(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 555 498 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **92102259.6**

(51) Int. Cl.[5]: **B01F 5/04**

(22) Date of filing: **11.02.92**

(43) Date of publication of application:
18.08.93 Bulletin 93/33

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IT LI LU MC NL PT SE

(71) Applicant: **APRIL DYNAMICS INDUSTRIES 1990 LTD.**
10 Ben Gurion Street
Ramat Gan 52573(IL)

(72) Inventor: **Fuks, Efim**
36 Adar Street, Apt. 12
Herzliah 46328(IL)
Inventor: **Fuks, Vadim**
15 Anilevitch Street
Herzliah 46328(IL)
Inventor: **Lunev, Vladimir**
74 Viliams Street, Apt. 86
Odessa(UA)

(74) Representative: **VOSSIUS & PARTNER**
Postfach 86 07 67
D-81634 München (DE)

(54) A two-phase supersonic flow system.

(57) A supersonic flow device for producing and maintaining a supersonic flow of a two-phase gas/liquid mixture and including a mixing chamber having an inlet (3) adapted to receive said mixture and an outlet (9) merging with a first end of an elongated neck portion, a second end of said neck portion communicating with an injector outlet, there being formed in an intermediate position of the neck portion a peripheral gap (15) which communicates with a housing chamber, said gap having a longitudinal axial dimension of the order of magnitude of the diameter of the neck portion. Preferably, the device is constituted by a supersonic two-phase flow injector and is formed with a housing (7) coaxial with the nozzle and having defined therein a liquid inlet chamber coaxial with and surrounding the nozzle, said mixing chamber merging at its inlet with said inlet chamber and converging towards its outlet.

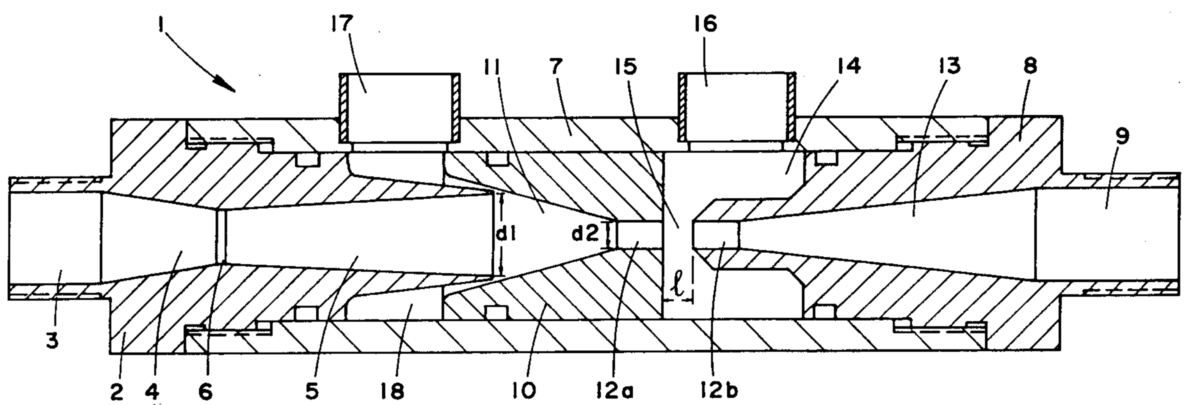


Fig. 1

EP 0 555 498 A1

FIELD OF THE INVENTION

This invention relates to a two-phase supersonic flow system of the kind wherein a liquid-gas mixture, flowing at supersonic speed (i.e. speed greater than the speed of sound for that mixture) undergoes continuing dissolving or condensation of the gas in the liquid. As a result, the speed of sound therein rises and the flow passes from supersonic to subsonic flow. This gives rise to the formation, in the transition zone from supersonic to subsonic flow, of a shock wave region in which there takes place an abrupt rise in the flow pressure as well as the rapid completion of the dissolving or condensation of the gas.

BACKGROUND OF THE INVENTION

Such two-phase supersonic flow systems have long been known and have been utilised, *inter alia,* so as to achieve a step-up in the flow pressure.

Such known supersonic flow systems have involved the use of supersonic nozzles, generally of the Laval type, in which an outlet of the nozzle communicates via a suitable, convergent mixing chamber with an elongated neck portion of substantially constant diameter, in which the shock wave region is created. The mixing chamber is formed with an opening through which a liquid can be drawn as a result of the rapid flow of the gas through and out of the nozzle.

It is known that the increase of the outflow pressure with respect to the highest input pressure of one of the constituents (usually the gas/steam constituent) is limited and this limit (in the case of water/steam flow) has been theoretically predicted by Deich, M.E. and Philippov, G.A. - *Gas dynamics of two phase systems,* Moscow 1968, pp. 267-274. In practice, and with commercially available supersonic injectors such as, for example, the MIH-jet models MBC-1 and MBC-2 manufactured by Jordan Equipment Co. of Houston, Texas, U.S.A., a pressure step-up ratio of 2 to 2.5:1 has been obtained.

It is furthermore known that the magnitude of the pressure step-up ratio which can be obtained and/or the maintenance of a stable, two-phase supersonic flow regime with a stable shock wave region, is influenced by the ratio of the diameter of the supersonic nozzle outlet to the diameter of the neck portion, and it has been postulated by Fisenko in SU Patent No. 1281761 that only when this ratio was within the range 1.1 to 1.7 was it possible to maintain a stable shock wave region and, in consequence, a stable two-phase supersonic flow.

It is furthermore known that progressively constricting or otherwise resisting the outflow from the elongated neck portion, whilst resulting in an increase in the outflow pressure, is nevertheless of limited effectiveness, seeing that any increase of the degree of constriction beyond a certain limit gives rise to an abrupt change of the flow regime, destroying the supersonic flow and the generation of the shock wave region.

In addition to the use of such two-phase supersonic flow systems in order to achieve a stepped-up pressure output, for example for use in steam jet cleaning equipment, it is also known to utilise such systems, for example in sterilising or homogenising a liquid. With such applications, it is the mechanical energy which is generated in the liquid owing to the creation of the shock wave region that is utilised in order to effect, for example, sterilisation without necessarily being accompanied by a stepped-up pressure. However, such systems have the known drawback that the generation of the required mechanical energy is accompanied by significant temperature rises, and such temperature rises can be very undesirable as far as the quality of the ultimate product is concerned.

It is an object of the present invention to provide a new and improved method for positioning and maintaining a stable shock wave region in a supersonic flow system, as well as to provide a new and improved supersonic two-phase injector for use in such a method, wherein the above-referred-to limitations and disadvantages are substantially reduced.

BRIEF SUMMARY OF THE INVENTION

According to the present invention, there is provided a method for positioning and maintaining a stable shock wave region in a supersonic flow system comprising the steps of:

creating a flow of a two-phase gas/liquid medium under such flow and condensation conditions as to generate a shock wave zone in the flowpath; and

draining at least a portion of the flow in the region immediately upstream of the shock wave zone.

Preferably, said flow downstream of the shock wave zone is constricted or is otherwise subjected to resistance.

According to a further aspect of the present invention, there is provided, for use in such a method, a supersonic flow device for producing and maintaining a supersonic flow of a two-phase gas/liquid mixture and including a mixing chamber having an inlet adapted to receive said mixture and an outlet merging with a first end of an elongated neck portion, a second end of said neck portion communicating with an injector outlet, wherein there is formed in an intermediate position of the neck portion a peripheral gap which communicates with a housing chamber, said gap having a longitudinal axial dimension of the order of magnitude of the diameter of the neck portion.

Preferably, the device constitutes a supersonic two-phase flow injector furthermore comprising a supersonic nozzle; a housing coaxial with the nozzle and having defined therein a liquid inlet chamber coaxial with and surrounding the nozzle and wherein said mixing chamber merges at its inlet with said inlet chamber and converges towards its outlet.

The housing chamber preferably communicates with a drain aperture formed in the housing.

In accordance with a preferred embodiment of the present invention, the ratio of the outlet diameter $\mathbf{d}_1$ of the nozzle to the inlet diameter $\mathbf{d}_2$ of the neck portion ranges from 0.8:1 to 4.0:1.

By virtue of the creation, in accordance with the invention, of such a stable shock wave region, and where the flow is drained from the region immediately upstream of the shock wave, it has been found that it is possible to constrict or otherwise restrict the flow of the liquid from the injector, even to the extent that the outflow is completely closed and all the liquid flows out of the drain aperture. This can be achieved without destroying the supersonic flow, but rather with maintaining a stable and increasingly narrowed shock wave region immediately adjacent and downstream from the region of drainage. In this way, the outflow pressure can be considerably stepped-up and/or an increasing amount of mechanical energy is imparted to the liquid and this with a lesser degree of heating of the liquid than was otherwise possible.

Furthermore, and when using the supersonic injector in accordance with the invention, it is possible to locate and maintain a stable shock wave region, even when no drainage of the liquid is effected, and this by virtue of the provision of the peripheral gap in the intermediate position of the neck portion and the association of this gap with the housing chamber, the shock wave region being created immediately downstream of this peripheral gap. In the latter case, of course, and where no draining is involved, the degree of constriction of the injector output is limited, as is the degree of attainable pressure step-up, which is nevertheless much higher than that obtainable with conventional injectors not provided with such a peripheral gap. This construction is, however, of particular interest where the application of the injector is in connection, for example, with obtaining maximum flow capacity and the requirement is for maximal transfer of mechanical energy to the liquid under these conditions, without at the same time unduly increasing its temperature.

BRIEF SUMMARY OF THE DRAWINGS

For a better understanding of the present invention, and to show how the same may be carried out in practice, reference will now be made to the accompanying drawings, in which:

Fig. 1 is a schematic, longitudinally sectioned view of a supersonic injector in accordance with the invention and which is to be used in carrying out the method in accordance with the invention; and

Fig. 2 shows the variation of outlet pressure under differing conditions of operation with a particular injector in accordance with the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

As seen in Fig. 1 of the drawings, a supersonic injector 1 comprises a Laval type nozzle 2 having an inlet port 3 communicating with a converging passage 4 which, in its turn, communicates with a diverging passage 5 via a narrow throat section 6.

A tubular housing 7 surrounds the nozzle 2 and is screw coupled thereto at one end thereof. An opposite end of the tubular housing 7 surrounds and is screw coupled to an injector outlet portion 8 formed integrally with an outlet port 9. An intermediate injector portion 10 is located within an intermediate portion of the housing 7 which surrounds it and is secured thereto. The intermediate injector portion 10 is formed with a converging passage 11 which communicates at its narrower end with a first section 12a of an elongated neck portion 12.

The injector outlet portion 8 is formed with a second elongated neck portion 12b which is coaxial with and spaced from the first neck portion 12a by a distance **1.** The neck portion 12b communicates with a diverging outlet portion 13 which, in its turn, communicates with the injector outlet port 9. Defined between adjacent ends of the intermediate portion 10 and the outlet portion 8 is an annular chamber 14 and a central gap portion 15. A drain port 16 is set into the wall of the housing 7 and communicates with the housing chamber 14.

Effectively, the neck portion sections 12a and 12b constitute a single neck portion 12, with the gap 15 between them being created by an effective peripheral aperture formed in the neck portion and communicating via the chamber 14 with the drain port 16.

A liquid entry port 17 is set into the wall of the housing 7 and communicates with an annular converging liquid entry passage 18 defined between adjacent walls of the nozzle 2 and the intermediate portion 10 and communicating with the chamber

11.

In operation, the outlet port 9 of the injector is coupled to an outlet hose (not shown) provided with suitable flow constricting means (also not shown).

When the gas/liquid medium employed is steam and water, steam enters the injector 1 via the inlet port 3 and emerges from the outlet of the nozzle 2 at a supersonic speed, i.e. a speed greater than the speed of sound in the steam medium. The passage of the steam out of the nozzle 2 gives rise to an inflow of water via the inlet port 17 and the converging passage 18 and the inflowing water mixes with the steam in the mixing chamber 11 and the steam/water mixture enters the neck portion 12a. As the steam mixes with the water, there is a progressive condensation of the steam in the water and this progressive condensation carries with it the following two effects:

a) The overall volume of the steam/water mixture is reduced, thereby reducing the overall flow speed of the mixture and,

b) in view of the fact that the speed of sound in the water is very substantially greater than the speed of sound either in steam or in a steam/water medium, a stage is reached wherein the speed of the medium passing through the neck portion suddenly drops below the speed of sound for the medium. When this happens, a shock wave region is set up in the neck portion with the medium on the upstream side of the shock wave travelling at a supersonic speed whilst the water on the downstream side of the shock wave travels at a subsonic speed.

The shock wave region is effectively set up in the neck portion section 12b immediately adjacent the gap 15, this being the region where the shock wave would normally be found if the outflow from the injector was not constricted.

If now the outflow is progressively constricted or is otherwise subjected to resistance then, by virtue of the provision of the gap 15 between the two neck portion sections 12a and 12b, the effect of constriction is to raise the pressure in the outflow passage 13 and compress the shock wave region within the neck portion section 12b without, however, displacing the shock wave region into and beyond the gap 15. With continued constriction of the outflow from the injector an increased pressure is created in the outflow whilst, by virtue of the fact that the shock wave region becomes steadily more compressed, condensation of steam which takes place in the shock wave region is accompanied by minimal heat transfer and maximum transfer of mechanical energy.

If now the outflow from the injector was wholly constricted, i.e. was blocked, and the entire liquid flow was removed via the drain port, then there would be generated at the outflow port region a significantly high, hydrostatic pressure.

Whilst in the embodiment just described the injector is provided with a neck portion 12 having an intermediate gap 15 which communicates via a chamber 14 with a drain port, it is found in practice that significant advantages can also be obtained even when there is no effective side drainage of liquid and this in view of the provision of the intermediate gap 15. Thus, even in the case where there is no side drainage, the provision of the intermediate gap within the neck portion of the injector ensures the attainment of a significantly higher stepped-up pressure output and/or the attainment of a richer gas/liquid mixture than would be the case where no such gap was provided. Similarly, and by virtue of the provision of the side gap, it is impossible to obtain a liquid output at a temperature which would be significantly less than the temperature of the liquid output where no such gap is provided for. The latter factor is of particular importance where the injector is to be used for the treatment of liquids such as, for example, their homogenisation and/or sterilisation by subjecting them to the very intense mechanical energies released as a result of condensation of the steam in the region of the shock wave.

Furthermore, the provision of the peripheral gap with or without side drainage ensures that the injector operates in a far more stable fashion and that a stable supersonic flow regime can be maintained over a wide range of varying external conditions. Thus, such varying conditions would, with a conventional injector, tend to disrupt the flow regime by, for example, giving rise to pressure pulses in the gas or liquid supply or varying resistance to outflow.

It is further found that, whereas with conventional supersonic injectors the ratio of the diameters $\mathbf{d}_1$ of the outlet of the supersonic nozzle to the diameter $\mathbf{d}_2$ of the neck portion lies between 1.1:1 to 1.7:1, with injectors in accordance with the invention they can be efficiently operated with ratios well above these figures, such as, for example, 3.3:1, where it is desired to obtain a pressure step-up. With such increased ratios, it is possible to achieve a pressure step-up reaching, for example, 22:1 for a steam input pressure of 0.5 bar. Where, however, the injector is designed for use not to achieve a pressure step-up, but rather to impart mechanical energy to the liquid, for example for the purpose of homogenisation or sterilisation, and this with minimum temperature rises, it is found that the injector can be designed so as to have the diameter ratios well below the known range such as, for example, a diameter ratio of 0.8:1.

Reference will now be made to Fig. 2 of the drawings, wherein are shown the variation in liquid

outflow pressure with differing percentages of side drainage for various steam inlet pressures and using an injector as described with reference to Fig. 1, having the following dimensions:
Overall length - 250 mm
$\mathbf{d}_1$ - 20 mm
$\mathbf{d}_2$ - 6 mm
1 - 7 mm

It can be seen that using such an injector in accordance with the invention with a water/steam mixture, very significant pressure step-ups can be achieved.

Thus, e.g., with a steam inlet pressure of 1 bar and with zero side drainage, the outlet pressure is about 8.5 bar whilst, with 100% side drainage, i.e. full construction, the outlet pressure is about 16 bar.

Claims

1. A method for positioning and maintaining a stable shock wave region in a supersonic flow system comprising the steps of:

creating a flow of a two-phase gas/liquid medium under such flow and condensation conditions as to generate a shock wave zone in the flowpath; and

draining at least a portion of the flow in the region immediately upstream of the shock wave zone;

characterised in that said flow downstream of the shock wave zone is constricted or otherwise subjected to resistance.

2. A method according to Claim 1, characterised in that said gaseous phase is constituted by steam.

3. A method according to Claim 1 or 2, characterised in that all the flow is drained upstream of the shock wave zone.

4. A supersonic flow device for producing and maintaining a supersonic flow of a two-phase gas/liquid mixture and including a mixing chamber having an inlet adapted to receive said mixture and an outlet merging with a first end of an elongated neck portion, a second end of said neck portion communicating with an injector outlet,

characterised in that there is formed in an intermediate position of the neck portion a peripheral gap which communicates with a housing chamber, said gap having a longitudinal axial dimension of the order of magnitude of the diameter of the neck portion.

5. A supersonic flow device according to Claim 4, and constituting a supersonic two-phase flow injector and furthermore comprising a supersonic nozzle;

characterised in that there is also provided a housing coaxial with the nozzle and having defined therein a liquid inlet chamber coaxial with and surrounding the nozzle, said mixing chamber merging at its inlet with said inlet chamber and converging towards its outlet.

6. A device according to Claim 5, characterised in that there is provided a drain aperture formed in said housing and communicating with said housing chamber.

7. A device according to Claim 6, characterised in that the ratio of the outlet diameter $\mathbf{d}_1$ of the nozzle to the inlet diameter $\mathbf{d}_2$ of the neck portion ranges from 0.8:1 to 4.0:1.

8. A device according to Claim 7, characterised in that said ratio is substantially equal to 0.8:1.

9. A device according to Claim 7, characterised in that said ratio is substantially equal to 3.3:1.

10. A device according to any one of Claims 4 to 9, characterised in that said peripheral gap has a longitudinal dimension of the order of magnitude of the diameter of the neck portion.

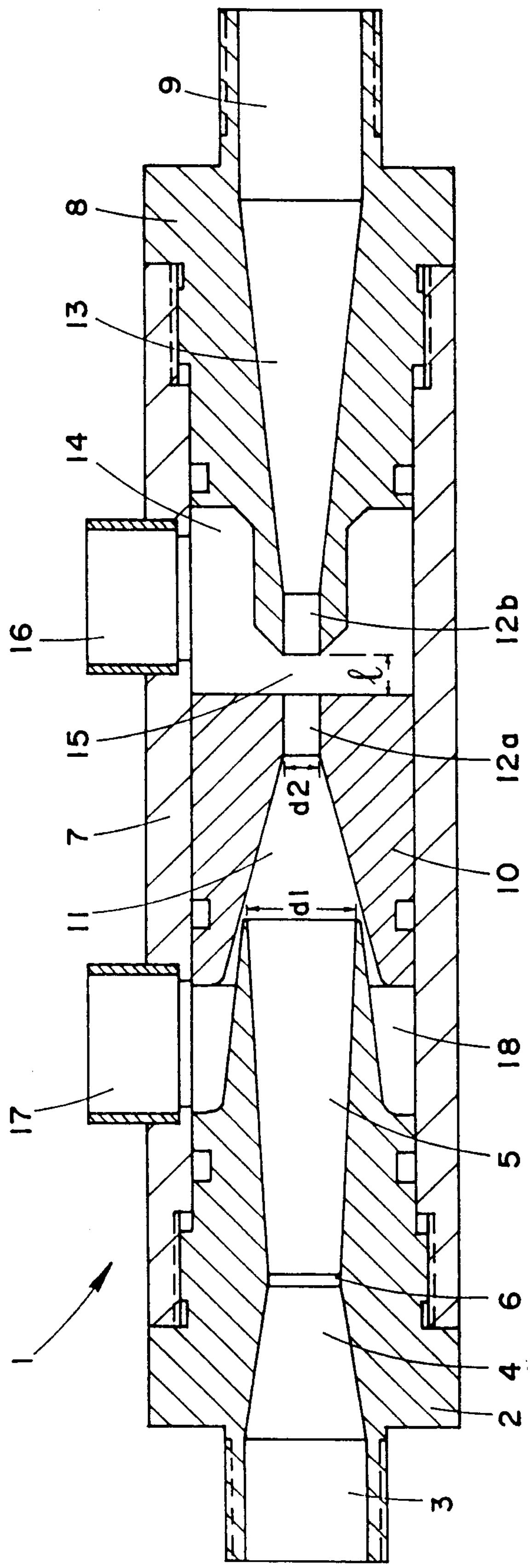
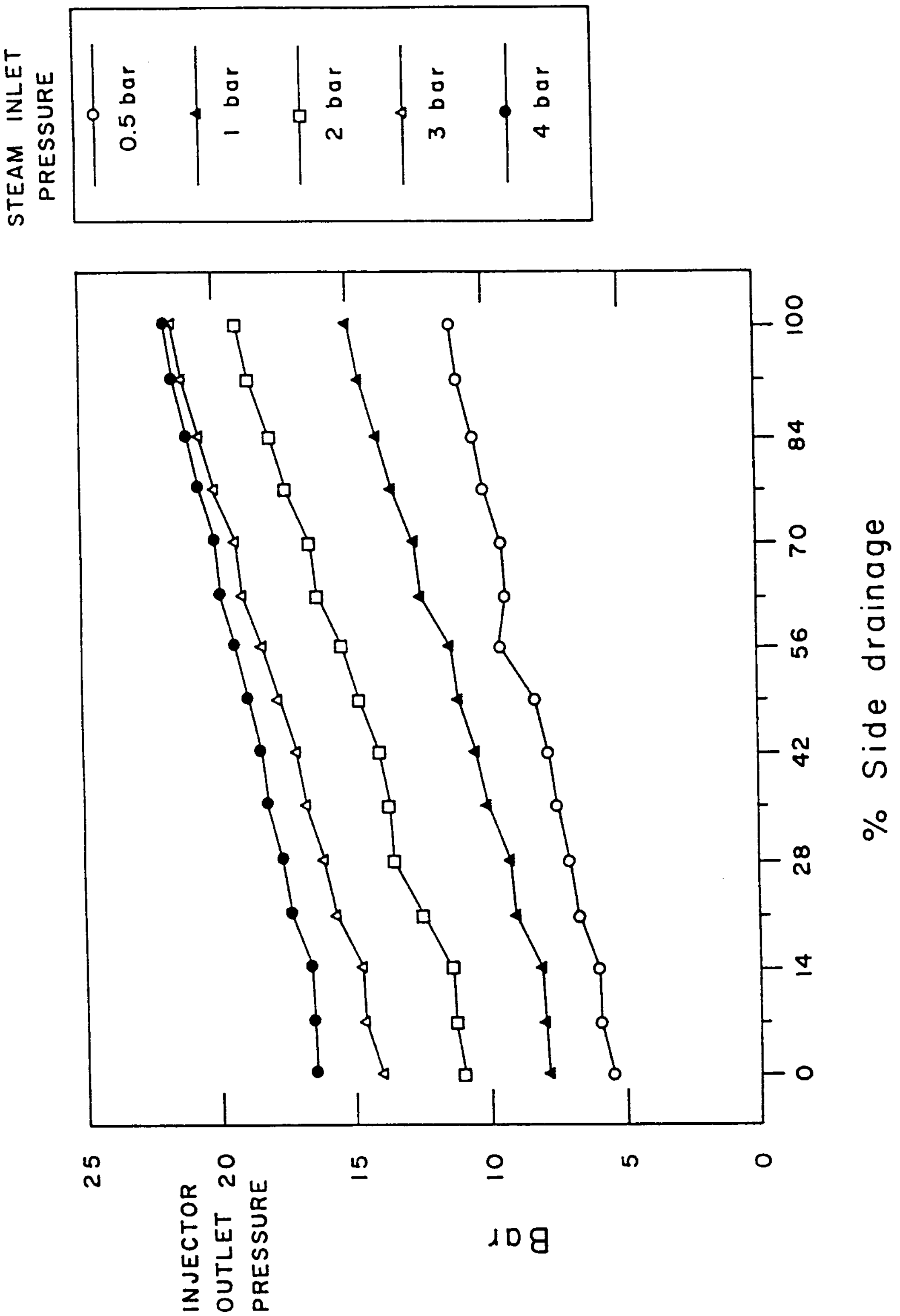


Fig. 1

Fig. 2


STEAM INLET PRESSURE
0.5 bar
1 bar
2 bar
3 bar
4 bar
INJECTOR OUTLET PRESSURE
Bar
25
20
15
10
5
0
0
14
28
42
56
70
84
100
% Side drainage

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 10 2259

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.5)
E	EP-A-0 475 284 (TRANSSONIC) ---	1-10	B01F5/04
A	EP-A-0 399 041 (INZHENERNY) -----	1-10	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			B01F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27 OCTOBER 1992	PEETERS S.

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