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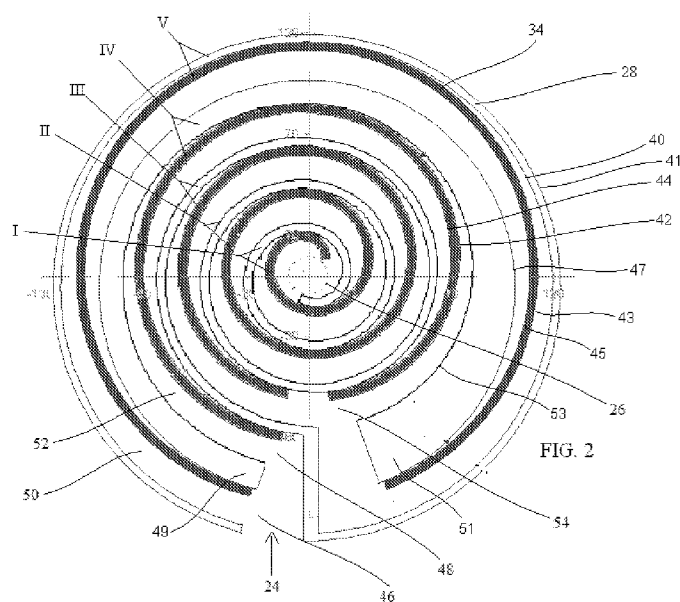
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MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
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(54) Title: SCROLL COMPRESSOR



(57) Abstract: The present invention relates to a scroll compressor (10) comprising a scroll pumping arrangement comprising two scrolls (20, 22) each having a scroll wall (28, 34) with inner and outer scroll wall surfaces which co-operate with respective outer and inner scroll wall surfaces of the other scroll wall providing two pairs of co-operating surfaces which, on relative orbiting motion of the scrolls, pump fluid from an inlet to an outlet of the arrangement, the scroll walls having a respective plurality of wraps I, II, III, IV, V between the inlet (24) and the outlet (26) and wherein the co-operating scroll wall surfaces of one of said pairs of at least one wrap are generally circular.

SCROLL COMPRESSOR

The present invention relates to a scroll compressor.

A prior art scroll compressor, or pump, 100 is shown in Figure 4. The pump 100
5 comprises a pump housing 102 and a drive shaft 104 having an eccentric shaft portion
106. The shaft 104 is driven by a motor 108 and the eccentric shaft portion is connected
to an orbiting scroll 110 so that during use rotation of the shaft imparts an orbiting motion
to the orbiting scroll relative to a fixed scroll 112 for pumping fluid along a fluid flow
path between a pump inlet 114 and pump outlet 116 of the compressor.

10 The fixed scroll 112 comprises a scroll wall 118 which extends perpendicularly to
a generally circular base plate 120. The orbiting scroll 110 comprises a scroll wall 124
which extends perpendicularly to a generally circular base plate 126. The orbiting scroll
wall 124 co-operates, or meshes, with the fixed scroll wall 118 during orbiting movement
of the orbiting scroll. Relative orbital movement of the scrolls causes a volume of gas to
15 be trapped between the scrolls and pumped from the inlet to the outlet.

Figure 5 shows the fixed scroll wall 118 and the orbiting scroll wall 124. The
fixed scroll wall has inner 128 and outer 130 scroll wall surfaces which co-operate with
respective outer 132 and inner 134 scroll wall surfaces of the orbiting scroll wall. This
arrangement provides two pairs 128, 132; 130, 134 of co-operating scroll wall surfaces
20 which, on relative orbiting motion of the scrolls, pump fluid from the inlet 136, 137 to the
outlet 138 of the arrangement. The scroll walls 118, 124 have a respective plurality of
wraps I, II, III, IV, V between the inlet and the outlet. The co-operating scroll wall
surfaces 128, 132; 130, 134 are involute from the inlet to the outlet.

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The specific scroll arrangement shown in Figure 5 is a so-called twin start arrangement having two inlets 136, 137 which in this example are located at the same circumferential angle but at different radii. Two parallel pumping channels extend from the inlets and converge to a single pumping channel after approximately 360 degrees. A
5 twin start arrangement is generally provided for increasing capacity.

Figure 6 shows a more detailed view of the fixed scroll 112. The fixed scroll comprises an annular flange 140 having a plurality of through holes 142 for fixing the fixed scroll to the remainder of the pump housing (not shown). An annular recess 144 receives an o-ring (not shown) for sealing between the fixed scroll and the pump housing.
10 The annular recess is located between the flange 140 and an annular raised portion 146. The outer wrap V of the fixed scroll has radially inner co-operating surface 128 which is an involute or spiral. The outer wrap V of the orbiting scroll wall fits between wraps IV and V of the fixed scroll wall. Therefore, the outer wrap V of the fixed scroll does not have an outer co-operating scroll wall surface.

15 As indicated above, in some applications it is desirable to increase a capacity of a scroll pump, and the arrangement shown in Figure 5 increases capacity by adopting a twin-start inlet. However, invariably when capacity is increased, it is at the expense of compression or requires a larger pump. In a twin-start pump, there is one less wrap available for gradual compression from the inlet to the outlet and therefore a twin-start
20 pump generally offers reduced compression. It should also be noted that a transitional point 150 (see Figure 5) where the two inlet channels converge to a single channel causes inefficiency in the arrangement since it is not possible to efficiently seal between wraps at the transitional point. Accordingly, performance of the pump is reduced.

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The present invention seeks to provide a scroll compressor having increased capacity and yet does not suffer, at least to the same extent, from one or more of the problems associated with prior art arrangements.

The present invention provides a scroll compressor comprising a scroll pumping
5 arrangement comprising two scrolls each having a scroll wall with inner and outer scroll wall surfaces which co-operate with respective outer and inner scroll wall surfaces of the other scroll wall providing two pairs of co-operating surfaces which, on relative orbiting motion of the scrolls, pump fluid from an inlet to an outlet of the arrangement, the scroll walls having a respective plurality of wraps between the inlet and the outlet and wherein
10 the co-operating scroll wall surfaces of one of said pairs of at least one wrap are generally circular.

The present invention also provides a scroll compressor comprising a scroll pumping arrangement comprising two scrolls each having a scroll wall with inner and outer scroll wall surfaces which co-operate with respective outer and inner scroll wall
15 surfaces of the other scroll wall providing two pairs of co-operating surfaces which, on relative orbiting motion of the scrolls, pump fluid from an inlet to an outlet of the arrangement, the scroll walls having a respective plurality of wraps between the inlet and the outlet and wherein the co-operating scroll wall surfaces of one of said pairs of at least one wrap have a rate of change of radius with respect to the angle which is less than said
20 rate of change of the other wraps so that the compression ratio of said one of said pairs is less than for the other wraps.

Other preferred and/or optional aspects of the invention are defined in the accompanying claims.

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In order that the present invention may be well understood, an embodiment thereof, which is given by way of example only, will now be described with reference to the accompanying drawings, in which:

Figure 1 shows schematically a scroll pump;

5 Figure 2 shows a first scroll pumping arrangement for the pump shown in Figure 1;

Figure 3 shows a second scroll pumping arrangement for the pump shown in Figure 1;

Figure 4 shows a prior art scroll pump;

10 Figure 5 shows a prior art scroll pumping arrangement of the pump shown in Figure 4; and

Figure 6 shows a fixed scroll of a prior art pump in more detail.

A scroll compressor, or pump, 10 is shown in Figure 1. The pump 10 comprises a pump housing 12 and a drive shaft 14 having an eccentric shaft portion 16. The shaft 14
15 is driven by a motor 18 and the eccentric shaft portion is connected to an orbiting scroll 20 so that during use rotation of the shaft imparts an orbiting motion to the orbiting scroll relative to a fixed scroll 22 for pumping fluid along a fluid flow path between a pump inlet 24 and pump outlet 26 of the compressor.

The fixed scroll 22 comprises a scroll wall 28 which extends perpendicularly to a
20 generally circular base plate 30. The orbiting scroll 20 comprises a scroll wall 34 which extends perpendicularly to a generally circular base plate 36. The orbiting scroll wall 34 co-operates, or meshes, with the fixed scroll wall 28 during orbiting movement of the orbiting scroll. Relative orbital movement of the scrolls causes a volume of gas to be trapped between the scrolls and pumped from the inlet to the outlet.

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As shown in Figure 2, the fixed scroll wall 28 has inner 38 and outer 40 scroll wall surfaces which co-operate with respective outer 42 and inner 44 scroll wall surfaces of the orbiting scroll wall 34 providing two pairs of co-operating surfaces 38, 42; 40, 44. On relative orbiting motion of the scrolls 20, 22, fluid is pumped from an inlet 46, 48 to an outlet 50 of the arrangement. The scroll walls have a respective plurality of wraps I, II, III, IV, V between the inlet and the outlet. The co-operating scroll wall surfaces 38, 42; 40, 44 of one of the pairs of at least one wrap are circular.

Typically, the co-operating scroll wall surfaces of a scroll pump are involute, or spiral. Since the volume of fluid trapped by each pair of co-operating surfaces reduces as the volume approaches the outlet 26 the pump compresses the fluid. As indicated above with reference to the prior art, many attempts have been made to increase pumping capacity, or the amount of fluid that can be pumped. These attempts have produced increased capacity but suffer from disadvantages such as reduced compression or increased back leakage. In the present invention, one pair of scroll wall surfaces is not involute but instead is substantially circular.

For Archimedean spirals and large angles of an involute, the geometry of a spiral in prior art pumps is such that the rate of change of the radius is generally constant with respect to the change in the angle. Where r is the radius and θ is the angle about the centre of the spiral, for an Archimedean spiral ($r = a\theta$), $dr/d\theta = a$, which is constant. For an involute, $dr/d\theta$ is not constant but changes a lot over the first $1/2$ turn and then it tends to a single value. In other words, for large angles, it becomes reasonable constant. For a circle, $dr/d\theta = 0$. That is, $dr/d\theta$ is a constant.

In the present invention, $dr/d\theta$ for at least one of the pairs of scroll surfaces 38, 42; 40, 44 for at least one wrap I, II, III, IV, V is reduced such that the spiral tends towards a

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circular path and departs from a geometrical spiral or involute as defined above. That is, if $dr/d\theta$ equals 'a' for a spiral and 0 for a circle, then for embodiments of the invention $dr/d\theta$ equals a value between 'a' and 0, preferably approaching 0. In its most preferred example therefore, the scroll wall surfaces are circular, although benefits of the invention can be achieved by decreasing $dr/d\theta$ thereby increasing the trapped volume between the scroll wall surfaces. Therefore, decreasing $dr/d\theta$ increases pumping capacity and decreases compression. The circular or generally circular scroll wall surfaces may be located at any one of the wraps I, II, III, IV, V, or may be located at more than one wrap or at all of the wraps, the latter of which is shown in the example described in more detail below with reference to Figure 3.

In the first example as shown in Figure 2, the fixed scroll wall 28 of the outer wrap V has only one co-operating surface 40, the other surface 41 being outside the pumped volume. The co-operating surface 40 is circular. The orbiting scroll wall 34 of the outer wrap V has two co-operating surfaces 43, 45 both of which are circular. The outer surface 43 co-operates with the inner surface 40 of the fixed scroll wall, whilst the inner surface 45 co-operates with the outer surface 47 of wrap IV of the fixed scroll wall. The other radially inward wall surfaces of the pump in this example are involute. The transition between circular and involute surfaces is formed by the fixed scroll wall of wrap 4. This scroll wall increases in radial thickness between a first portion 49 and a second portion 51 thereby defining an outer surface 47 which is circular and an inner surface 53 which is involute.

Typically, as shown in Figure 6, the fixed scroll casing 140, 144, 146 148 is generally circular so that the fixed scroll has a small overall volume and foot-print. However, the inner scroll wall surface 128 of the fixed scroll wall 118 is spiral.

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Therefore, referring to prior art Figure 5, a region between circle 152 and the outer wrap V of the fixed scroll is lost and not usefully available for pumping fluid. It is an advantageous feature of the present embodiment in Figure 2 that the lost pumping region is brought within the pumping volume of the scrolls. In this regard, instead of having a transition between circular and spiral which is outside a pumping volume, the transition is brought within the pumping volume. Accordingly, as shown, the inner scroll surface of the fixed scroll wall 28 is circular and the transition between the circular and spiral surfaces occurs at wrap IV of the fixed scroll. Therefore, the pumping capacity of the pump is increased without an increase in the overall volume or foot-print of the pump.

It will be appreciated that a single circular wrap does not achieve compression since the trapped volume between co-operating scroll wall surfaces is not reduced by pumping along a circular surface. However, capacity is increased because the circular scroll wall surfaces are inherently able to trap more volume than spiral surfaces at the same radius and hence greater capacity is achieved. Furthermore, if the co-operating surfaces of the outer scroll wrap are circular, a previously unused region of the pump is brought within the pumping volume.

Referring again to Figure 2, wraps I to III are involute, wrap V is circular and wrap IV is transitional between circular and spiral. In the example shown, the fixed scroll wall of wrap IV has an outer scroll wall surface 47 which is circular and an inner scroll wall surface 53 which is spiral. The transition necessitates a relatively thick scroll wall and therefore it is advantageous that the transition takes place on the stationary fixed scroll, since a thicker orbiting scroll wall would increase the weight of the moving components of the pump. Alternatively the transition may take place on the orbiting scroll, and in this case the orbiting scroll may be hollow to reduce the amount of mass

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which must be moved during orbiting motion. In this regard, the outer wrap V of the orbiting scroll may have an outer scroll wall surface which is circular and an inner scroll wall surface which is spiral. In this arrangement, only the co-operating surfaces at the outer wrap of the scroll walls are circular. In other words, only an outer most pumping
5 channel is circular.

It will be noted that the transition between circular and spiral pumping surfaces may take place on any of the wraps of the orbiting scroll or any of the wraps of the fixed scroll (except the outer wrap of the fixed scroll).

The inlet 24 to the scroll pumping arrangement shown in Figure 2 is sub-divided
10 into inlets 46, 48 to respective pumping channels 50, 52. Typically, as described above in relation to the prior art, a two-start or multi-start arrangement is often used to increase pumping capacity. The example shown comprises two inlets 46, 48 on different radii, although in other examples, the inlets may be provided on the same radius at different circumferential positions. The present invention encompasses all such examples.

15 A problem that exists with multi-start arrangements occurs where the pumping channels converge as shown by 150 in Figure 5. In more detail, the scroll wall is not continuous at the convergence between multiple and single channels and therefore there is a gap in the tip seals which resist back-leakage. Accordingly, back-leakage is increased thereby reducing the pumping efficiency.

20 In the embodiment of the invention, the pumping channels 50, 52 converge at 54 and the convergence is a source of some pumping inefficiency as the tip seals are discontinuous thereby reducing the capacity of the pump. However, the increased pumping capacity produced by the circular pumping channel 50 at least partially and preferably fully compensates for the back-leakage at the convergence 54. In this regard,

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pumping channel 50 has two pairs of co-operating surfaces formed on both sides of the outer wrap V of the orbiting scroll wall 34. Accordingly, the embodiment provides a multi-start scroll pumping arrangement which does not suffer from reduced efficiency.

Whilst a multi-start arrangement is shown in Figure 2, the present invention
5 applies equally to single start arrangements. That is, the fixed scroll wall may define one pumping channel between successive wraps (as in a single start arrangement) or more than one pumping channel between successive wraps of the scroll wall which may converge.

In an alternative arrangement, a multi-start or single start scroll arrangement
10 comprises one or more circular pumping channels and one or more involute pumping channels and the circular pumping channels are deeper than the involute pumping channels. The transition from deep to shallow channels in prior art pumps can often be a cause of inefficiency because the tip seals are not continuous. In this example of the invention however, the circular nature of the deeper pumping channels compensates for
15 the back-leakage caused at the transition.

In a further scroll pumping arrangement, there are one or more circular pumping channels and one or more involute pumping channels, and a flow intersection between the circular pumping channels and the involute pumping channels is in flow communication with a blow-off valve for releasing over pressure from the scroll arrangement. The
20 intersection is a suitable location for the blow-off valve as it is located at the transition between a high capacity region and a low capacity region and when running at high inlet pressures substantial over-pressure may occur.

A still further scroll arrangement is shown in Figure 3. The fixed scroll 22 comprises a scroll wall 60 having four discrete generally circular sections. The orbiting

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scroll 20 comprises a scroll wall 62 having four discrete generally circular sections. The orbiting scroll wall 62 co-operates, or meshes, with the fixed scroll wall 60 during orbiting movement of the orbiting scroll. Relative orbital movement of the scrolls causes a volume of gas to be trapped between the scrolls and pumped from the inlet 64 to the outlet 66.

As shown in Figure 3, the fixed scroll wall and the orbiting scroll wall each have four wraps I, II, III, IV which in this example are formed by four circular wall sections. The fixed scroll wall sections of successive wraps form therebetween four circular pumping channels 68, 70, 72, 74. For example, the fixed scroll wall sections of wraps III and IV form pumping channel 68. The four sections of the orbiting scroll wall are located within respective pumping channels.

With regard to the outer pumping channel 68, the fixed scroll wall sections of wraps III and IV form outer 76 and inner 78 scroll wall surfaces respectively. The orbiting scroll wall section of wrap IV forms inner 80 and outer 82 scroll wall surfaces which co-operate with respective outer 76 and inner 78 of the fixed scroll wall surfaces forming two pairs of co-operating surfaces 76, 80; 78, 82 in pumping channel 68. On relative orbiting motion of the scrolls, fluid in the outer pumping channel 68 is trapped between both pairs of co-operating surfaces and pumped from a channel inlet 84 to a channel outlet 86.

Each pumping channel extends through less than 360° (although not substantially less than 360° , e.g. about 350°) so that the pumping channel forms an incomplete circle. The ends of each pumping channel are closed by one or more wall closures 88, 90 thereby separating the inlet from the outlet in a pumping channel. The closures are arcuate so that

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an end of an orbiting scroll wall section sweeps across its face during orbiting motion.

This arrangement allows fluid to be trapped efficiently by the orbiting scroll wall.

The outlet 86 of each channel is connected by a duct (shown by arrows 92) to an inlet 84 of the next inward pumping channel. Trapped fluid in channel 68 is forced along
5 a duct 92 entering channel 70 and so on until fluid is forced through the outlet of the most inward channel 74 to the outlet 66 of the pumping arrangement. As fluid is pumped from one channel to the next it becomes compressed because the trapped volume becomes progressively smaller. Accordingly, compression occurs even though all the pumping channels, and co-operating surfaces are circular.

10 Circular wall profiles are easier to design, manufacture and inspect. The simple profile allows better tolerances to be achieved. Having all the wraps as circular avoids over compression between any of the stages, which maximises pumping efficiency.

In Figure 2, an outer pumping channel is circular and the remaining pumping channels are spiral. This arrangement reduces dead space in the pump and thereby
15 increases capacity. A circular pumping channel achieves increased capacity without compression. In Figure 3, all the pumping channels are circular. The invention also encompasses any arrangement between these two examples, such as where one, two or three wraps or pumping channels are circular. Therefore, the invention covers arrangements in which only one pair of co-operating scroll wall surfaces are circular or at
20 least generally circular, and in which all of the co-operating surfaces are circular and all possibilities in between.

In a multi-start pump, one pumping channel at a first start may be circular, a plurality of pumping channels at more than one start may be circular or all of the pumping channels at all of the starts may be circular.

CLAIMS

1. A scroll compressor comprising a scroll pumping arrangement comprising two
5 scrolls each having a scroll wall with inner and outer scroll wall surfaces which
co-operate with respective outer and inner scroll wall surfaces of the other scroll
wall providing two pairs of co-operating surfaces which, on relative orbiting
motion of the scrolls, pump fluid from an inlet to an outlet of the arrangement, the
scroll walls having a respective plurality of wraps between the inlet and the outlet
10 and wherein the co-operating scroll wall surfaces of one of said pairs of at least
one wrap are generally circular.
2. A scroll compressor as claimed in claim 1, wherein the scroll walls have an outer
wrap adjacent the inlet and wherein the co-operating scroll wall surfaces of one of
15 said pairs of the outer wrap are circular.
3. A scroll compressor as claimed in claim 2, said scrolls comprise a fixed scroll
wall and an orbiting scroll wall which can move relative to the fixed scroll wall
for pumping fluid from the inlet to the outlet, and wherein the radially inner co-
20 operating scroll wall surface of the outer wrap of the fixed scroll wall and the
radially outer co- operating scroll wall surface of the outer wrap of the orbiting
wall are circular.

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4. A scroll compressor as claimed in any one of the preceding claims, wherein one scroll wall has a radially inner co-operating surface which is involute and a radially outer co-operating surface which is circular.
- 5 5. A scroll compressor as claimed in any one of the preceding claims, wherein said fixed scroll wall defines one or more pumping channels between successive wraps thereof.
6. A scroll compressor as claimed in claim 5, wherein the scroll arrangement has a plurality of inlets through which fluid can be pumped along respective pumping channels, and an outer pumping channel is circular.
- 10 7. A scroll compressor as claimed in claim 5 or 6, wherein one or more of said respective pumping channels are circular and converge to form a single involute pumping channel.
- 15 8. A scroll compressor as claimed in any one of claims 5 to 7, wherein the scroll arrangement comprises one or more circular pumping channels and one or more involute pumping channels and the circular pumping channels are deeper than the involute pumping channels.
- 20 9. A scroll compressor as claimed in any preceding claim, wherein the scroll arrangement comprises one or more circular pumping channels and one or more involute pumping channels, and a flow intersection between the circular pumping

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channels and the involute pumping channels is in flow communication with a blow-off valve for releasing over pressure from the scroll arrangement.

10. A scroll compressor comprising a scroll pumping arrangement comprising two scrolls each having a scroll wall with inner and outer scroll wall surfaces which co-operate with respective outer and inner scroll wall surfaces of the other scroll wall providing two pairs of co-operating surfaces which, on relative orbiting motion of the scrolls, pump fluid from an inlet to an outlet of the arrangement, the scroll walls having a respective plurality of wraps between the inlet and the outlet and wherein the co-operating scroll wall surfaces of one of said pairs of at least one wrap have a rate of change of radius with respect to the angle which is less than said rate of change of the other wraps so that the compression ratio of said one of said pairs is less than for the other wraps.

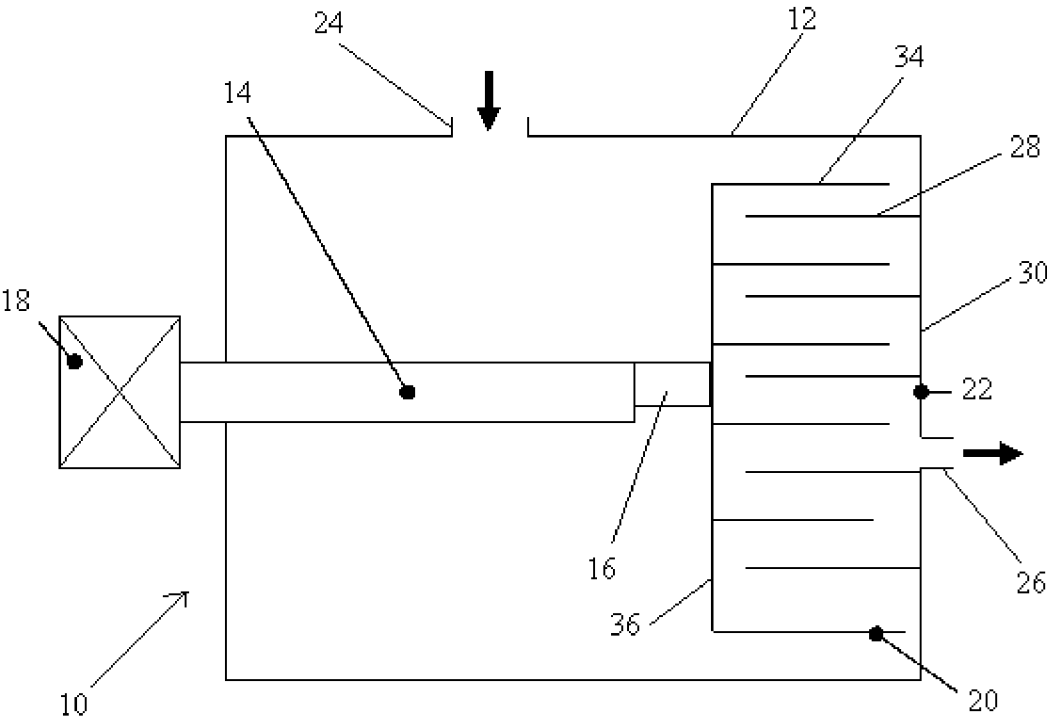
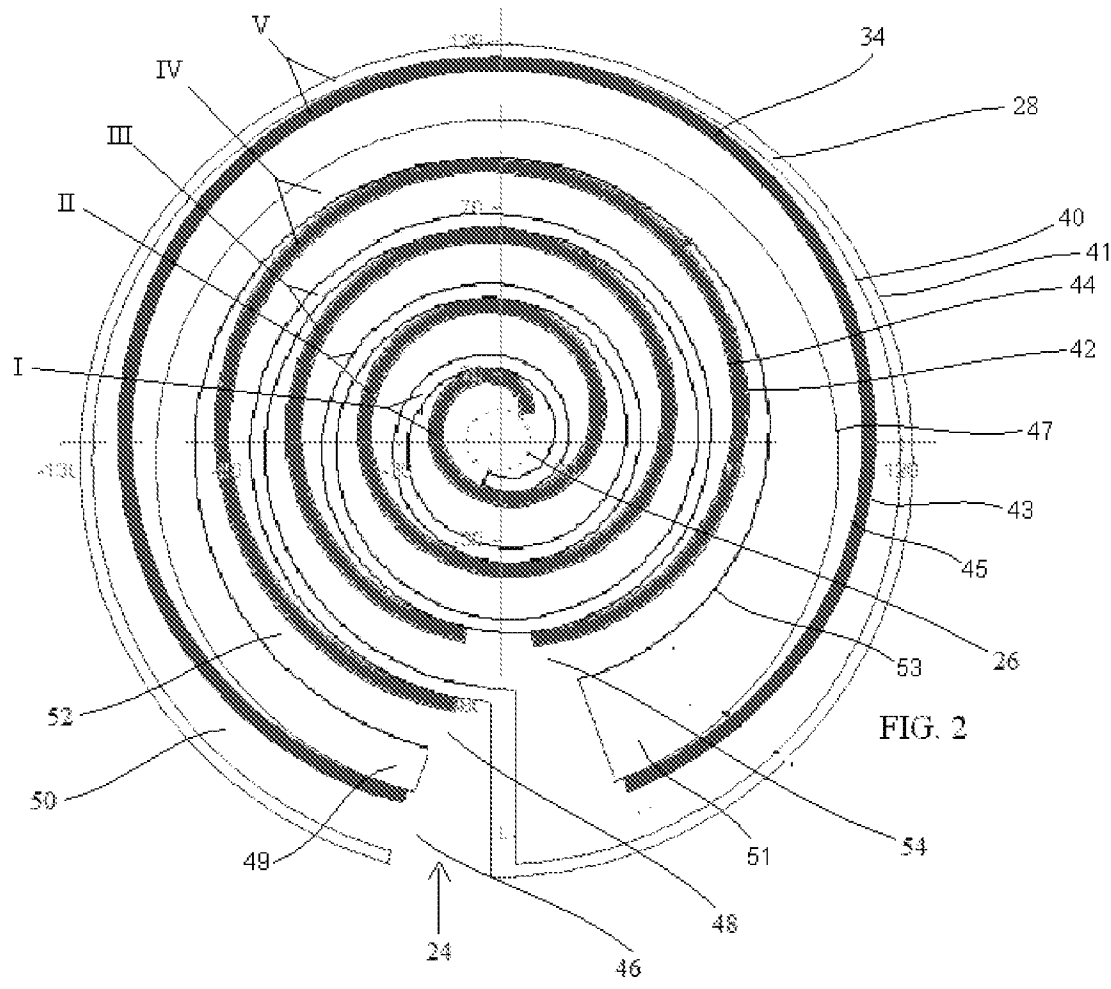
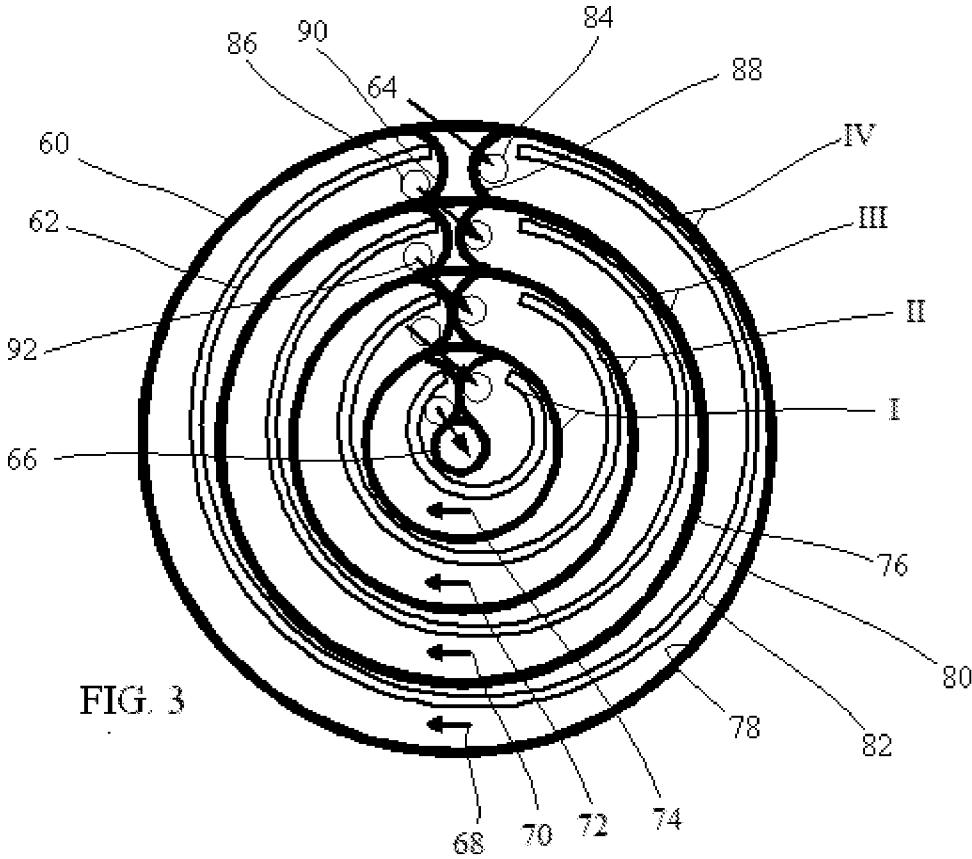


FIG. 1





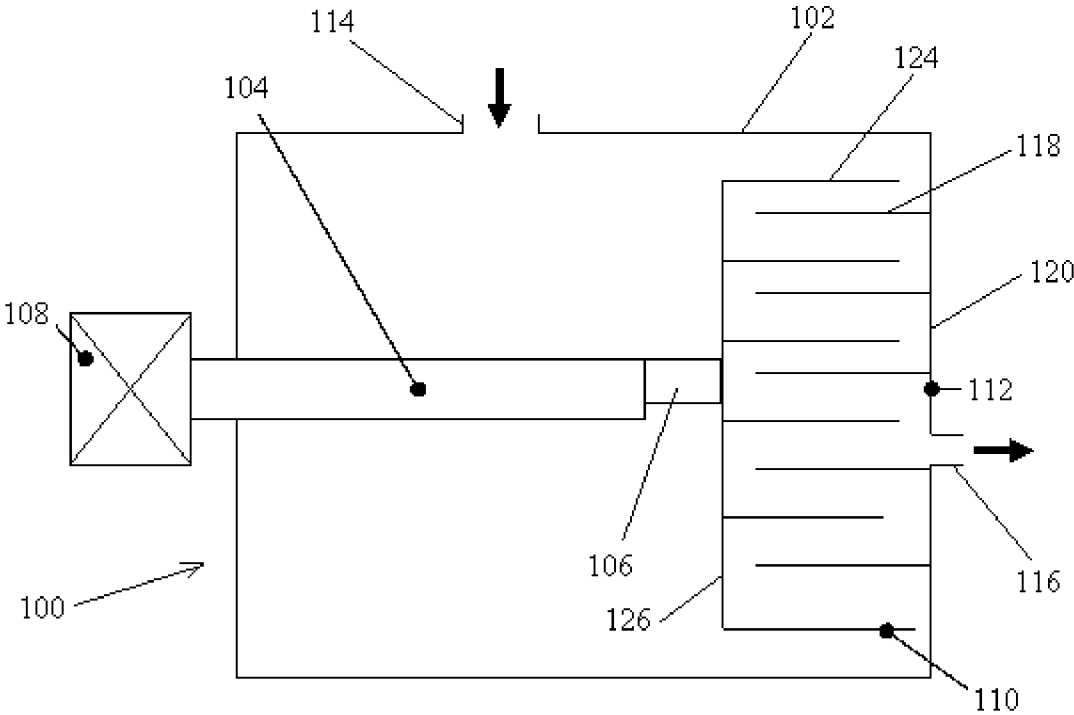
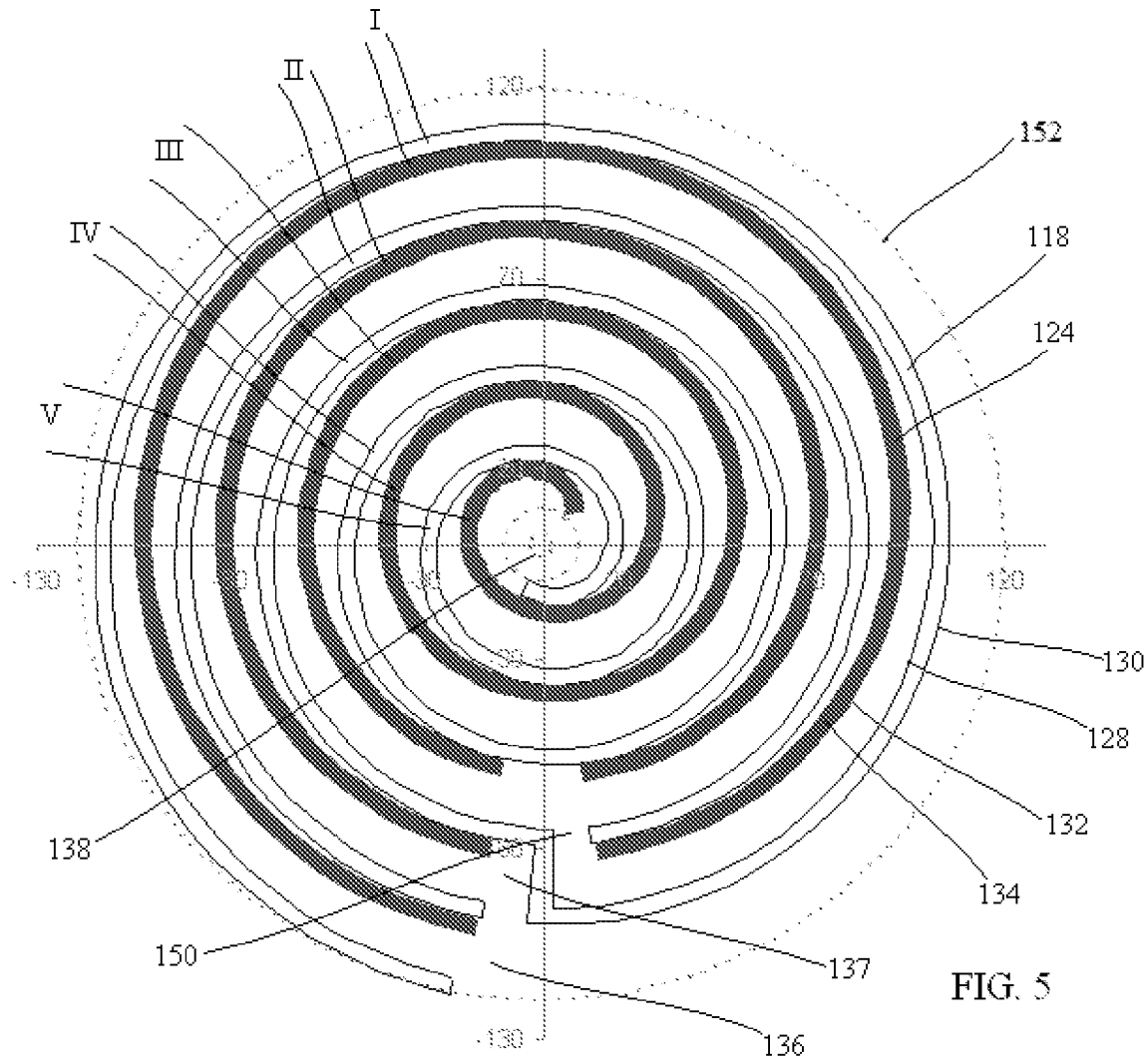
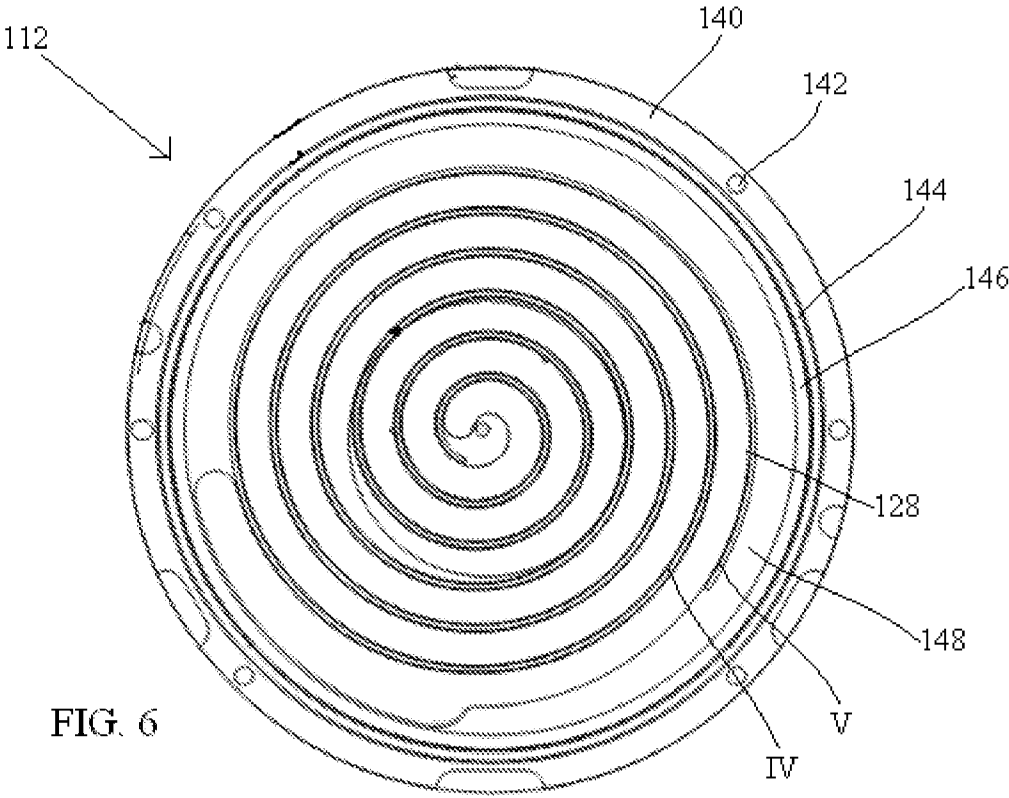


FIG. 4





INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER
INV. F04C18/02
ADD.

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)
F04C

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 5 938 417 A (TAKAO KUNIHICO [JP] ET AL) 17 August 1999 (1999-08-17)	1-4,9,10
Y	column 1, line 5 - line 43 column 3, line 65 - column 6, line 3 column 6, line 63 - column 7, line 11 column 10, line 42 - line 53 claim 1; figures 1-3,8a,11	5-9
X	WO 99/15763 A1 (SCROLL TECH [US]) 1 April 1999 (1999-04-01)	1-4,10
A	page 3, line 17 - page 14, line 24 claim 1; figures 1-11	5-9
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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Bocage, Stéphane

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2013/051517

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	paragraph [0027] paragraph [0034] - paragraph [0041] figures 3-8 -----	1-4,9,10
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