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(54) Improvements relating to fuel/air fully pre-mixed burners

(57) The present invention provides a ceramic burner flame strip. The flame strip is designed to cause elimination of burner resonant noise, by providing that the "land width" (z) around each port (19) is reduced. The land width is the width of the flame strip surface which not only surrounds the port, but which also lies at right angles thereto. The land width can be reduced by providing that the ports (19) are arranged in rows with alternate rows having ports at a different height in the flame strip surface from the other ports, which has the effect of ensuring that the land width of all ports (19) is reduced so reducing the said noise.

The flame strip may be made up of individual plates or by a plaque (36) which is provided with the ports and then is machined to provide slots (46) in alignment with alternate rows of ports, so that these ports are at a different height in the flame strip surface with the effect as described above.

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Description

This invention relates to fully pre-mixed burners which are used for example in water heating boilers and other heating devices. The burners are called fully pre-mixed because the fuel, usually gas, and a quantity of air equal to or exceeding the stoichiometrically correct amount of air to support the combustion of the fuel, are supplied and are mixed to produce a combustible mixture which subsequently is ignited to produce a burner flame which, in the case of heating the water in a boiler, is applied to a heat exchanger of the boiler. The term pre-mixed arises therefore because of the mixing of the fuel and air before the ignition; there are other types of burner which operate in a mode in which a sub-stoichiometric amount of primary combustion air is mixed with the fuel before ignition, and secondary air, required for completing the combustion process, is supplied to, or more usually induced into, the flame after ignition of the fuel/primary air mixture. These other burners are known as partially pre-mixed burners.

The present invention is concerned with fully pre-mixed burners and when the expression burner is used hereinafter, unless the context does not otherwise permit, a fully pre-mixed burner is intended.

It is foreseeable that partially pre-mixed burners will be used less and less in the future because they are rather inefficient and generate high levels of nitrogen oxides (NOx) during the combustion process. They also tend to be limited in their firing orientation, and in boiler applications the control of the burners usually is limited to and on/off type of operation. In consequence, they are becoming unsuitable for the majority of modern high efficiency boilers which are being developed and used today. These boilers, one type of which is known as a condensing boiler, because the combustion products are cooled to such an extent as to condense out the water vapor and increase the thermal efficiency by transferring the latent heat of condensation into the circulating water, benefit from the use of the fully pre-mixed burners, in that the burner can be fired downwards into the heat exchanger, thereby simplifying collection and disposal of condensation at the base of the appliance

In addition, fully pre-mixed burners are high intensity burners in which high volumes of fuel/air mixture are forced through the burner, and specifically through flame strip ports in a burner flame strip to give a compact, high intensity flame which sits on a flame strip face of the burner.

Unfortunately, due to the high intensity flame, and the environment in which it operates, there often results what is called resonant noise in the system, the system being the burner, and the structure in which it is located and/or of which it forms a part. Thus, the burner in addition to the flame strip has a plenum chamber to the opposite side from the flame strip face, and in which the fuel and air are mixed, there is a combustion chamber either above or below the flame strip, depending upon the firing orientation, the heat exchanger has passages through which the products of combustion pass, the boiler has a flue and it may have a pre-flue, and any of these parts (or other parts) of the system may have a resonant frequency which could be excited by the amplified flame instabilities and/or the passage of the gases through the system.

As the mixture of air and fuel passes through the ports of the flame strip, the flow will generally be laminar and will not be affected by upstream flow disturbances, but upon discharge from the ports, the flow enters a region of lower stability, where it may be exposed to intermittent oscillatory and re-circulating currents, causing interaction with the flows from the ports, which flows can also interact with each other, and complex multi-dimensional pressure gradients can arise from the presence of the flame front downstream of the ports. Under certain circumstances the resulting variations in heat release at the flame front will selectively amplify these fluctuations, leading to the creation of the resonant noise.

Whatever the reason, these burners frequently develop this resonant noise (of which the frequencies of greatest energy lie in the range over which the human ear is most sensitive) over part or all of the operating range of the burner, and it is highly audible and irritating at best and at worst, it is unacceptable to the boiler manufacturer and his customers, and the present invention is concerned with burner construction and manufacture with the objective of elimination of burner resonant noise.

Prior to indicating the invention and its various aspects, it should also be mentioned that the burner flame strips are more and more constructed as plates or plate elements of a material such as a ceramic material, which will be of low thermal conductivity and of sufficient thermal resistance to withstand the high temperatures at which the burners operate, and of a construction to prevent the effect known as "light back" or "flash back" which is the passage of the flame back into the plenum chamber, and ignition of the mixture in that chamber. Specifically, it is preferred to use a plate or plates, or plaques as they are sometimes called,, to form the flame strip, the plaques having sufficient thickness to provide a flame strip of sufficient strength to be capable of being handled, and being formed preferably from a ceramic material.

As to the ceramic material which is used, it is preferred that the ceramic material is fibrous in nature. The material which is used for producing the plaque is preferably a clay material such as Kaolin or China clay which pressed or otherwise formed from a slurry of the material, and then after pressing, which produces a plaque in the “green state”, is fired at approximately 1100'C with bonded refractory materials which are preferably of aluminate or silicate composition, the resulting ceramic being of a strong, heat resistant nature. There is also another material a silica material which can be used and that material is one which mixed with a freezable liquid, such as water and the mixture, a slurry, is frozen and then the water is driven off leaving a plate structure, again in a green state, which is then fired to produce a fused silica plate. This freezable material is easier to mould than the fibrous material referred to above.

The ceramic plaque may be produced by forming a slurry and then by compression moulding that slurry between a pair of dies, at least one of which is provided with pins or other needle like projections to form the passages (the ports), followed by sucking the liquid component from the slurry whilst it is held under compressed conditions. The firing of this green state pressing produces a lightweight, strong, and heat resistant material which is ideal for use in a fully premixed burner. The plaque can, of course, be formed by other methods such as compression of dry ceramic, powdery materials and the ports can be formed by drilling if required.

Reference to this material is made as it is pertinent to an aspect of the present invention disclosed hereinafter.

The present invention is based upon the examination of the burner configuration, and a study of the resonant conditions which may be set up as a result of firing the burner in a boiler system including at least a combustion chamber, a heat exchanger, and a flue. This study considers the flow of a fluid, such as the fuel/air mixture out of the end of a passage, and the eddy currents which are induced or shed at the surface of the body which defines the passage immediately where the flow emerges. That surface will usually be at right angles (or substantially at right angles) to the flow direction, and eddy currents will be induced as spirals turning towards that surface. It has been found that the greater the width of that surface adjacent the flow the greater the shedding of eddy currents and the greater the tendency for resonant noise to be established, and therefore that width should be in a particular range, and preferably should be as small as possible.

In the case of a burner, the surface is the surface of the plaque.

In accordance with the present invention in its general aspect, a burner flame strip has ports therein through which the fuel air mixture in use flows, and either the "land width" or the width of material of the flame strip between ports is controlled to be as small as practical to prevent eddy currents from being shed from the flow of the fuel/air mixture such as to cause resonant noise, or the flame ports are arranged high and low such that eddies which are formed over the top lands are swept downstream by the combustible mixture or flame emerging from the lower ports, thereby preventing, or carrying away the characteristic shedding frequencies, or destroying them.

Preferably, the flame strip comprises a plaque or plaques of said ceramic material, and preferably also the land widths are controlled by making slits or cuts to the surface of the plaque or plaques, preferably when in the green state. These slits or cuts may lie in register with alternate rows of port passages of the flame strip, so that the outlets from the alternate rows lie at the bottom of said slits or cuts.

The slits are preferably of outwardly tapering form from the bases upwards, so that there are in fact no lands adjacent the outlet ports at the bases of the slits, but rather the passages open into the tapering sides of the slits.

Indeed, the slits may be such that the high ports open into the tapering slit sides, thereby providing that at least in one direction, there are no lands to the sides of the high ports.

In connection with an aspect of the invention, there is therefore provided a method of making a burner plaque having ports therein, wherein the plaque is slotted by machining, in order to reduce the land width between ports. The plaque may be and preferably is of fired ceramic material, and is made by a slurry pressing process as described above. The slits are preferably formed in the plaque whilst it is in the green state. The said slurry pressing process provides the plaque ports, and the operation of the slitting or cutting of the slots or slits is carried out subsequently.

The method can be applied to burner flame strips which are of metal or are of ceramic heat resistant material but are produced by another method. The slots or slits preferably are spaced and parallel.

Depending upon the method by which the plaque is made, the slits may be moulded into the plaque during its formation.

The invention will now be described, by way of example in various embodiments thereof, with reference to the accompanying diagrammatic drawings, wherein,-

Fig. 1 shows the elements of a boiler flue system including a burner;

Fig. 2 is a perspective view of part of the burner flame strip of the burner shown in Fig. 1;

Fig. 3 is an enlarged plan of three of the burner ports to indicate the spatial disposition thereof;

Fig. 4 is a fragmental sectional elevation of the burner flame strip;

Fig. 5 is a view similar to Fig. 4, but shows how the flame strip can be modified to improve its performance as regards resonant noise;

Fig. 6 is a view similar to Fig. 4, but shows another way of modifying the flame strip to reduce burner noise;

Fig. 7 is a view similar to Fig. 4, but shows another way of modifying the flame strip to reduce burner noise; and

Fig. 8 is a side view showing one method of modifying the burner flame strip to configure it to the form shown in Fig. 6 or Fig. 7, depending upon the shape of the cutters.

Referring to the drawings, in Fig. 1 a boiler flue system is shown and it will be seen to comprise a burner 10, having a plenum chamber 12 into which, as indicated by arrows 14, and by virtue of supply pipe 16, a mixture of fuel and air is supplied by means of a fan which is adjustable manually and/or automatically to enable the burner to operate over a substantial range of settings. The burner has a flame strip 18, of a construction to be described, on top of which in use there is established a flame 20, by virtue of the passage of the fuel/air mixture through ports 19, see Fig. 2, in the flame strip. The flame 20 exists in a combustion chamber 22, and the products of combustion, indicated by arrows 24 pass upwards through passages 26 in the boiler heat exchanger 28, and eventually into the boiler flue 30 from which they are eventually discharged into the atmosphere. Arrows 32 indicate the flow of the products of combustion through the flue 30, after they have passed through the heat exchanger, giving up heat as they go.

The burner has been shown as firing in an upwards direction, and although it is not of significance to the present invention, the burner can be arranged to fire in any direction, such as a downwards direction, where for example the boiler is a condensing boiler and the heat removed from the products of combustion as such as to cause the condensation of moisture from said products. The present invention concerns the design and construction of the flame strip, with the objective, as stated herein, of reducing the resonant noise of the flame.

By virtue of the requirement for the supply of the mixture at a high flow rate, and by virtue of the need to have the burner operate over its range of adjustment, the establishment during running of resonant noise, which is extremely irritating and loud, is not unusual in a wide range of burner designs. One method suggested for the reduction of burner noise is to shape the flame strip so that it is of tapering thickness from the centre, as set forth in US Patent No. 5,417,566. We have not tested this method and cannot vouch for its effectiveness.

It is believed however that resonant noise can be established over a range of frequencies as the flame, which is a roaring and intensive kinetic mass, may resonate with any of the different parts of the system, e.g. the plenum chamber 12, the combustion chamber 22, the heat exchanger passages 26, or the flue 30 or different parts of the flue 30, if it is of a complicated design, probably caused by back pressure waves from these parts of the system.

Our theory as to why resonant noise is created or why it may be aggravated, is related to the rate at which eddy currents are created on the flame strip face on which the flame is established.

Thus, referring to Fig. 2, a plain, conventional, burner flame strip 18 is shown, and it may be made up of one or more plates or plaques 36 of appropriate thickness, and provided with the ports 19 therein. In the arrangement-illustrated, the ports 19 are circular sectioned holes of constant cross section, but it is to be stressed that although there are many advantages in using such ports, it is not essential that such ports be used. The ports could be elongated slits or slots or of other configuration. The plaque (or plaques) is preferably of the ceramic material described herein, but again this is not necessary and the plaques could be made of any suitable material. It is preferred however that the material should be of such a character to withstand the temperatures to which the plaque will be subjected in use.

The ports 19 are in the example shown arranged in a regular array of rows, with alternate rows offset as shown to provide what is known as a close packed hexagonal arrangement, but again this arrangement is not necessary. The centres of the ports 19 are spaced by "lands" 38 on the plain top of the plaque 36 and these lands, are of a width "x" which must be sufficient especially in relation to a ceramic burner plaque 36, to impart sufficient strength to the plaque 36, to enable it to be handled and fitted into the burner. In this connection, the plaque may have shoulder 40 which is adapted to be fitted into the burner frame which enables the plaque 36 to be connected to the plenum chamber 12. From a practical point of view, the plaque 36 thickness should be such that the port length is at least five times the hydraulic width or diameter of the ports 19.

For a conventional ceramic plaque 36 the distance "x" typically would be between 1.25 and 3.0 mm, for a port diameter of 1.8 mm. With such an arrangement, the fast flow of the mixture through the ports 19 creates or "sheds" eddy currents 42 at a frequency which is in the range which induces or leads to the resonant noise.

The present invention alms at solving or mitigating the resonant noise problem by minimizing or reducing the effective land width, as the frequency of eddy current shedding is dependent upon the land width, or alternatively by arranging flame ports such that the shed eddies are swept downstream and not allowed to form at their characteristic frequencies. The land width can be made smaller during the manufacture of the plaque 36, or, as provided in one important aspect of the present invention, especially applicable where the plaque is of the ceramic material herein described and is produced by the vacuum forming of a slurry of ceramic material (e.g. fibres) and liquid, wherein the liquid is drawn off in the forming operation, the land width can be reduced in the face of the flame strip on which the flame is established, by a machining operation after the plaque, complete with ports, has been formed, and is still in the green state.

Therefore referring to Fig. 5, in this Fig., the land "x" is shown as having been provided with slots or slits 44 (only one shown) between the ports 19. These slits 44, made by suitable disc or blade cutters, preferably are parallel and extend from side to side and/or from end to end of the plaque 36. Such slits 44 reduce the land width without noticibly reducing the overall strength of the plaque 36 in that the slits 44 only extend part way e.g. in the order of 3mm minimum through the thickness of the plaque 36. The slits 44 are shown in Fig. 5 as lying between the ports 19, but this is not necessary, and the slits can intersect the ports 19 fully or partly, as long as the land width on the top surface of the plaque 19 is reduced.

For example, as shown in Fig. 6, the slits 46 made in the plaque 36 may lie in alignment with and intersect every second row of ports 19, so that ports 19 in adjacent rows are at high and low levels. In each of Figs. 5 and 6 it can be seen that the effective land width adjacent the ports and adjacent the high ports respectively, has been reduced, to "y" in the case of Fig. 5 and "z" in the case of Fig. 6, so as to be less than the original width "x", although the fall distance between the ports remains unchanged, and so the strength of the plaque is not impaired.

Also in the case of Fig. 6, the regular formation of eddies over land z" is destroyed by the passage of gas air mixture and/or flame from combustion at the lower ports 19 past lands "z" thereby carrying the eddies downstream on the combustion products flow.

Fig. 7 shows how the effect can be further enhanced. The flame strip is similar to that of Fig. 6, except that the slits 46 are of the tapered configuration shown. This means that the low ports 19 open into the tapered side walls of the slits 46, so that there are no lands adjacent the low ports 19 in the cross sectional direction shown, which enhances smooth flow from the low ports to the high ports 19, causing sweeping away of the eddies which might tend to form at the upper ports 19, with minimum turbulence, which contributes to reduction in noise.

Fig. 7 also shows in dotted lines that the tapering of the sides of the slits 46 may be such as to eliminate the lands at the upper ports 19 in the cross sectional direction shown, but tapering the slit sides in this way may lead to the result that the peaks P of material in alignment with the high ports 19, may be liable to breakage or friability, and an appropriately strong material may be required.

The slitting need not be in alignment with the rows of ports, but could be offset in relation thereto.

Finally, Fig. 8 shows how the plaque, in one method according to the invention, may be machined to form the slits 44 of Fig. 5 or the slits 46 of Fig. 6. In this method, a series of parallel cutting discs 50 (of the appropriate cross sectional shape) mounted on a drive shaft 52 are driven as indicated by arrow 54, and the plaque 36, in the green state, is passed under the rotating discs 50 so as to make the parallel slits 44 or 46 therein. The plaque 36 may be moved in a translation movement relative to the discs 50 or vice versa.

In a specific arrangement, the effective land width after machining preferably is in the range 0.25 to 1 mm, and preferably is in the range 0.3to 0.7 mm, for a port diameter in the range of 0.8 to 1.8 mm and preferably 1.3 mm, or a slot port of width 0.7 mm.

The test carried out with conventional burner plaques of ceramic material provided with slits have shown extremely effective results, and resonant noise has been eliminated or suppressed over a wide or the whole range of operation of the burner. In a modification where no burner plaque is used, the flame strip is preferably made up of a plurality of small similar plates stacked face to face, and the dotted lines L in Figs. 5, 6 and 7 show the face to face contact regions between the faces. Clearly, in this construction, no machining of the plaque as envisaged in relation to Fig. 8 is needed, but the flame strip is again constructed to give the advantages of the present invention of reduction in resonant noise.

Specific tests have been carried out in a boiler under typical operating conditions and have shown the following results.

1. Flat ceramic plaque of 15 mm thickness with ports in closely packed hexagonal arrangements

Port diameter	0.8 mm
Land width	0.9 mm
Port pitch	1.7 mm

Results
Resonance on ignition, satisfactory operation at thermal equilibrium (land width close to the limit of acceptability)

2. Flat ceramic plaque of 12 mm thickness with ports in closely packed hexagonal arrangement

Port diameter	1.2 mm
Land width	0.8 mm
Port pitch	2.0 mm

Results
Occasional resonance on ignition, and in thermal equilibrium (again, the land width must be close to the limit)

3. Flat ceramic plaque of 16 mm thickness with ports in closely packed hexagonal arrangement

Port diameter	1.7 mm
Min. land width	1.2 mm
Port pitch (row)	2.9 mm
Port pitch (angled)	3.7 mm

Results
Resonance on ignition and in thermal equilibrium

4. Plaque as in 3) above, but with 3.0 mm channels cut along alternate lines of ports to give castellated surface profile
Results

Resonance eliminated, both on ignition and in thermal equilibrium.
Resonance has a greater tendency to return if castellation depth is reduced below about 2.0 - 2.5 mm.

5. Perforated metal burner of 0.55 mm gauge thickness slotted port pattern.

Slots 5 mm x 0.8 mm
With 0.7 mm land

No resonance (but overheats rapidly)
So max. tolerable land width must be in the region of 0.7 - 0.8 mm.

6. Steel gauze mesh

Hole size ~ 0.5 mm
Wire land ~ 0.3 mm

No resonance, but overheats within a few minutes.

Claims

1. A burner flame strip (18) having ports (19) therein through which the fuel air mixture in use flows, and the "land width" (y, z) is minimized or reduced to prevent resonant noise, eddy currents from being shed from the flow of the fuel/air mixture as it leaves the ports (19).

2. A burner flame strip according to claim 1, wherein the flame strip comprises a plaque or several plaques (36) or a stack of plates of ceramic material, and preferably also the land widths are controlled by providing grooves (44, 46) in the surface of the plaque, plaques or stack of plates.

3. A burner according to claim 2, wherein the grooves (44, 46) lie in register with alternate rows of ports (19) of the flame strip, so that the ports (19) of the alternate rows lie at the bottom of said grooves (44, 46)

4. A burner according to claim 2 or 3, wherein the grooves (44, 46) are of outwardly tapering form from the bottom upwards.

5. A burner according to claim 3 and claim 4, wherein the grooves are of such width at the bottom thereof, that there is no land adjacent the low ports in a direction at right angles to the length of the grooves (44, 46).

6. A burner according to any preceding claim, wherein the ports (19) are circular and are of a diameter of 0.8 to 1.8 mm, and the land width (y, z) is in the range 0.25 to 1.0 mm.

7. A burner according to claim 6, wherein the land width (y, z) is in the range 0.3 to 0.7 mm.

8. A burner according to any preceding claim, wherein the ports (19) are of rectangular configuration, and are of a width 0.7 mm, and the land width (y, z) is in the range 0.3 to 0.7 mm.

9. A method of making a burner plaque (36) having ports (19) therein, wherein the plaque (36) is slotted by machining, in order to reduce the land width around the ports (19).

10. The method according to claim 9, wherein the plaque (36) is of fired ceramic material, made by a pressed slurry process to produce the plaque in a green state.

11. The method according to claim 10, wherein the slotting of the plaque is performed whilst the plaque is in the green state.

12. The method according to claim 9, 10 or 11, wherein the slotting is in the form of slots or slits which are spaced and parallel.

13. The method according to claim 12, wherein the slots are in alignment with alternate rows of the ports in the plaque.

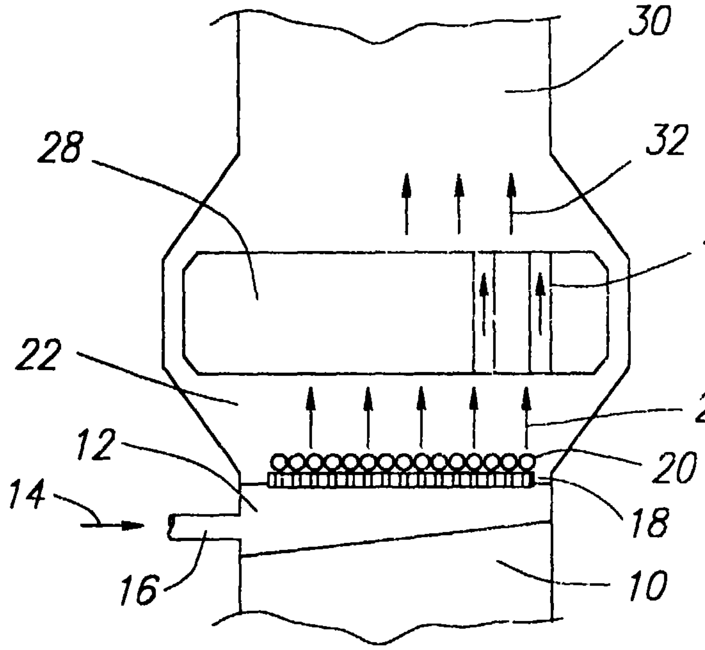
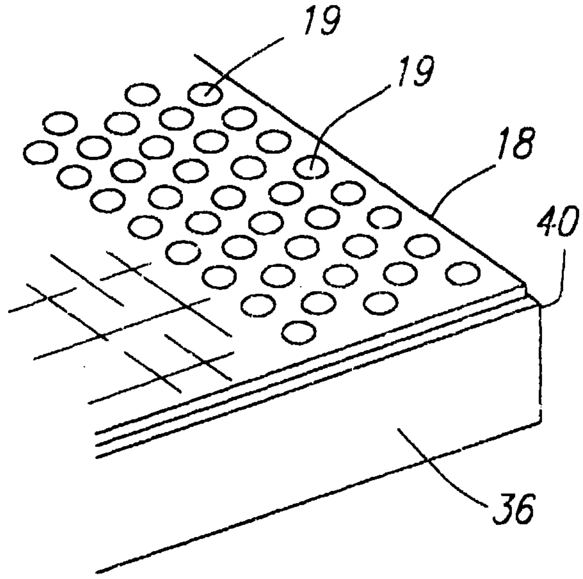


FIG. 1

FIG. 2



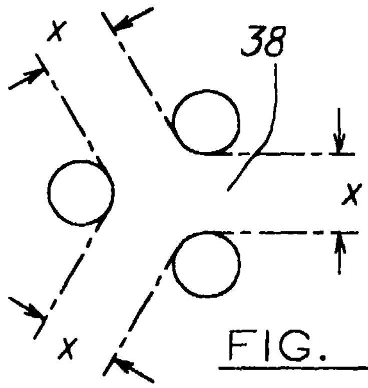


FIG. 3

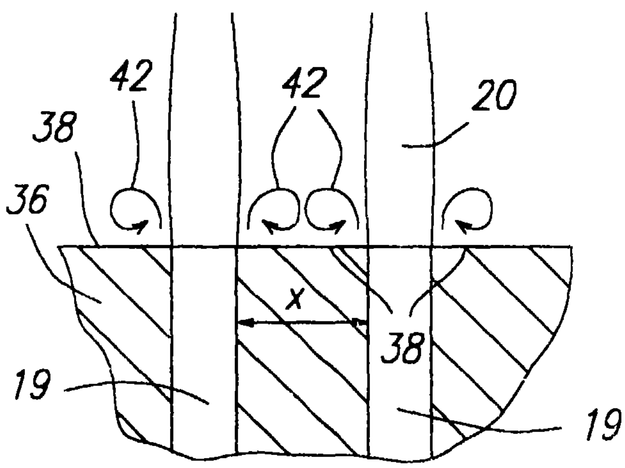


FIG. 4

FIG. 5

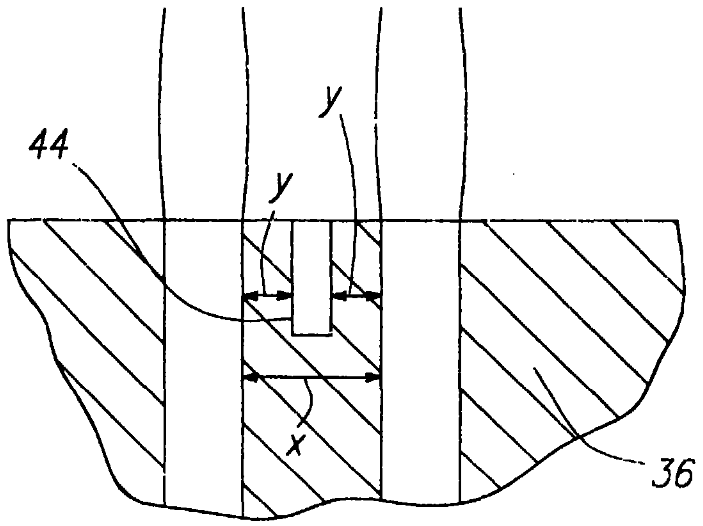


FIG. 6

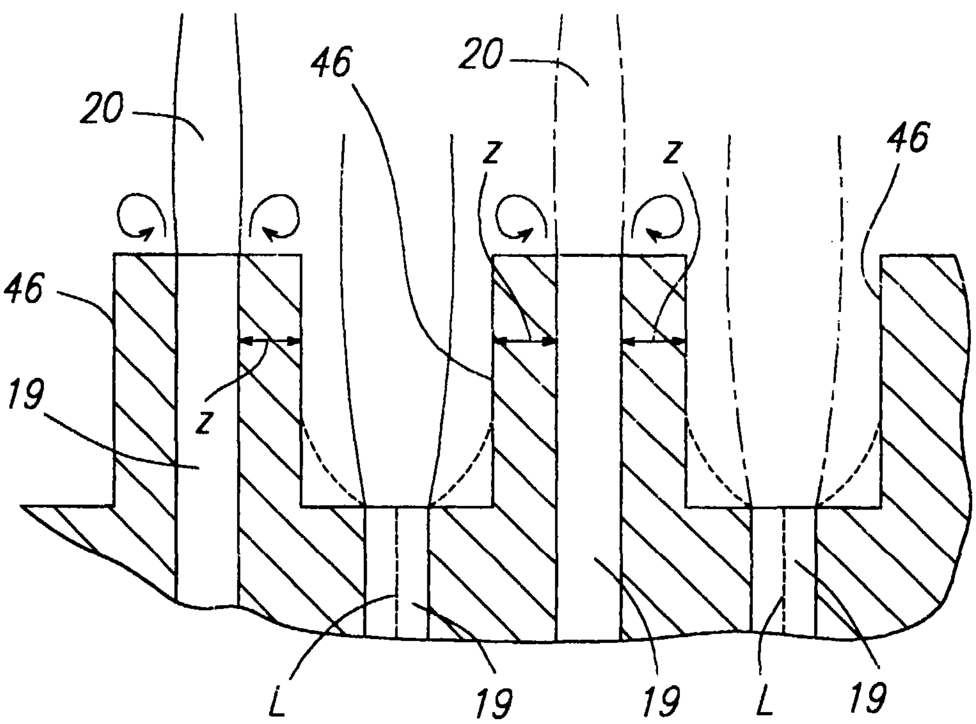


FIG. 7

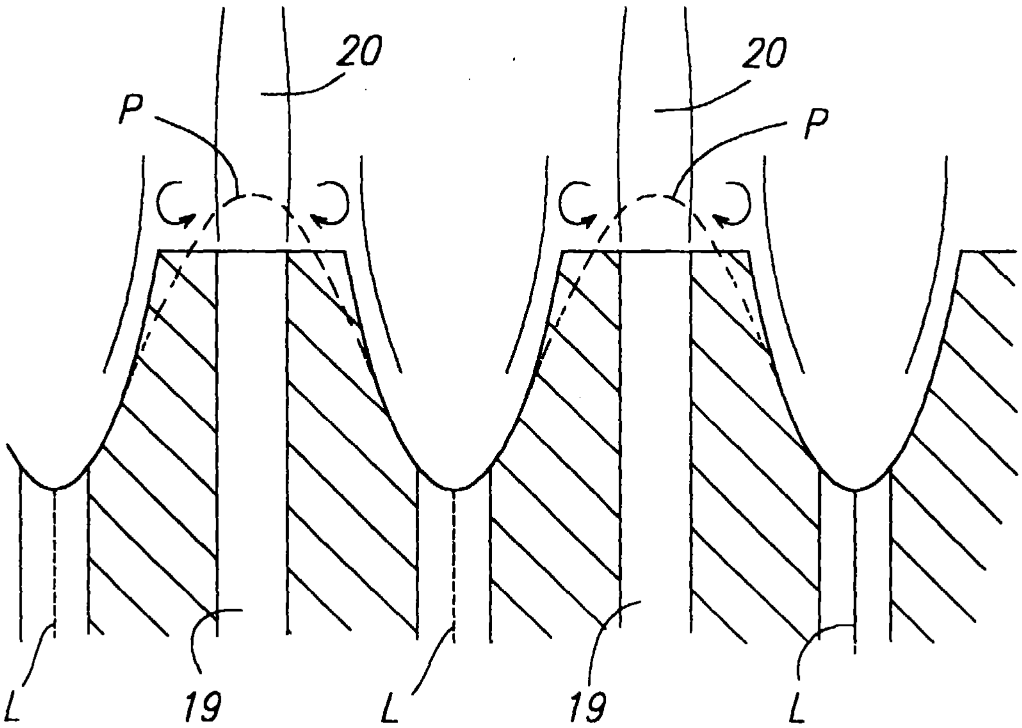


FIG. 8