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(54) Condenser

(57) A condenser primarily for use in an automotive air conditioning system has a first and second heat transfer tube arrangements in upstream and downstream portions of the condenser of different hydraulic diameters. The hydraulic diameters of the downstream tube arrangement is typically of larger value. The arrangement provides amelioration of reduced flow 'choking' effects, particularly for sub-cooled liquid refrigerant passes.

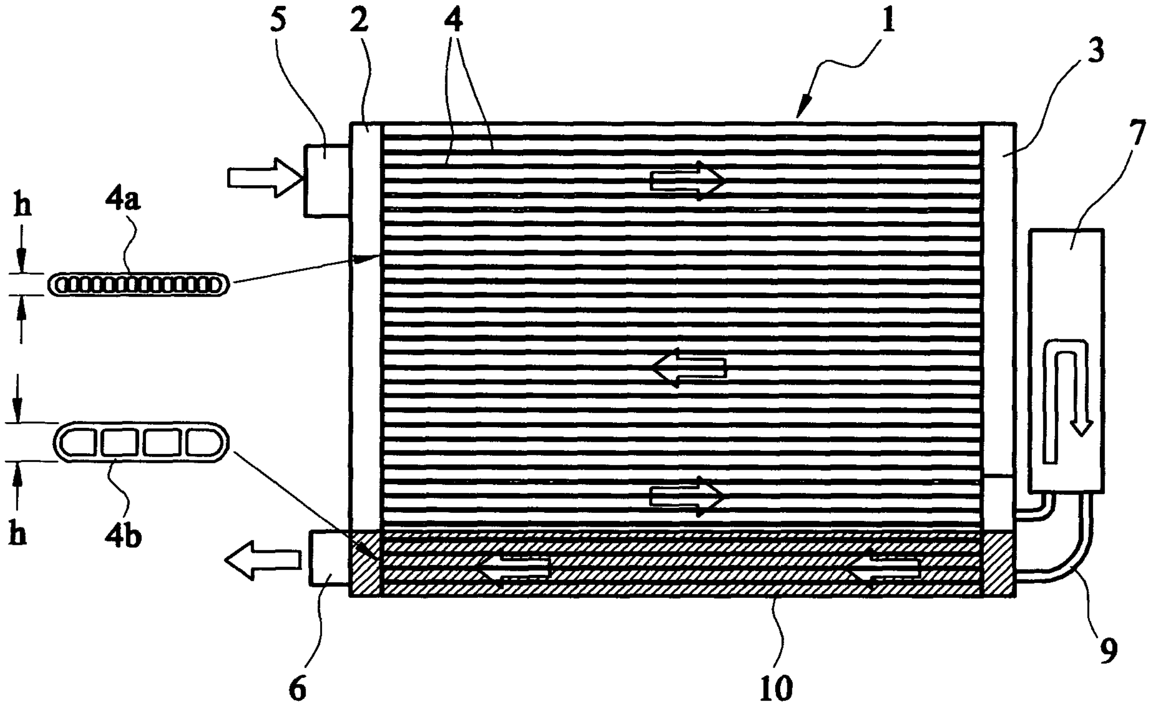

FIG. 1

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Description

[0001] The present invention relates to a condenser, and in particular to a condenser comprising part of an automotive airconditioning system.

[0002] It is known for automotive air conditioning system condensers to use heat exchange tubes of small hydraulic diameter for condensing the system refrigerant. EP0219974 discloses that optimum performance maybe achieved where the hydraulic diameter is between about 0.4mm and 1mm. Typically the tubes comprise discrete flow channels or ports between 8 and 20 in number for each tube.

[0003] An improved arrangement has now been devised.

[0004] According to the present invention, there is provided a condenser comprising a first heat transfer tube arrangement in a relatively upstream portion of the condenser, and a second heat transfer tube arrangement relatively downstream of the first tube arrangement, wherein the hydraulic diameter of the first tube arrangement is different to the hydraulic diameter of the second tube arrangement.

[0005] It is preferred that the hydraulic diameter of the second tube arrangement is greater than the hydraulic diameter of the first tube arrangement.

[0006] Beneficially, the second tube arrangement is in the sub cooled region of the condenser. The second tube arrangement is preferably provided in the sub cooled region of the condenser and also immediately upstream of the sub cooled region of the condenser. A receiver dryer may be positioned flowise between the sub cooled region of the condenser and the immediately upstream tube arrangement.

[0007] In certain embodiments, it is preferred that the external depth dimension of tubes in the first and second tube arrangements is substantially the same. For example in a so called unified (or combined) condenser and radiator arrangement where banks of radiator and condenser tubes are arranged side by side, it is beneficial to have the radiator tubes and condenser tubes in line with one another in order to streamline airflow through the combined radiator and condenser arrangement.

[0008] In alternative embodiments it may be acceptable to have the external depth dimension of tubes in the first and second tube arrangements being substantially different, where the hydraulic diameter ofthe second tube arrangement is greater than the hydraulic diameter of the first tube arrangement, in such embodiments the external depth dimension of the second tube arrangement will preferably be substantially greater than that of the first tube arrangement.

[0009] In certain embodiments it is preferred that the spacing between adjacent tubes in the first tube arrangement is substantially the same as the spacing between adj acent tubes in the second tube arrangement.

[0010] In certain embodiments, it is beneficial that the spacing between adjacent tube major axes in the first tube arrangement is substantially the same as the spacing between adjacent tube major axes in the second tube arrangement. For example in a so called unified (or combined) condenser and radiator arrangement where banks of radiator and condenser tubes are arranged side by side, it is beneficial to have the radiator tubes and condenser tubes in line with one another in order to streamline airflow through the combined radiator and condenser arrangement.

[0011] It is preferred that the hydraulic diameter of the tubes of the second tube arrangement is substantially at or above 1.3 times the hydraulic diameter of the tubes of the second arrangement. More preferably, the hydraulic diameter of the tubes of the second tube arrangement is substantially at or above 1.5 times the hydraulic diameter of the tubes of the second arrangement. More preferably still, the hydraulic diameter of the tubes of the second tube arrangement is substantially at or above 1.7 times the hydraulic diameter of the tubes of the second arrangement. In certain embodiments, the hydraulic diameter of the tubes of the second tube arrangement may be substantially at or above 2 or even 2.5 times the hydraulic diameter of the tubes of the second arrangement. For example, suitable performance has been achieved using first tube arrangement of hydraulic diameter (HD) of 0.71 mm and second tube arrangement of tube hydraulic diameter (HD) of 2mm giving a ratio for the second tube arrangement of 2.8 times the first tube arrangement hydraulic diameter.

[0012] Advantageously, the hydraulic diameter ofthe tubes ofthe second arrangement is substantially in the range 0.8mm to 3mm. In some embodiments, it is preferred that the hydraulic diameter of the tubes of the second arrangement is substantially in the range 1.2mm to 3mm, more preferably 1.4mm to 3mm, more preferably 1.7mm to 3mm.

[0013] Beneficially, respective tubes of the second arrangement each include a plurality of channels extending in the longitudinal direction of the tube. In some preferred embodiments between 2 and 6 channels are provided, more preferably 4 or 5 channels are provided.

[0014] Preferably respective tubes of the first arrangement each include a plurality of channels extending in the longitudinal direction ofthe tube. In some preferred embodiments 10 or more channels may be provided.

[0015] It is preferred that in some embodiments the first and second tube arrangements comprise extruded tubes. Beneficially the first and second tube arrangements comprise aluminium material tubes.

[0016] The invention will now be further described in specific embodiments, by way of example only, and with reference to the accompanying drawings in which:

Figure 1 is a schematic side view of an exemplary condenser in accordance with the invention;

Figure 2 is a schematic side view of an alternative embodiment of a condenser in accordance with the invention;

Figure 3 is a schematic side view of an alternative embodiment of the invention for use as the condenser side of a combined (or unified) radiator condenser arrangement;

Figure 4 is a plot of pressure drop against free flow area for a range of tube designs; and

Figures 5A to 5E are schematic sectional views of exemplary tube geometries in accordance with the present invention.

[0017] Referring to Figure 1 there is shown schematically an exemplary condenser 1 for use in an automotive air conditioning system.

[0018] The condenser 1 comprises a pair of spaced headers 2, 3 and interconnecting headers 2, 3, plurality of heat exchange tubes 4 arranged in a bank with air gaps intermediate respectively tubes 4. An air way matrix of fins (not shown) is typically provided intermediate adjacent spaced tubes in the bank. The headers 2, 3 contain internal baffles ensuring that refrigerant flow through the condenser takes place in a number of discrete passes between headers 2, 3 as shown by the arrows in Figure 1. The refrigerant enters condenser 1 via inlet 5 in vapour form and is condensed during passage through the condenser. Prior to exiting the condenser via outlet 6 the refrigerant passes through a receiver dryer 7 (which includes a desiccant cartridge or the like) ensuring that all gasses are removed from the refrigerant. The refrigerant leaving receiver dryer 7 is directed via line 9 into a sub-cool section 10 of the condenser which cools the refrigerant further to ensure that all refrigerant exiting outlet 6 is in liquid form.

[0019] An important feature of the present invention is the relationship between the heat exchange refrigerant tubes 4 present in the sub-cool section 10 and the upstream section within the condenser. Shown in Figure 1 at reference 4a is a multiported refrigerant tube 4 which is present in the portion of the condenser upstream of the sub-cool section 10 and receiver dryer 7. Shown at reference 4b in Figure 1 is a refrigerant tube which is present in the sub-cool section 10 of the condenser 1. Tube 4a has 14 internal ports or channels extending along the length of tube 4a and a hydraulic diameter which is typically in the range 0.4 to 1.0 mm. Tube 4b has only four ports and a hydraulic diameter which is significantly greater than the hydraulic diameter of tube 4a. Typically the hydraulic diameter will be between 1.3 and 2.5 or more times the hydraulic diameter of tube 4a. The hydraulic diameter of tubes 4b will typically be varied between 1.2mm and 2 to 3mm plus. The hydraulic diameter (HD) is defined as four times the cross-sectional area of the tube (or channel) divided by the wetted perimeter of the tube (or channel).

[0020] It is well understood and accepted within the automotive air conditioning field that decreasing the port size and hence hydraulic diameter for a condenser tube improves the efficiency/heat dissipation of the condenser. Although this is the case for a conventional condenser, there are adverse affects where low hydraulic diameter multi-ported tubes are used for a sub-cool condenser such as shown in Figure 1. Sub-cooled liquid refrigerant passing through tubes suffer from reduced flow because of 'choking' effect in the small hydraulic diameter tube ports. This can result in high pressure drop across the condenser giving adverse condenser performance. In the embodiment shown in Figure 1, it should be noted that the depth dimension (h) is greater for tube configuration 4b that tube configuration 4a.

[0021] By ensuring that the free flow area of the ports in tube 4b is significantly larger than the free flow area of ports in tube figure a (the hydraulic diameter of tube 4b hence being significantly larger than the hydraulic diameter of tube 4a), it is possible to have greater liquid flow in the tubes 4b in the sub-cool section 10 of the condenser ameliorating choking effect.

[0022] The arrangement shown in Figure 2 is generally similar to the arrangement shown in Figure 1, however in this embodiment the tubes 4b are also provided upstream ofthe sub-cool section 10 in the last pass (from header 2 to header 3) prior to entering the receiver dryer 7. In this last pass 11, the refrigerant is mostly in liquid phase and therefore benefits from the increased hydraulic diameter of the tubes 4b present in this last pass.

[0023] In the arrangement shown in Figure 3 the tubes 4 in the sub-cool section 10 are of the configuration 4c. These tubes 4c have larger free flow area ports and increased hydraulic diameter relative to the tubes 4a upstream of the receiver dryer. However the tube depth h is the same for tubes 4c and 4a. This ensures that, for regularly spaced tubes in the condenser bank, the spacing between the major axes of adjacent tubes is identical for the sub-cool section and also the section upstream of the sub-cool section and receiver dryer. Additionally, the spacing between adjacent tubes in the sub-cool section 10 and the tube bank section upstream of the sub-cool section and receiver dryer 7 are also the same. This enables the condenser arrangement to be conveniently used in so-called unified (or combined) condenser and radiator arrangements.

[0024] By ensuring that maximum liquid refrigerant flow can occur along the sub-cool section, it is possible to reduce the width dimension w shown in Figure 2a which is a plan view of the condenser of Figure 2. This minimises the space envelope for the condenser and hence has weight and other utilisation benefits.

[0025] Figures 5A to 5D show various multi-port configurations of heat exchange tubes 4. The tubes of Figures 5A, 5D and 5E will be suitable for use in the sub-cool section of the condenser. Typically the tubes of Figures 5B and 5C will be used in the section of the condenser upstream of the sub-cool section and receiver dryer 7. The tube of Figure 5A has 4 ports and a hydraulic diameter (HD) of 1.2mm. The tube of Figure 5B has 15 ports and a hydraulic diameter (HD) of 0.65mm. The tube of Figure 5C has 14 ports and a hydraulic diameter (HD) of 0.71mm. The tube of Figure 5D has 4 ports and a hydraulic diameter (HD) of 2mm. The tube of Figure 5C has 3 ports and a hydraulic diameter (HD) of 3mm.

[0026] Figure 4 shows a plot of pressure drop versus free flow area for condenser tubes. It can be seen that increasing the tube port size and hydraulic diameter for the sub-cool phase of a typical sized heat exchanger can reduce the refrigerant pressure losses dramatically (experimental results show by up to 84 per cent). It should be noted that while a hydraulic diameter step change has been shown for condenser tubes between the sub-cool section and condenser bank tubes upstream of the sub-cool section and receiver dryer, the step change in hydraulic diameter does not need to take place but could rather be more gradual having adj acent tubes in successive passes having tube hydraulic diameters slightly increased over the previous pass up to a maximum hydraulic diameter in the sub-cool section. Therefore whilst condensers have been shown having only tube configurations of two alternative hydraulic diameters (the largest hydraulic diameter being in the sub-cool section 10), it is envisaged that multiple tubes of increasing hydraulic diameter towards the outlet end of the condenser could be provided.

[0027] Additionally, where tubes of differing depth dimension h are provided through the condenser then the respective tube plates of condenser headers 2, 3 will require to be provided with receiving apertures of appropriate receiving dimensions.

Claims

1. A condenser comprising a first heat transfer tube arrangement in a relatively upstream portion of the condenser, and a second heat transfer tube arrangement relatively downstream of the first tube arrangement, wherein the hydraulic diameter of the first tube arrangement is different to the hydraulic diameter of the second tube arrangement.

2. A condenser according to claim 1, wherein:

    i) the hydraulic diameter of the second tube arrangement is greater than the hydraulic diameter of the first tube arrangement; and/or

    ii) the second tube arrangement is in the sub cooled region of the condenser.

3. A condenser according to claim 1 or claim 2, wherein the second tube arrangement is in the sub cooled region ofthe condenser and also immediately upstream ofthe sub cooled region of the condenser, preferably wherein a receiver dryer is positioned flowise between the sub cooled region of the condenser and the immediately upstream tube arrangement.

4. A condenser according to any preceding claim, wherein:

    i) the external depth dimension of tubes in the first and second tube arrangements is substantially the same; or

    ii) the external depth dimension of tubes in the first and second tube arrangements is substantially different; and/or

    iii) the hydraulic diameter of the second tube arrangement is greater than the hydraulic diameter of the first tube arrangement, and the external depth dimension of the second tube arrangement is substantially greater than that of the first tube arrangement; and/or

    iv) the spacing between adjacent tubes in the first tube arrangement is substantially the same as the spacing between adj acent tubes in the second tube arrangement; and/or

    v) the spacing between adjacent tube major axes in the first tube arrangement is different to the spacing between adjacent tube major axes in the second tube arrangement; and/or

    vi) the hydraulic diameter of the tubes of the second tube arrangement is substantially at or above 1.3 times the hydraulic diameter of the tubes of the second arrangement.

5. A condenser according to any preceding claim, wherein:

    i) the hydraulic diameter of the tubes of the second tube arrangement is substantially at or above 1.5 times the hydraulic diameter of the tubes of the first arrangement, preferably wherein the hydraulic diameter of the tubes of the second tube arrangement is substantially at or above 1.7 times the hydraulic diameter of the tubes of the first arrangement, more preferably wherein the hydraulic diameter of the tubes of the second tube arrangement is substantially at or above 2 times the hydraulic diameter of the tubes of the first arrangement; and/or

    ii) the hydraulic diameter of the tubes of the second arrangement is substantially in the range 0.8mm to 3mm, preferably substantially in the range 1.2mm to 3mm; more preferably substantially in the range 1.4mm to 3mm, preferably substantially in the range 1.7mm to 3mm.

6. A condenser according to any preceding claim, wherein respective tubes of the second arrangement each include a plurality of channels extending in the longitudinal direction of the tube.

7. A condenser according to claim 6, wherein between 2 and 6 channels are provided, preferably wherein 4 or 5 channels are provided.

8. A condenser according to any preceding claim, wherein respective tubes of the first arrangement each include a plurality of channels extending in the longitudinal direction of the tube, preferably wherein 10 or more channels are provided.

9. A condenser according to any preceding claim, wherein the first and second tube arrangements comprise extruded tubes.

10. A condenser according to any preceding claim, wherein the first and second tube arrangements comprise aluminium material tubes.

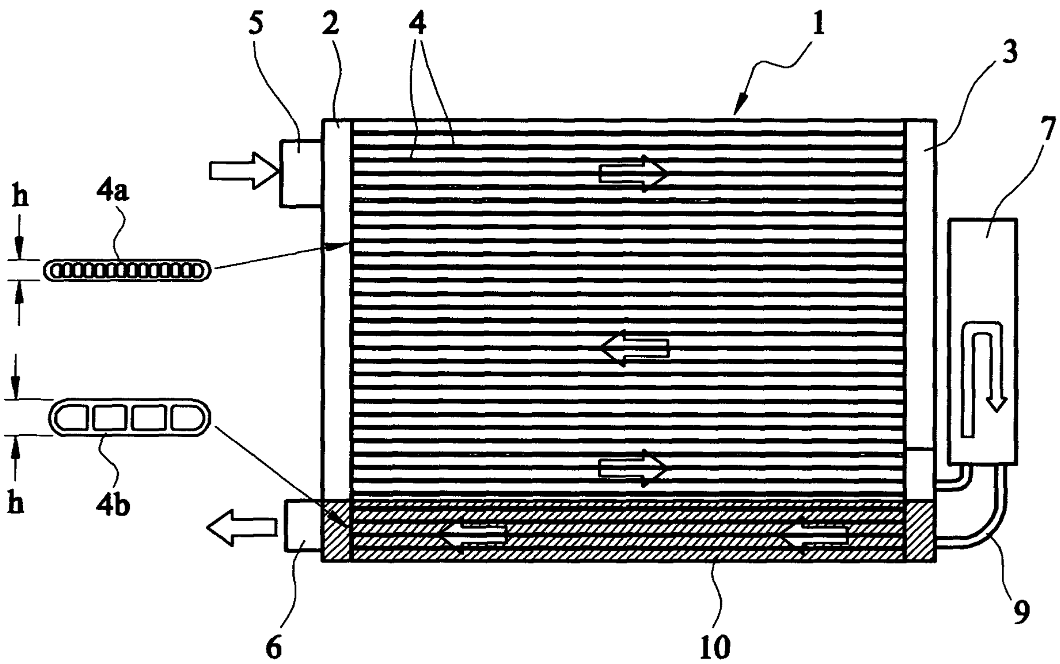


FIG. 1

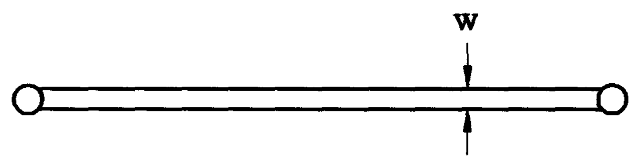


FIG. 2A

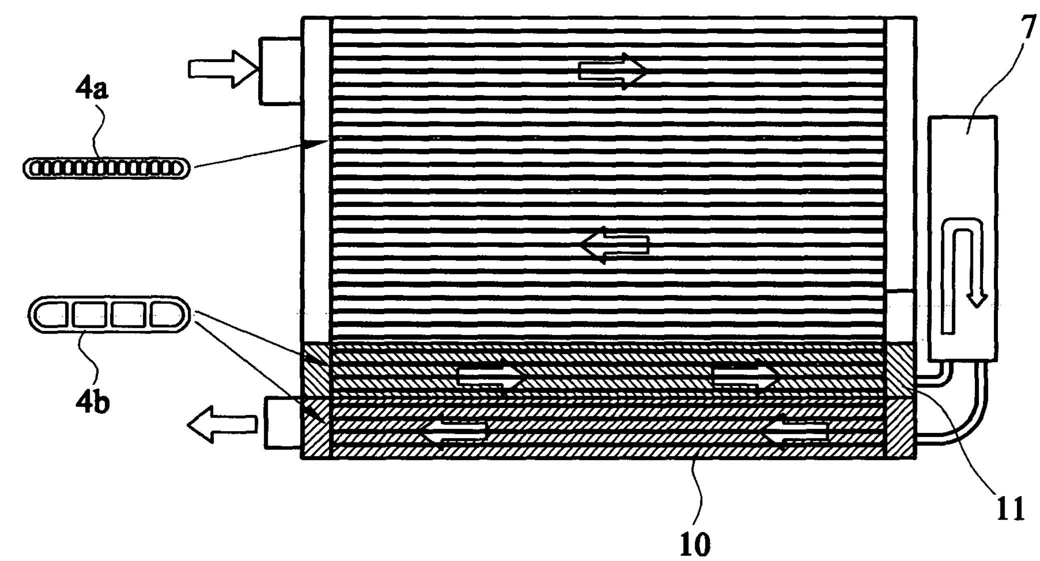


FIG. 2

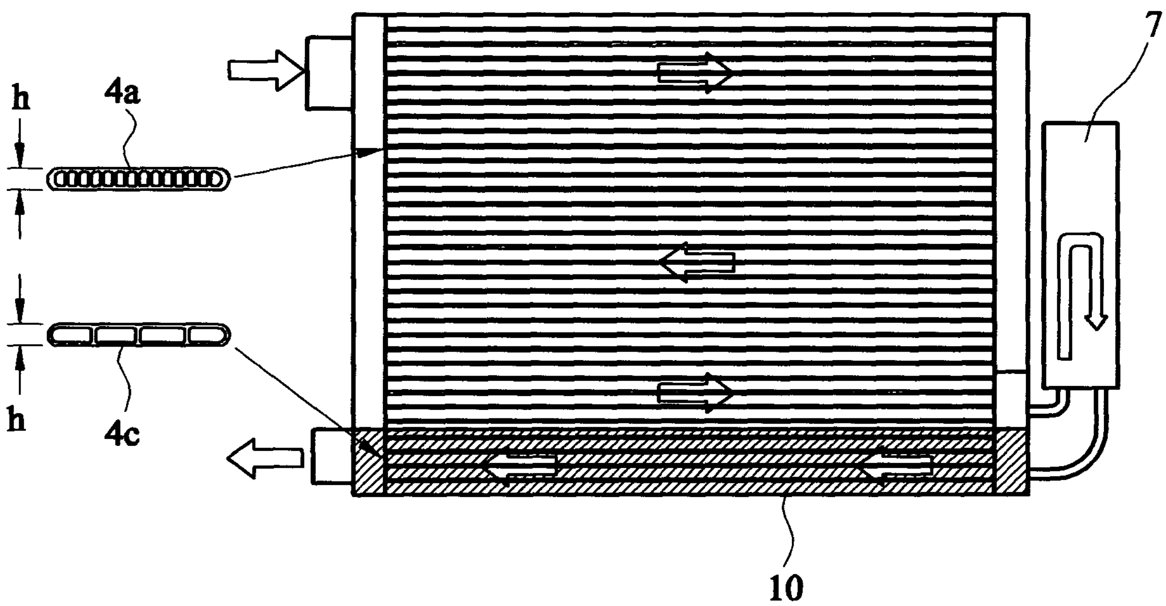


FIG. 3

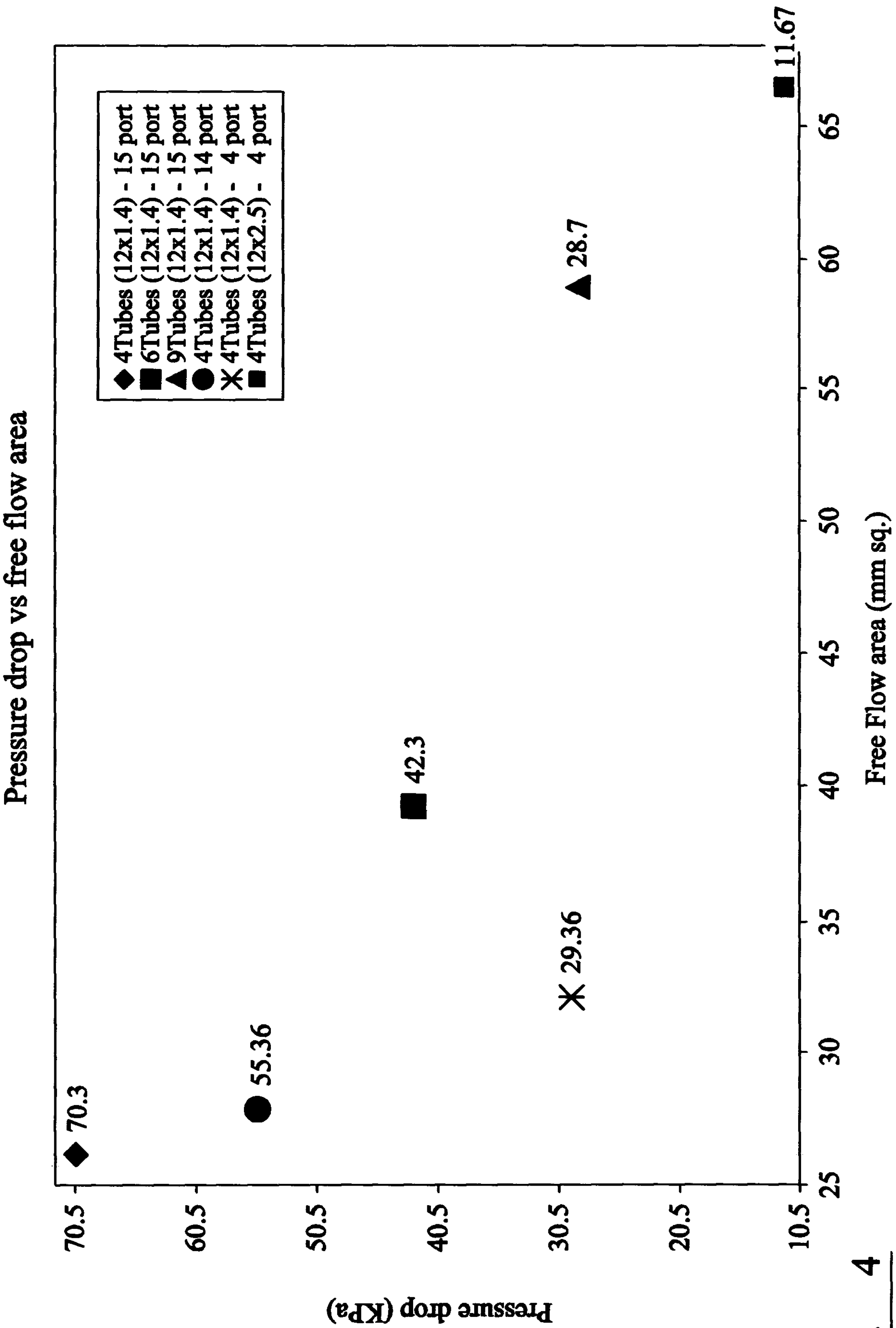
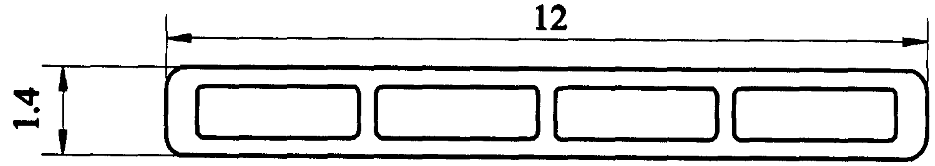

Pressure drop vs free flow area
Pressure drop (KPa)
Free Flow area (mm sq.)
70.5
60.5
50.5
40.5
30.5
20.5
10.5
25
30
35
40
45
50
55
60
65
70.3
55.36
29.36
42.3
28.7
11.67
4Tubes (12x1.4) - 15 port
6Tubes (12x1.4) - 15 port
9Tubes (12x1.4) - 15 port
4Tubes (12x1.4) - 14 port
4Tubes (12x1.4) - 4 port
4Tubes (12x2.5) - 4 port

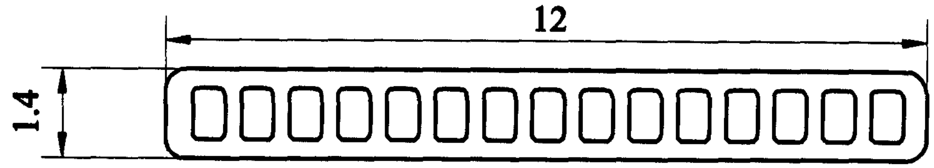
FIG. 4

FIG. 5A



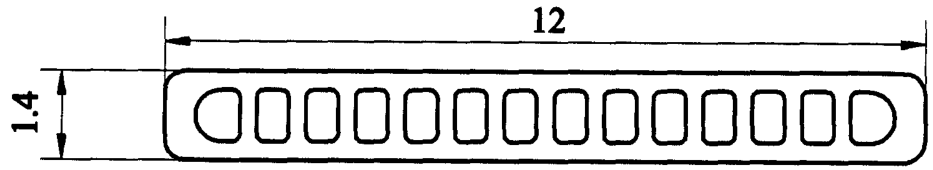
CONFIGURATION:
4 port
HD = 1.2 mm

FIG. 5B



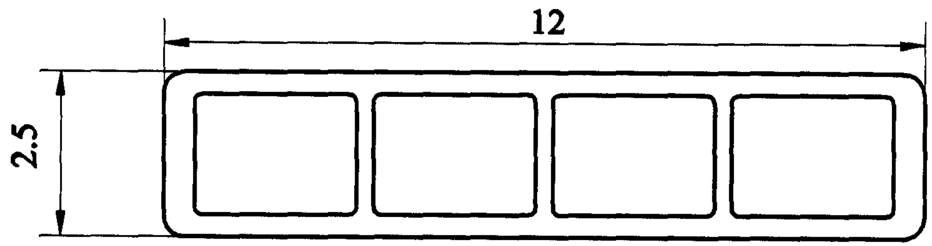
CONFIGURATION:
15 port
HD = 0.65 mm

FIG. 5C



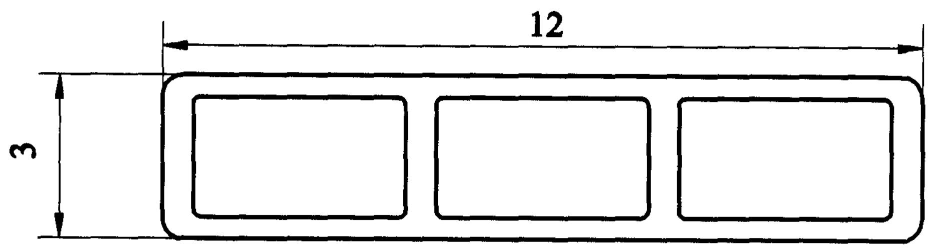
CONFIGURATION:
14 port
HD = 0.71 mm

FIG. 5D



CONFIGURATION:
4 port
HD = 2 mm

FIG. 5E



CONFIGURATION:
3 port
HD = 3 mm