circulation of steam is continued until the viscosity of the oil in the span is sufficiently reduced so that it can be displaced or driven. Pressure differential

between the injection and production wells is then used to flush or drive the oil in the span into the production well, through which it is produced;

- In the second phase of the process, the injection well is dedicated to injecting steam and the production well is dedicated to producing fluid. As steam is injected into the formation through the injection well, it rises, contacts and heats cold oil and the heated oil drains, along with steam condensate, down to the production well and is produced. Gradually an upwardly and outwardly developing steam chamber is formed. See Figure 2. The oil originally in the chamber has drained and been produced. The chamber pores are now filled with steam. Newly injected steam rises to the boundary surface of the chamber, heats cold oil at the boundary and continues the gradual expansion of the chamber. As shown in Figure 1, the chamber continues growing upwardly and outwardly, with a generally conical cross-section, until it reaches the overburden overlying the reservoir and contacts an adjacent steam chamber. The process is usually terminated when the operation becomes uneconomic due to ineffective heating and declining oil production;
- It needs to be understood that the SAGD oil production is of a flowing nature. Downhole pumps are generally not used during the second phase of the SAGD process.

The present invention is concerned with alleviating a problem associated with the SAGD process. More particularly, a large amount of energy or heat is retained in the steam chamber when the process becomes mature. This is illustrated in Figure 3. It is therefore the objective of the present invention to provide a post-SAGD step to recover some of the energy remaining at the end of the process for the production of oil.

SUMMARY OF THE INVENTION

At the conclusion of the second phase of the SAGD process, the steam chamber is under pressure and at high temperature. Example conditions might be a temperature of 263°C and a pressure of 5000 kPa.

Following the second phase, in accordance with the invention:

- steam injection is terminated while flowing production is continued, to lower the reservoir pressure
- a downhole pump is then positioned in the production well – the pump is operable from ground surface in conventional fashion;
- the pump is actuated to produce fluid from the production well and draw down the pressure in the reservoir;
- as a result of the pressure draw-down, liquid water in the reservoir will evaporate as the pressure is reduced – this in situ-produced "new" steam will function to heat cold oil at the steam chamber boundary. In addition, residual heat in the chamber will also act to warm and mobilize some of the reservoir oil.

In one embodiment, the invention is concerned with a process for recovering heavy oil from an underground reservoir comprising: providing a production well and an injection well, both wells horizontally penetrating the reservoir, the wells being generally parallel and co-extensive, the injection well being spaced above the production well, so that the pair of wells are capable of cooperating in the practice of steam assisted gravity drainage; practicing steam assisted gravity drainage production of oil from the reservoir on a flowing basis by injecting steam into the reservoir through the injection well to enlarge a steam chamber and heat reservoir oil so that it drains into and is produced through the production well; then terminating steam injection; inserting a downhole pump in the production well; and actuating the pump to produce oil on a pumping basis from the reservoir and reduce the steam chamber pressure.

DESCRIPTION OF THE DRAWINGS

Figure 1 is a fanciful side view showing adjoining mature steam chambers in contact with each other and the overburden, said chambers having been created by two pairs of co-operating SAGD wells;

Figure 2 is a fanciful end view showing a steam chamber with a pair of co-operating SAGD wells;

Figure 3 is a representation of data from a numerical modelling run during second phase SAGD, illustrating the temperature isotherms produced in connection with a steam chamber, together with the flux of steam (represented by the cross-hatching); and

Figure 4 is a representation of data from the numerical modelling run after one-half year of post-SAGD pumping, illustrating the temperature isotherms produced, together with the flux of steam.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention is an improvement on a conventional steam-assisted gravity drainage process wherein, in a first phase, fluid communication is established between a co-operating pair of upper injection and lower production horizontal wells positioned in a reservoir containing cold oil and water, and, in a second phase, steam is injected through the injection well and heated oil and steam condensate are produced through the production well, thereby developing a steam chamber having elevated temperature and pressure. The improvement comprises: terminating steam injection while continuing to produce the production well under flowing condition, thereby reducing reservoir pressure; positioning a downhole pump in the production well and actuating the pump to produce fluid from the reservoir, thereby further reducing the steam chamber pressure, so that water in the reservoir evaporates and produces steam in situ to further heat cold oil in the reservoir and render it producible.

The utility of the described process is demonstrated by the following results from a numerical modelling run incorporating the invention:

- Amounts of oil production and steam injection over a 4 year term of second phase SAGD, were:

oil production	291,770 m^3
steam injection	757,420 m^3
steam:oil ratio	2.60

- Amounts of additional oil production and steam injection obtained by continuing the run during 418 days of pumping post-SAGD:

oil production	67,380 m^3
steam injection	0
overall steam:oil ratio	2.11.

From the foregoing, it will be noted that substantial additional oil can be recovered without steam injection, using the residual energy present in the steam chamber after SAGD, when coupled with mechanical pumping. Pumping functions to reduce the steam chamber pressure. The run demonstrates a consequent reduction in the overall steam ratio.

The predicted isotherm and steam flux results of the numerical modelling run are illustrated in Figure 4 for a half year period. The steam chamber is cooled from 263°C to 215°C. This change in temperature corresponds to about 20% chamber residual energy utilization. It is predicted that up to 40% of the residual energy can be utilized.

The timing for switching from second phase SAGD to the post-SAGD is dependent on the maturity or completeness of second phase SAGD. The optimum timing can be determined by a numerical simulation study. Usually it will occur after 2 to 6 years of second stage SAGD operation.

1. A process for recovering heavy oil from an underground reservoir comprising:

providing a production well and an injection well, both wells horizontally penetrating the reservoir, the wells being generally parallel and co-extensive, the injection well being spaced above the production well, so that the pair of wells are capable of cooperating in the practice of steam assisted gravity drainage;

practicing steam assisted gravity drainage production of oil from the reservoir on a flowing basis by injecting steam into the reservoir through the injection well to enlarge a steam chamber and heat reservoir oil so that it drains into and is produced through the production well;

then terminating steam injection;

inserting a downhole pump in the production well; and

actuating the pump to produce oil on a pumping basis from the reservoir and reduce the steam chamber pressure.

2. A process for recovering heavy oil from an underground reservoir comprising:

providing a production well and an injection well, both wells horizontally penetrating the reservoir, the wells being generally parallel and co-extensive, the injection well being spaced above the production well, so that the pair of wells are capable of cooperating in the practice of steam assisted gravity drainage;

practicing steam assisted gravity drainage production of oil from the reservoir on a flowing basis by injecting steam into the reservoir through the injection well to enlarge a steam chamber and heat reservoir oil so that it drains into and is produced through the production well;

terminating steam injection;

continuing to produce oil from the reservoir by flowing it through the production well for a predetermined period; and

then inserting a downhole pump in the production well; and

actuating the pump to produce oil on a pumping basis from the reservoir and reduce the steam chamber pressure.

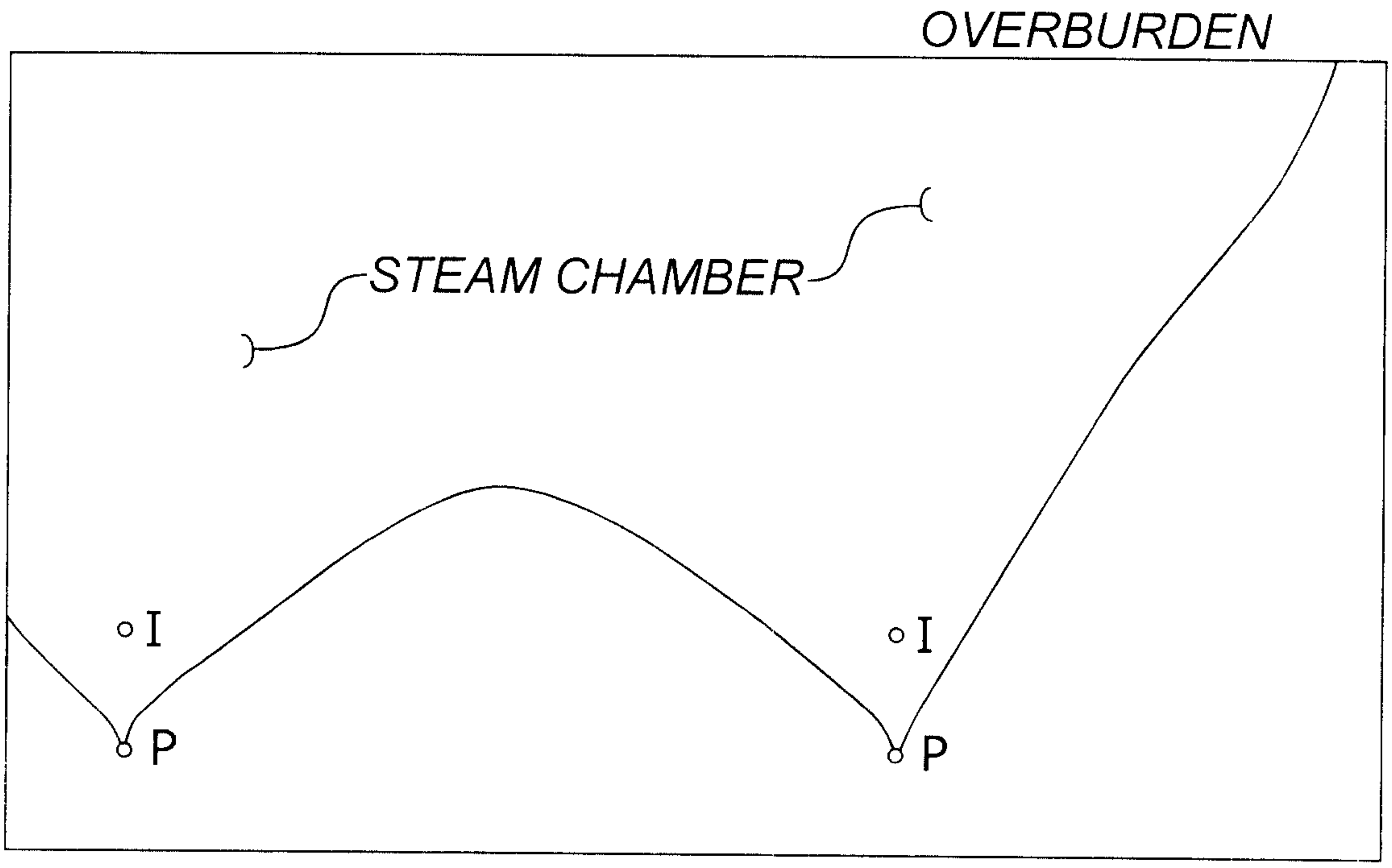


FIG. 1

FIG. 2

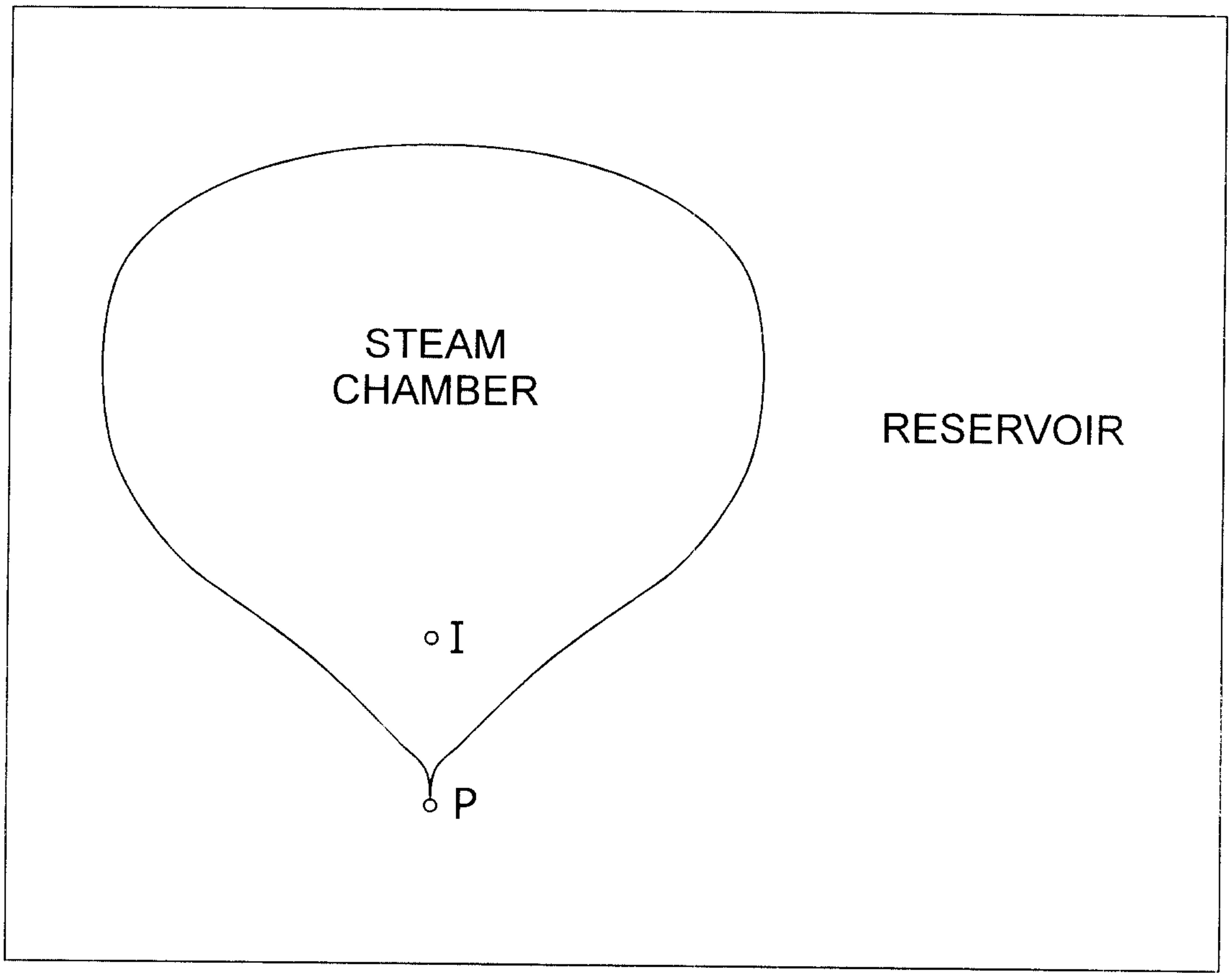


FIG. 3

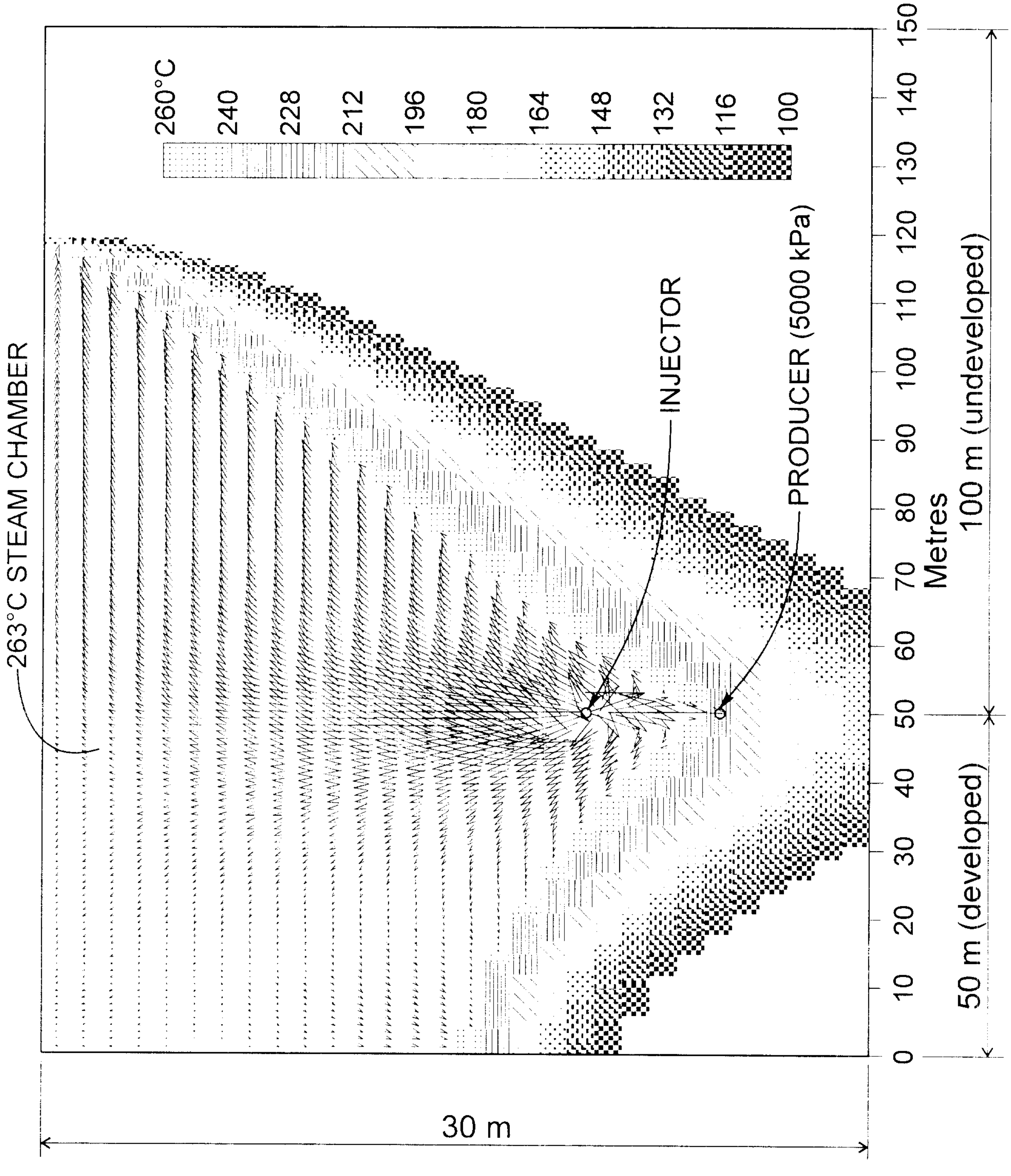
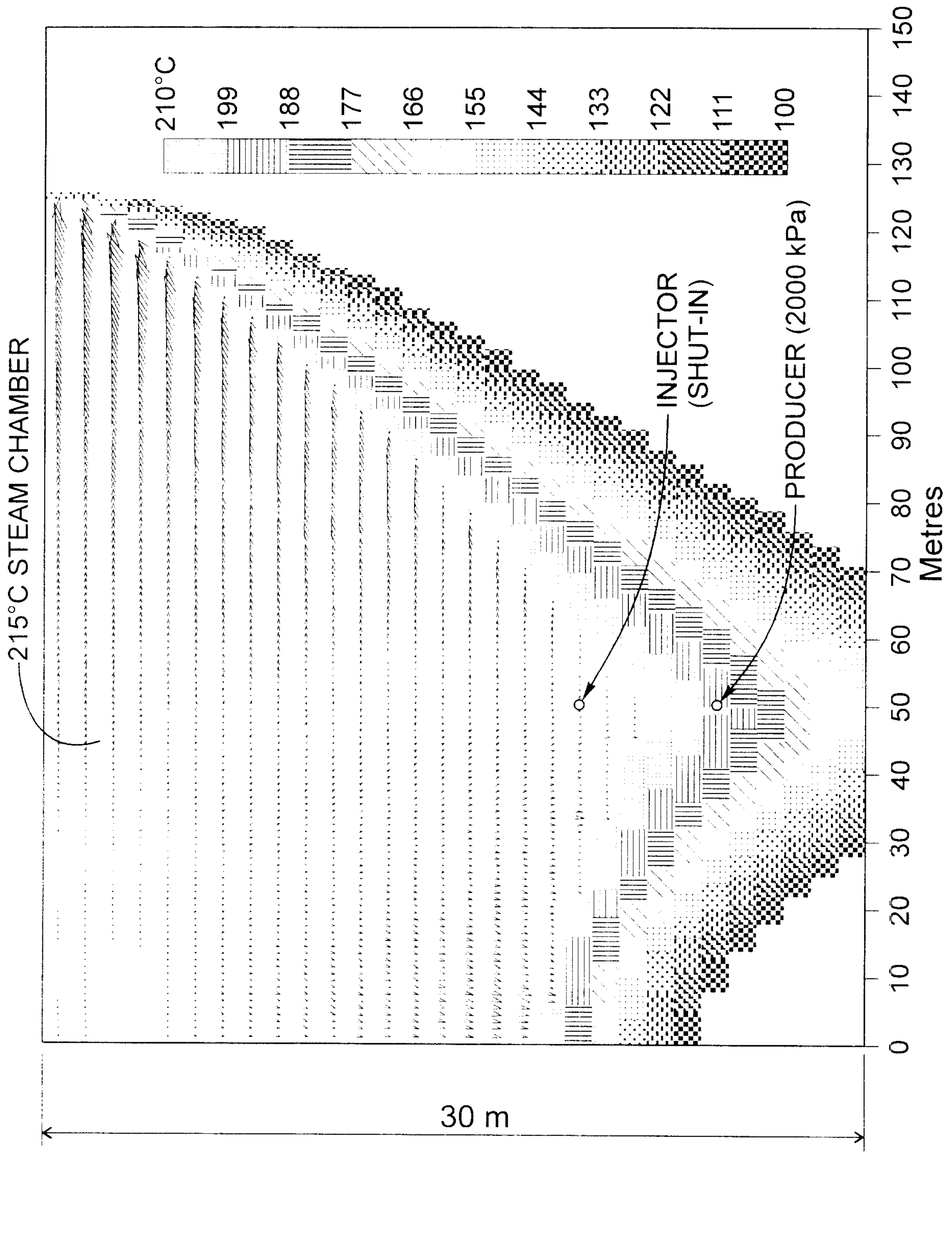
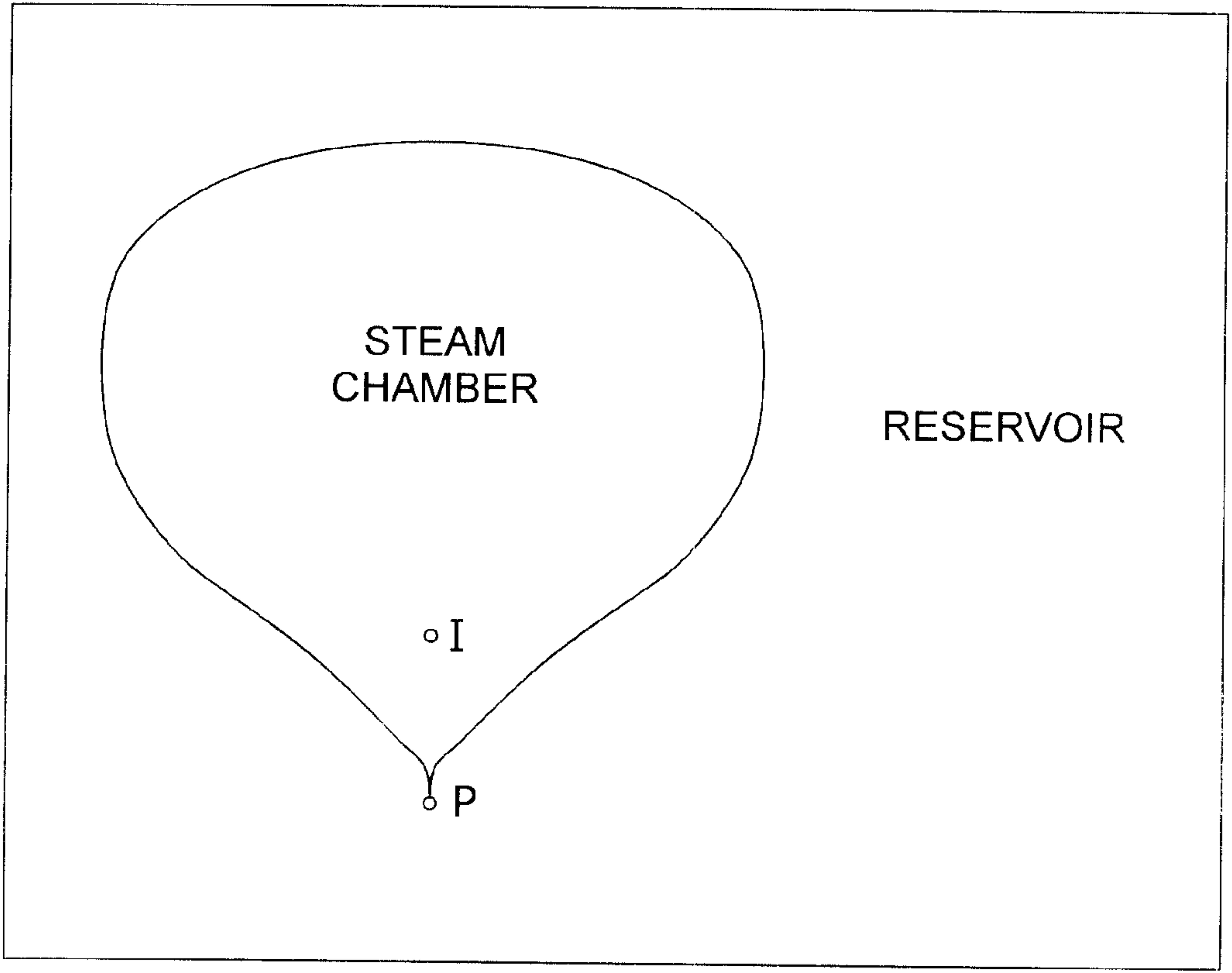

263°C STEAM CHAMBER
INJECTOR
PRODUCER (5000 kPa)
260°C
240
228
212
196
180
164
148
132
116
100
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Metres
50 m (developed)
100 m (undeveloped)
30 m

FIG. 4


215°C STEAM CHAMBER
210°C
199
188
177
166
155
144
133
122
111
100
INJECTOR
(SHUT-IN)
PRODUCER (2000 kPa)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Metres
30 m



STEAM
CHAMBER
RESERVOIR
I
P