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# (54) Rotary positive displacement blower with noise and shock reduction

(57) A roots-style blower (210) has a housing (214), rotors (230) and manifolds (212) for the housing (214). The housing (214) forms an inlet plenum (220), a rotor chamber (224) and a discharge plenum (228). The rotors (230) have straight lobes (232) spaced by pockets (240). The pocket (240X) that traps gas between a leading and following lobe (232) and an inside wall of the rotor chamber (224) is a temporary closed cell (240X). The manifolds (212) and the housing (214) form a pair of back-pass loops (250-251), one for each rotor (230). Each back-pass loop (250-252) comprises a back-pass chamber (250), outer channels (252) from the discharge plenum (228) to the back-pass chamber (250), and inner channels (251) to the rotor chamber (224). Wherein, the back-pass chamber (250) volume as a percentage of closed cell (240X) volume ranges between about fifty-six percent (56%) and one-hundred-seventeen percent (117%).

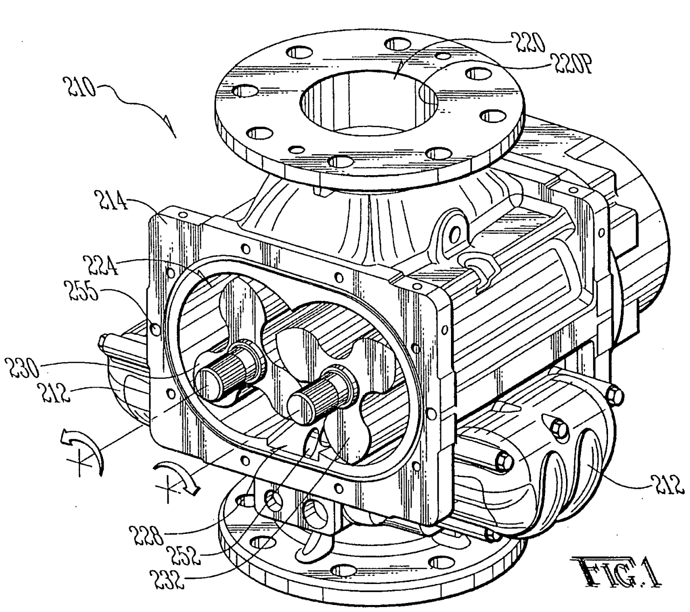


FIG.1

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## Description

Background and Summary of the Invention

**[0001]** The invention relates to rotary positive displacement blowers (of the Roots type) and, more particularly, to a back-pass loop for gradually pressurizing the working cell to outlet pressure in order to weaken the strength of the pulsations that would otherwise happen without such a back-pass loop, and thereby reduce noise and shock (and perhaps better efficiency as well).

**[0002]** Briefly, the performance of such blowers is typically measured (or specified) in terms of the following factors:- flow, pressure, efficiency, noise, and reliability.

**[0003]** It is an object of the invention to provide improvements in particular for at least two or three of those factors, namely, noise and reliability, plus perhaps efficiency.

**[0004]** Although the invention perhaps neither betters nor harms flow rate and pressure performance to a significant degree, to be sure, these are important factors to users.

**[0005]** So, briefly (and very briefly), the following remarks are offered about flow and pressure. Regarding flow rate, blowers of this type can be built to all kinds of sizes (including very large). Hence design flow rate is an operating point that is scalable over a wide range.

**[0006]** As for pressure, the operating pressure differential ($\Delta$p) across such blowers might typically vary under the circumstances between very slight (eg., 1 to 2 psi or ~ 1/l5th to 2/15th atm) to something typical (eg., 15 psi or ~ 1 atm). It might be just as typical that a blower of this type be rated for up to 18 psi duty (~ 1-3/15ths atm pressure differential).

**[0007]** As concerns a separate consideration, some end-use applications may require that the discharge line supply flow at a pressure as high as 100 psig (~ 7-2/3rds atm). To do this, the pressure in the inlet line has to be elevated to within 18 psi (~ 1-3/15ths atm pressure differential) or less of the target pressure for the discharge line.

**[0008]** Moreover, high reliability is expected of these kinds of blowers. They might be designed and expected to operate more or less continuously (excluding routine maintenance) for years on end.

**[0009]** This application is owned by assignment in common with the same owner of U.S. Patent No. 5,702,240 - O'Neal et al., namely TUTHILL CORPORATION of Burr Ridge, Illinois. This blower was referred to by the TUTHILL CORPORATION as the "Acoustic Air" design.

**[0010]** The Acoustic Air blower introduced some matters in blower design which have been changed, substantially or so, here for better meeting the objects of the invention. These changes fall under two major categories. One major category comprises changes in design for purely or substantially pneumatic reasons. The other major category comprises changes in design for purely or substantially ease of manufacture reasons.

**[0011]** In common with one of the objects of the invention here, an object of the invention for the Acoustic Air design included reducing pressure pulsations, and thereby reducing resulting noise and vibration.

**[0012]** The Acoustic Air design sought to do this by the following two ways. One, the Acoustic Air design included a backflow loop. Generally speaking, a backflow loop is meant to gradually pre-pressurize a low-pressure closed cell (eg., 64 or 66) so that when the closed cell (eg., 64 or 66) opens across an edge 78 or 80 into the higher-pressure discharge chamber 46, the backflow loop eliminates or weakens the direct backflow from the discharge chamber 46 into the opening closed cell (eg., 64 or 66). Without a backflow loop, the backflow from the discharge chamber 46 flows directly into the opening closed cell (eg., 64 or 66) and is the source of the sonic pop (eg., the noise) as well as the momentary opposition to the rotation of the rotors 50, 52 (eg., the vibration).

**[0013]** With reference to Figs. 3 and 6 therein, the Acoustic Air blower has backflow chambers 106, 108, 120, 122 filled by backflow ports 112, 116, 126, 130 and for pre-pressurizing fluid in the sealed pocket (eg., 64, 66) by injector ports 110, 114, 124, 128. The patent contains this remark on the effectiveness of this design.

> ... Therefore, after a pocket 64 has been in fluid communication with the injector ports 110 and 114, the pressure in the now pre-pressurized pocket 64 is greater than the first pressure of the fluid within the intake chamber 44, but is usually still somewhat lower than the second pressure of the fluid within the discharge chamber 46. U.S. Patent No. 5,702,240, col. 6, lines 28-34:

In other words, the backflow loop was not as effective as hoped for. The other way the Acoustic Air design sought to eliminate or weaken backflow was by curved edges 78 and 80 opening into the discharge chamber 46.

**[0014]** Despite owning the rights to the Acoustic Air design, the owner of the patent thereon put together the present team of inventors to do even better. Noise and vibration are serious problems. It is an object of the invention to overcome the shortcomings of the prior art.

**[0015]** Now to turn to the improvements herein, various features and objects of the invention will be apparent in connection with the following discussion of preferred embodiments and examples.

## Brief Description of the Drawings

**[0016]** There are shown in the drawings certain exemplary embodiments of the invention as presently preferred. It should be understood that the invention is not limited to the embodiments disclosed as examples, and is capable of variation within the scope of the skills of a person having ordinary skill in the art to which the invention pertains. In the drawings,

FIGURE 1 is a perspective view of a rotary positive displacement blower with noise and shock reduction improvements in accordance with the invention;
FIGURE 2 is an exploded view thereof;
FIGURE 3 is an enlarged scale detail view of the rotor chamber and discharge plenum in FIGURE 2;
FIGURE 4 is a vertical sectional view taken through the rotary positive displacement blower of FIGURE 1, taken perpendicular to the plane of the rotor axes, and, taken along an offset plane to contain not only the centerline of one inner port(s) in the rotor chamber (as well as portions thereabove), but also, the centerline of one (of the two) outer port(s) in the discharge plenum (as well as portions therebelow); and
FIGURE 5 is a chart showing the effect of back-pass manifold chamber volume on the fluctuation away from mean discharge flowrate.

## Detailed Description of the Preferred Embodiments

**[0017]** FIGURES 1 through 4 provide line drawings of a rotary positive displacement blower 210 with noise and shock reduction improvements in accordance with the invention. It is an aspect of the invention to incorporate a pair of back-pass manifolds 212.

**[0018]** This is a Roots style blower. FIGURE 4 shows better that, it has a substantially hollow housing 214 defining an inlet plenum 220, a rotor chamber 224, and a discharge plenum 228. (Preferably the housing 214 is cast, but the flange surfaces would be machined and ground.)

**[0019]** A pair of rotors 230 are disposed in the rotor chamber 224. The rotors 230 would be sealed inside by a pair of opposed end plates (far side end plates shown in FIGURES 1 and 2). The rotors 230 are driven to rotate counter-rotationally to each other. For instance, the left rotor 230 rotates counter-clockwise (CCW).

**[0020]** In the drawings, the blower 210 is shown with the inlet port 220P up and the discharge port 228P down. However, the blower 210 can be mounted in any orientation, and accordingly, terms like "up" and "down", "left" and "right" are used merely for convenience in this description and do not limit the installation of the blower 210 to any particular orientation.

**[0021]** The rotors 230 are identical. Each rotor 230 comprises three lobes 232. Each lobe 232 culminates in a tip 232T. The lobes 232 are spaced by pockets 240.

**[0022]** The inlet plenum 220 transitions into the rotor chamber 224 at a pair of spaced ledges 242L, and these define an inlet opening 242 for the blower 210. Likewise, the rotor chamber 224 transitions into the discharge plenum 228 at another pair of spaced ledges 244L, and these define a discharge opening 244 for the blower 210. FIGURE 4 shows that the left rotor 230's upper lobe tip 232T is about to sweep (counterclockwise) past the left ledge 242L of the inlet opening 242. When it does so, that lobe 232 will trap gas in the pocket 240X immediately ahead of it, between the surface of the rotor 230 and surface of the housing 214. The pocket 240X which temporarily traps gas in it, carrying the trapped gas from the inlet plenum 220 to the discharge plenum 228, is referred to as the 'closed cell' (ie., indicated as 240X). Each pocket 240 in turn will form the temporarily existing closed cell 240X, successively, and in an endless succession.

**[0023]** The trapped gas is carried around in the closed cell 240X, from the inlet plenum 220 to the discharge plenum 228, at the pressure of the inlet plenum 220 while being carried around like that. In contrast, the trapped gas will be ultimately discharged into the discharge plenum 228, at the pressure of the discharge plenum 228.

**[0024]** When the lobe tip 232T of the lobe 232 leading the closed cell 240X sweeps past the ledge 244L of the discharge opening 244, suddenly something happens. Two different pressurized spaces at two different pressures have open communication with each other. This allows for the free exchange of gases between the (formerly) closed cell 240X and the discharge plenum 228. This 'opening' of the (formerly) closed cell 240X to the discharge plenum 228 also allows for the consequential equalization of pressure between the two. That is, the closed cell 240X, as it travels from inlet space to discharge space, holds fairly steady at the inlet pressure. But that changes, suddenly, when the lobe tip 232T of the leading lobe 232 crosses the ledge 244L of the discharge opening 244. At that moment, the closed cell 240X is suddenly no longer closed but 'open' to the discharge plenum 228. Gases in the discharge plenum 228 are free to flow back into the (formerly) closed cell 240X.

**[0025]** There are numerous consequences to this 'moment' that the closed cell 240X opens to discharge space. There is noise (eg., an audible sonic pop or snap, something akin to a popping balloon or snapped cell of bubble wrap), and there is a puff of reverse flow from the discharge plenum 228 into the opening closed cell 240X. Noise aside (for the moment), the reverse flow is a problem of its own. The reverse flow creates an opposing force in opposition to the turning rotors 230, and the rotors 230 have to power through the reverse flow. Hence the reverse flow is a readily identifiable source of inefficiency. The reverse flow also has another effect, which is likewise detrimental, which is that of causing mechanical shock through the blower (vibration), and not just to the blower's castings but also to the joints, couplings, bearings, seals and so on.

**[0026]** To come to terms with the problematic effects of reverse flow, it pays to appreciate that the reverse flow comprises a pulsing phenomenon. That is, for each revolution of the rotors 230, there are six reverse flow events. The rotors 230 are typically driven at 1200, 1800 or 3600 RPM. At the high value given there, that corresponds to 1.3 million reverse flow pulses -- each hour.

**[0027]** Hence the effects of reverse flow comprise an unceasing hammering on the blower, and over its whole lifetime. Accordingly, it is an object of the invention to not just weaken but eliminate each reverse flow event. It is a further object of the invention to reduce vibration, and not so much the frequency of the vibration but the shock value (amplitude) of each pulse. It is a corresponding object of the invention to enhance reliability.

**[0028]** These and other objects and aspects are provided according to the invention in a rotary positive displacement blower 210 (of the Roots type) with a back-pass loop 250-52 for gradually pressurizing the closed cell 240X to the pressure of the discharge plenum 228 in order to weaken the strength of the pulsations that would otherwise happen, and thereby reduce noise and shock.

**[0029]** FIGURES 1 and 4 show a rotary positive displacement blower 210 provided with a pair of flanking manifolds 212. In FIGURE 2, both manifolds 212 are shown dismounted and apart from the main housing 214. Conversely in FIGURES 1 and 4, both manifolds 212 are shown mounted to the main housing 214.

**[0030]** Just as the main housing 214 is a monolithic casting of (preferably) steel, so is each manifold 212 its own separate monolithic casting of steel. The flange surfaces for the bolt-on surfaces are preferably ground very smooth, as are the mating surfaces on the main housing 214.

**[0031]** FIGURES 1 and 2 allow discernment that the manifolds 212 mount to the main housing 214 by a pattern of bolts (bolts not shown). Each manifold 212 defines a back-pass chamber 250.

**[0032]** The main housing 214 is bored through from both sides in order to form a number of channels 251 and 252 for connecting each back-pass chamber 250 into a back-pass loop 250-52 with the blower 210. That is, the main housing 214 is bored through a series of times into each side of the rotor chamber 224 to form a pattern -- a line parallel with the axis of the rotor 230 - of inner channels 251 to the rotor chamber 224. The main housing 214 is furthermore bored through two times into each side of the discharge plenum 228 to form a pattern of (eg., two in-line) outer channels 252 ('outer' relative to the rotor chamber 224). FIGURE 3 shows better the ports 251P and 252P of the inner and outer channels 251 and 252, respectively, in the rotor chamber 224 and discharge plenum 228, respectively.

**[0033]** It is a design preference at present time that the cumulative cross-sectional flow area for the two outer channels 252 feeding one manifold 212 chamber 250 equals or is substantially close in value to the cumulative cross-sectional flow area of all the inner channels 251 serving the same manifold 212 chamber 250. Hence for each manifold 212 chamber 250, the ratio of the cumulative cross-sectional area of the outer channels 251 to that of the inner channels 251 is about one to one (1:1).

**[0034]** FIGURE 4 shows better that the flow axis of gas through the blower 210 is generally perpendicular to the plane containing the rotor axes. This plane (that contains the rotor axes) is referred to herein for convenience sake as the rotor plane. (It might alternatively be referred to as the dowel plane. As FIGURE 1 shows better, it is typical that a housing 214 for a Roots blower would contain a pair of flanking dowels 255 in this same plane. These dowels 255 provide for alignment to the end plates and support to the housing 214 in this plane, and hence promote proper lobe tip 232T clearance.)

**[0035]** Given the foregoing, the manifolds 212 mount to the main housing 214 on the discharge side of the rotor plane.

**[0036]** FIGURE 4 allows reckoning of the following matters. The lobes 232 of the rotors 230 are angularly spaced apart by 120°. The ledge 242L of the inlet opening 242 and the ledge 244L of the discharge opening 244 are angularly spaced apart by about 180°(relative to rotor rotation).

**[0037]** Hence, in the absence of the improvements of the invention, the temporarily existing closed cell 240X is formed for a time period corresponding to a 60° arc of the rotor rotation. In other words, there is a window of opportunity during that 60° arc in which to gradually pressurize the closed cell 240X from inlet pressure to discharge pressure.

**[0038]** It is an object of the invention to gradually pressurize the closed cell 240X from inlet pressure to discharge pressure over the last 30° to 40° or so of rotation of the closed cell 240X to its opening to the discharge opening 244.

**[0039]** The design in accordance with the invention was obtained by virtual prototyping with the use of three-dimensional CFD software from SIMERICS, INC., that goes by the brand name PUMPLINX®.

**[0040]** The CFD analysis was performed with an existing blower of TUTHILL VACUUM & BLOWER SYSTEMS, model QX-3208, serving as the basis for blower dimensions. The operating point for the analysis was chosen to be 3600 RPM at 15 psi (~ 1 atm pressure differential).

**[0041]** Following that, a physical prototype was built, and tested, at the following operating points:

- 1200 RPM @ 10 psig (~ 2/3rds atm pressure differential).
- 1800 RPM @ 10 & 15 psig (~ 2/3rds and 1 atm pressure differential).
- 3600 RPM @ 10, 15 & 18 psig (~ 2/3rds, 1 and 1-3/15ths atm pressure diff.).

**[0042]** At the CFD operating point of 3600 RPM at 15 psig (~ 1 atm pressure differential), the prototype blower 210 in accordance with the invention compares to the un-modified original QX-3208 as follows. There was 8.9 db drop and a 12.4 dBA drop in sound pressure levels. There was an average drop across all tested speeds and pressures of 7.4 dB and 10.7 dBA. The maximum sound pressure level drop was 3600 RPM and 18 psi (~ 1-3/15ths atm differential pressure) for both linear and A-weighted scales. These results were 13.2 dB and 17.1 dBA respectively.

**[0043]** (Note: Sound pressure levels were recorded by four microphones located on the horizontal plane bisecting the blowers - the rotor plane - located six inches or roughly 15 cm from the corners of the main housings and centered on axis passing through the inlet and discharge ports.)

**[0044]** There is a noticeable difference in not just the quieting of the sound of the blower 210 in accordance with the invention, but also the quality of the sound. Indeed, there are still personnel employed by TUTHILL VACUUM & BLOWER SYSTEMS who can personally recall the Acoustic Air blower referenced above in connection with U.S. Patent 5,702,240. One such person includes one of the original inventors. The remarks about the change in sound quality with the blower 210 in accordance with the invention is something as follows:- the blower 210 in accordance with the invention is not just merely a quieter jack hammer, it has sort of lost its jack hammer staccato to where it just sounds like the hum of process machinery.

**[0045]** The CFD analysis in combination with building and testing a number of prototypes discovered that perhaps the following five (5) factors are chiefly responsible for the blower 210 in accordance with the invention working so well.

**[0046]** These five (5) factors include the following:-

1 - ease of manufacture,
2 - cumulative flow area of inner channels 251,
3 - angle of attack of and like matters with the inner channels 251,
4 - timing, or separation between plane of the outer channels 252 and plane of the discharge opening ledges 244L, and
5 - ratio of manifold chamber 250 volume to closed cell 240X volume.

(1) To begin with, a nod is given to ease of manufacture as an important factor. The improved blower 210 was prototyped out of a stock QX-3208 blower of TUTHILL BLOWER & VACUUM SYSTEMS. The casting of the stock blower had to be beefed up in the regions where the inner and outer channels 251 and 252 were to be drilled, as well as where the manifolds 212 bolt on. However, the manifold 212 is its own casting. In the Acoustic Air blower, the backflow chambers were cast to size in the main housing casting for the blower. In accordance with the invention, the method of manufacture of the blower 210 with its separate cast manifolds 212 allowed much more flexibility in specifying different sizes and arrangements of inner and outer channels 251 and 252 as well a volume of the manifold 212 chambers 250.

(2) The second important factor is the cumulative flow area of the inner channels 251. With a given back-pressure in the manifold 212 chamber 250 and under-pressure in the closed cell 240X, the cumulative flow area is selected to fill the closed cell 240X with about 100 % plus of the make-up mass of air in the angular time that the inner channels 251 are filling the closed cell 240X (eg., about 30° to 40° angular degrees). It is preferred that the outer channels 252 cumulatively form about the same cross-sectional flow area for each manifold 212 chamber 250 as do the inner channels 251 therefor. The inner channels 251 cannot be undersized or else there will be backflow when the leading lobe tip 232T of the closed cell 240X crosses the discharge ledge 244L. Conversely, the inner channels 251 cannot be grossly oversized or else it just moves the moment of backflow from ● when the leading lobe tip 232T of the closed cell 240X crosses the discharge ledge 244L to ● when leading lobe tip 232T of the closed cell 240X crosses the inner channels 251. In sum, the inner channels 251 have to fill gradually, and do so all the way until the leading lobe tip 232T of the closed cell 240X crosses the discharge ledge 244L, and then for a little while longer too.

(3) The third important factor is a series of factors, and comprises the angle of attack angle of, and like matters concerning the, inner channels 251. The angle of attack of the inner channels 251 is preferably is as close to a tangent line with the curve of the rotor chamber 224 and blowing onto the backside of the leading lobe tip 232T of the closed cell 240X as it crosses the inner channels 251. Also, a prototype was built and tested where there were a series of inner channels 251 on three lines. It is believed from that experiment that closed cell 240X wants to open all the inner channels 251 on one line that is parallel to the rotor axes.

(4) The fourth most important factor is a timing factor. Briefly, by way of background, the pressure in the discharge plenum 228 oscillates. The back-pass loop 250-252 goes a long way to dampening the fluctuations. But it does not flatten the fluctuations to zero. Indeed, modest to mild fluctuations are a good thing. The pressure fluctuations are

propagated at the plane of the discharge ledges 244L and move down (or away in) the discharge plenum until eventually the pressure fluctuations have moved so far away from the plane of the discharge ledges 244L that they have canceled each other out into a mean pressure (with no fluctuations). But near the plane of the discharge ledges 244L, there are measurable fluctuations. The timing issue relates to where to locate the outer channels 252 relative to the plane of the discharge ledges 244L. FIGURE 4 illustrates where the outer channels 252 should be located. Given the right side of FIGURE 4, it is preferred that a maximum of pressure fluctuation in discharge plenum 228 (even though propagated at the plane of the ledges 244L) should reside at the plane of the outer channels 252 when the closed cell 240 on the right rotor 230 is about to cross the ledge 244L. That way, the manifold 212 chamber 250 is pulling mass out of the discharge plenum 228 at the moment the closed cell 240 is about to blow out across the discharge ledge 244L, which will be experiencing a local minimum in the pressure fluctuation. By scaling the outer channels 252 in connection with other proportions, the timing can be managed such that the opening closed cells 240/240X never experience backflow when crossing the ledges 244L.

(5) The fifth factor is left for last perhaps because its range was most elusive. That is, it has been inventively discovered that the effectiveness of the blower 210 in accordance with the invention is sensitive to the ratio of closed cell 240X volume to manifold 212 chamber 250. Moreover, it is believed to be highly preferable that there be one dedicated manifold 212 chamber 250 pursuant to each rotor 230. In contrast to the fourth factor above, the measure of performance here has to do with flow fluctuations.

**[0047]** If the mean discharge flow rate is 100 feet per second (~30 m/s), then local flowrate at the plane of the discharge ledges 244L fluctuates. How little it fluctuates is a measure of how effective the back-pass loop 250-252 is working. Recall that, in prior art blowers without a backflow loop or the like, the fluctuations can even go negative.

**[0048]** FIGURE 5 is a chart showing the effect of back-pass manifold 212 chamber 250 volume relative to volume of the closed cell 240X on the fluctuation away from mean discharge flowrate.

**[0049]** FIGURE 5 shows that the best performance is obtained when manifold 212 chamber 250 volume relative to closed cell 240X volume is 100% (eg., the volumes are equal, or, there is one-to-one correspondence. The fluctuation as a percentage of flowrate discharge is 12.8%. That means that, if the mean discharge centerline flowrate is 100 feet per second (~30 m/s), then the fluctuations in the flowrate are between about 93 feet per second (~28 m/s) and 107 feet per second (~32 m/s).

**[0050]** FIGURE 5 shows that when manifold 212 chamber 250 volume as a percentage of closed cell 240X volume is any of the following three values:--

- 83%,
- 56 %, and/or
- 117%,

the fluctuation percentages of the discharge flowrate is still believed to be within acceptable ranges of 14.6%, 14.8% and 17.5% respectively.

**[0051]** However, it is only when manifold 212 chamber 250 volume as a percentage of closed cell 240X volume is about 134% that the fluctuation percentage of the discharge flowrate is believed to have climbed to an un-preferred value of 25.3 %

**[0052]** Given the foregoing, it is a preference of the invention that the manifold 212 chamber 250 volume as a percentage of closed cell 240X volume should fall between about 56 % and 117 % in order to obtain the preferred performance of the blower 210.

**[0053]** One way to characterize how the back-pass loop 250-52 in accordance improves blower performance to the extent it does, might be the following. The back-pass loop 250-52 weakens the pulsations by having an out-of-phase flow with chambers 250 comparable in volume to the closed cell 240X.

**[0054]** The invention having been disclosed in connection with the foregoing variations and examples, additional variations will now be apparent to persons skilled in the art. The invention is not intended to be limited to the variations specifically mentioned, and accordingly reference should be made to the appended claims rather than the foregoing discussion of preferred examples, to assess the scope of the invention in which exclusive rights are claimed.

<u>REFERENCE LIST (NUMERICAL)</u>

**[0055]**

210, blower

212, manifolds

| | |
|---|---|
| 214, | housing (main) |
| 220, | inlet plenum |
| 224, | rotor chamber |
| 228, | discharge plenum |
| 230, | rotors |
| 220P, | inlet port |
| 228P, | discharge port |
| 232, | lobes |
| 232T, | lobe tip |
| 240, | pockets |
| 242L, | ledges (of inlet opening) |
| 242, | inlet opening |
| 244L, | ledges (of discharge opening) |
| 244, | discharge opening |
| 240X, | closed cell |
| 250-52, | back-pass loop |
| 250, | back-pass chamber |
| 251, | inner channels |
| 252, | outer channels |
| 251P, | ports, inner channels |
| 252P, | ports, outer channels |
| 255, | dowels |

<u>REFERENCE LIST (ALPHABETICAL)</u>

**[0056]**

| | |
|---|---|
| back-pass chamber, | 250 |
| back-pass loop, | 250-52 |
| blower, | 210 |
| closed cell, | 240X |
| discharge plenum, | 228 |

| | |
|---|---|
| discharge port, | 228P |
| discharge opening, | 244 |
| dowels, | 255 |
| housing (main), | 214 |
| inlet port, | 220P |
| inlet plenum, | 220 |
| inlet opening, | 242 |
| inner channels, | 251 |
| ledges (of discharge opening), | 244L |
| ledges (of inlet opening), | 242L |
| lobe tip, | 232T |
| lobes, 232 manifolds, | 212 |
| outer channels, | 252 |
| pockets, | 240 |
| ports, inner channels, | 251P |
| ports, outer channels, | 252P |
| rotor chamber, | 224 |
| rotors, | 230 |

**Claims**

**1.** A roots-style positive displacement blower (210) comprising:

a housing (214) defining an inlet plenum (220), a rotor chamber (224) and a discharge plenum (228);
a pair of rotors (230), each comprising at least three axially-straight lobes (232), wherein each lobe (232) culminates in a tip (232T) and the lobes (232) are spaced by pockets (240); and wherein the pocket (240X) that traps gas between a leading and following lobe (232) and an inside wall of the rotor chamber is a temporary closed cell (240X);
a pair of back-pass loops (250-251), one for each rotor (230);
each back-pass loop (250-252) comprises a manifold (212) of the housing (214) formed with a back-pass chamber (250), outer channels (252) formed in one or both of the manifold (212) and housing (214) between the discharge plenum (228) and back-pass chamber (250), and inner channels (251) formed in one or both of the manifold (212) and housing (214) between the back-pass chamber (250) and rotor chamber (224);
wherein the back-pass chamber (250) volume as a percentage of closed cell (240X) volume ranges between about fifty-six percent (56%) and one-hundred-seventeen percent (117%).

**2.** The blower (210) of claim 1 wherein the main housing (214) comprises a casting.

**3.** The blower (210) of any of claims 1 to 2 wherein each manifold (212) comprises a separately removable part from the main housing (214).

**4.** The blower (210) any of claims 1 to 3 wherein each manifold (212) comprises an independent casting which is bolted onto the main housing (214).

**5.** The blower (210) of any of claims 1 to 4 wherein the inner channels (251) are formed by drill holes through the main housing (214) into the rotor chamber (224).

**6.** The blower (210) of any of claims 1 to 5 wherein the inner channels (251) of each back-pass loop (250-252) are formed by a series of drill holes through the main housing (214) and into the rotor chamber (224), all aligned linearly on a line parallel with the rotor axes.

**7.** The blower (210) of any of claims 1 to 6 wherein the inner channels (251) of each back-pass loop (250-252) are formed by a series of drill holes through the main housing (214) and into the rotor chamber (224), all aligned with an angle of attack that is close to a tangent line with the rotor chamber (224)'s inside wall's curvature, and aimed at the backside of a leading lobe tip (232T) of the closed cell (240X) as the leading lobe tip (232T) crosses the inner channels (251).

**8.** The blower (210) of any of claims 1 to 7 wherein from where a leading lobe tip (232T) of the closed cell (240X) crosses the inner channels (251) to where said leading lobe tip (232T) crosses a ledge (244L) of a discharge opening (244) into the discharge plenum (228) comprises between about 30° to 40° angular degrees.

**9.** The blower (210) of any of claims 1 to 8 wherein the inner channels (251) for each back-flow loop (250-252) form a cumulative flow area which, when given a specified back-pressure in the back-pass chamber (250) and a specified under-pressure in the closed cell (240X) pursuant to the pressure of the inlet plenum (220), said cumulative flow area is selected to fill the closed cell (240X) with about 100% of the make-up mass of gas in the angular time that a leading lobe tip (232T) of the closed cell (240X) crosses the inner channels (251) to where said leading lobe tip (232T) crosses a ledge (244L) of a discharge opening (244) into the discharge plenum (228), comprising between about 30° to 40° angular degrees.

**10.** The blower (210) of any of claims 1 to 9 wherein the outer channels (252) define a cumulative flow area and the inner channels (251) define a cumulative flow area substantially close to the cumulative flow area of the outer channels (252).

**11.** The blower (210) of any of claims 1 to 10 wherein the outer channels (252) are formed by drill holes through the main housing (214) into the discharge plenum (228).

**12.** The blower (210) of claim 1 wherein the back-pass chamber (250) volume as a percentage of closed cell (240X) volume ranges between about eighty-three percent (83%) and one-hundred-seventeen percent (117%).

**13.** The blower (210) of either claim 1 or 12 wherein each rotor (230) consists of three axially-straight lobes (232).

**14.** The blower (210) of any of claims 1 or 12 to 13 wherein the back-pass chamber (250) volume as a percentage of closed cell (240X) volume comprises substantially close to one-hundred percent (100%).

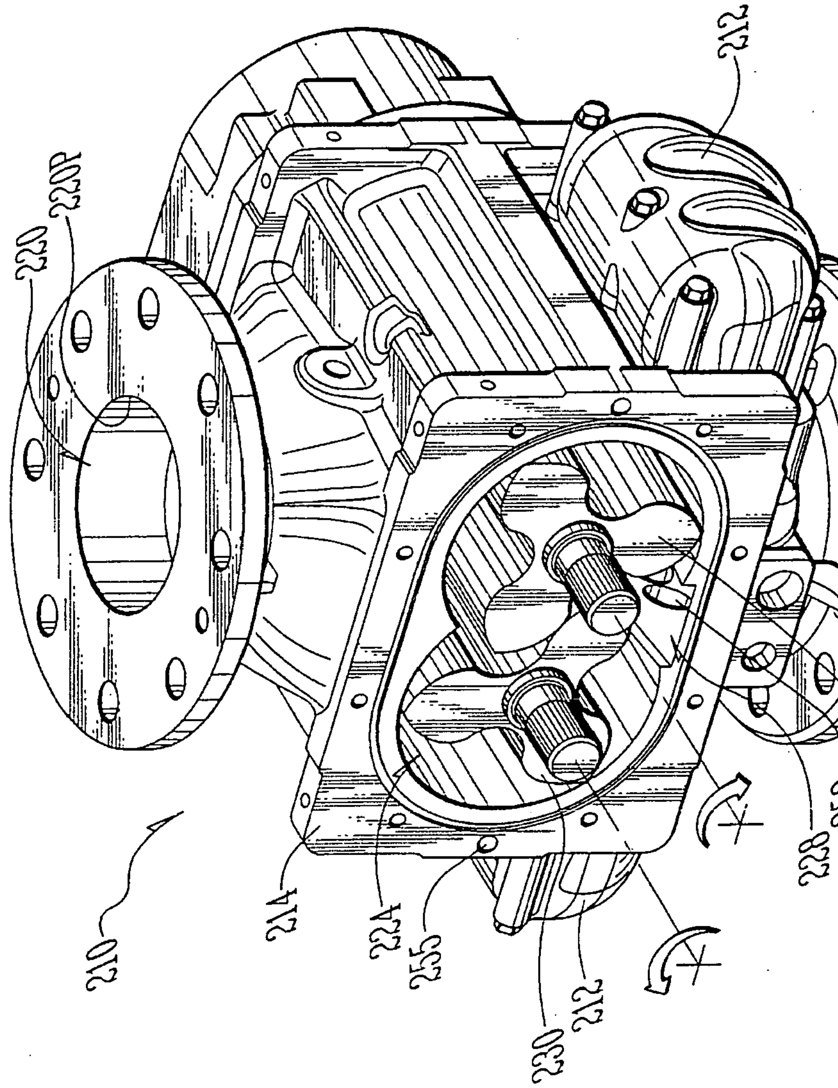


FIG. 1

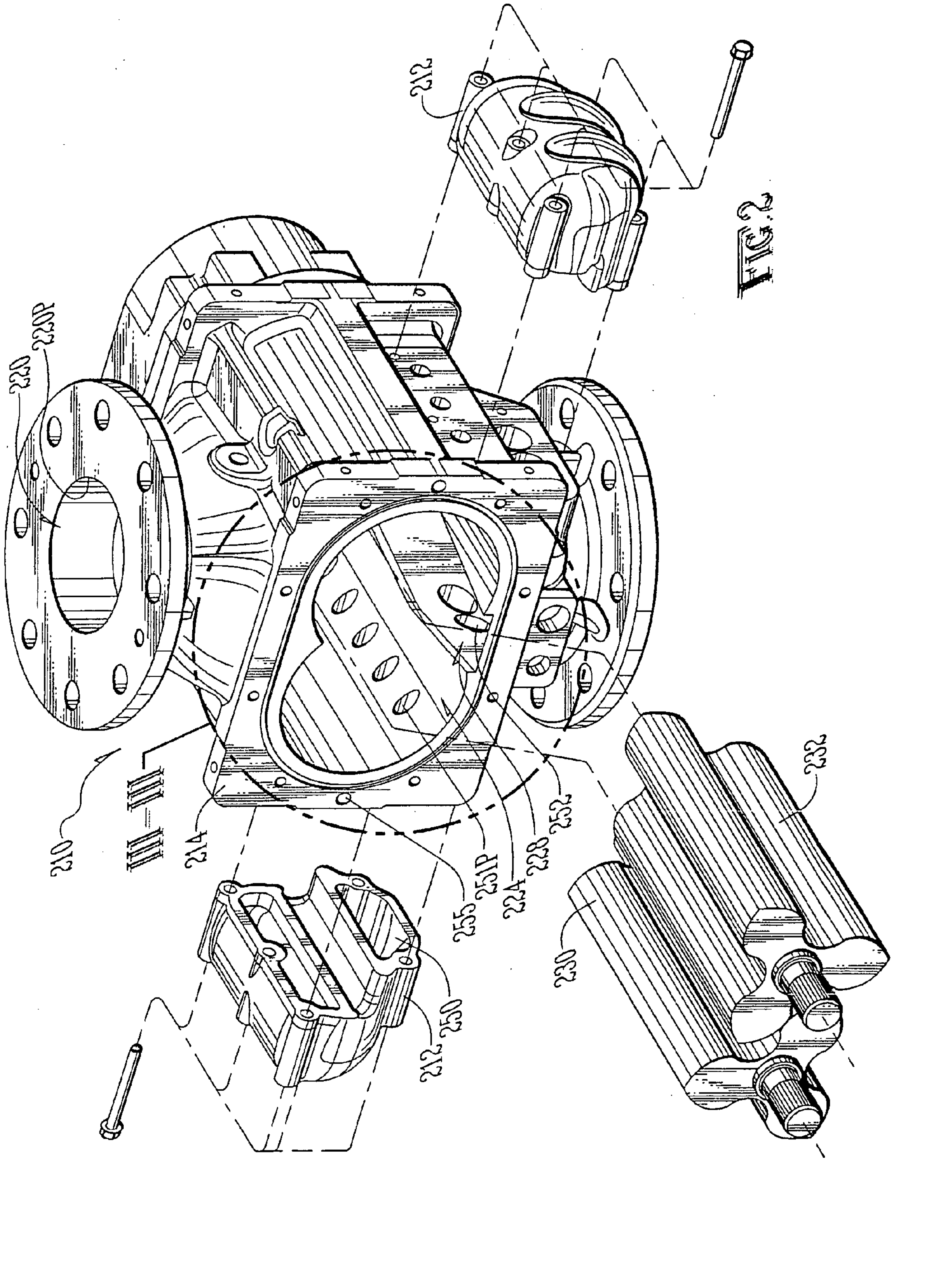


FIG. 2

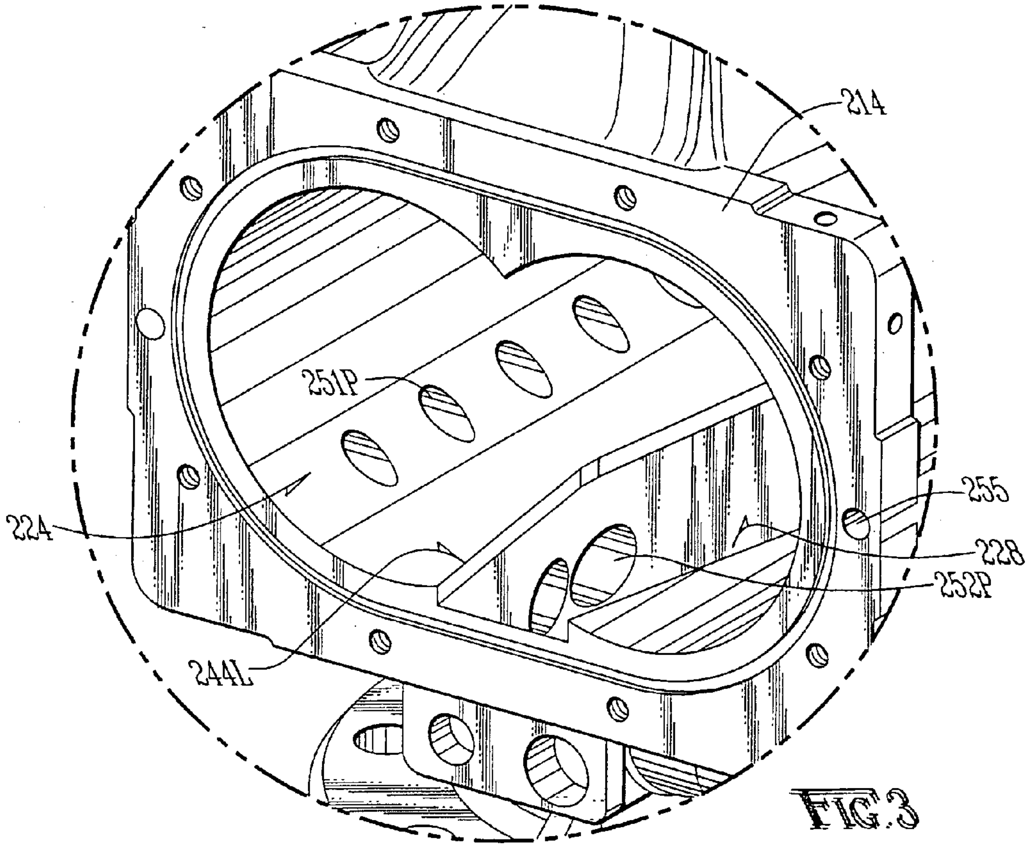


FIG.3

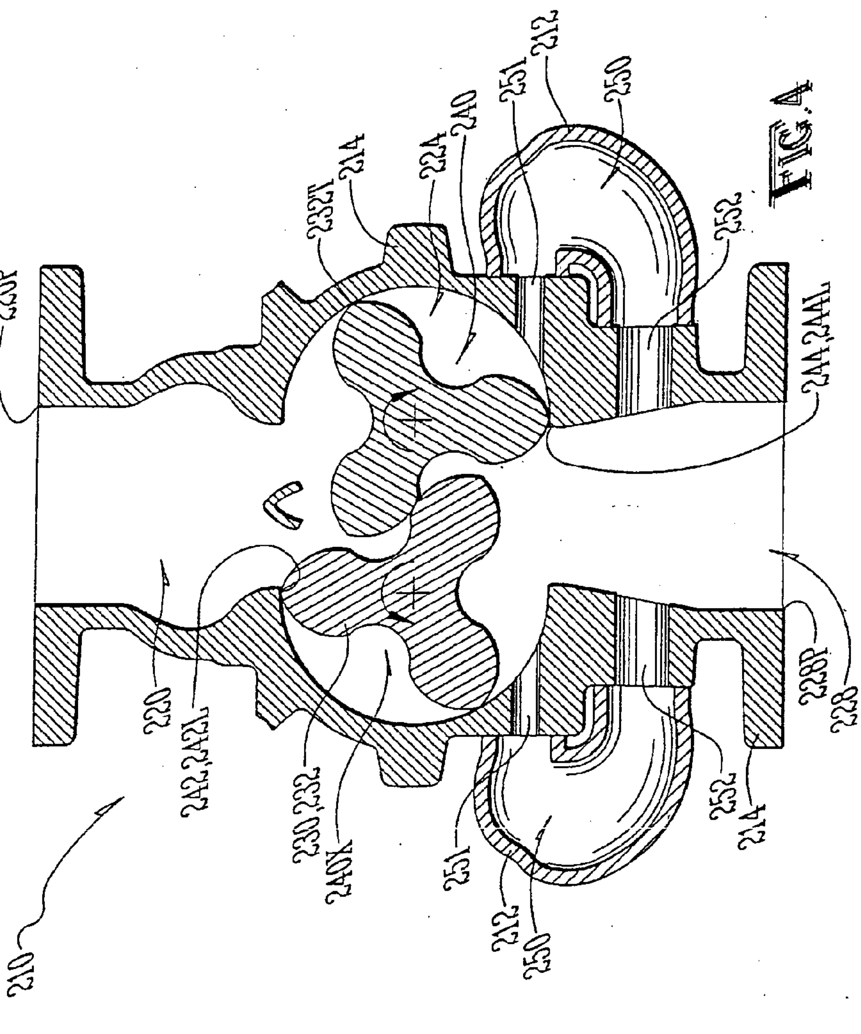
210
220P
232T
214
224
240
251
212
250
252
244,244L
228P
228
220
242,242L
230,232
240X
251
212
250
252
214

FIG. 4

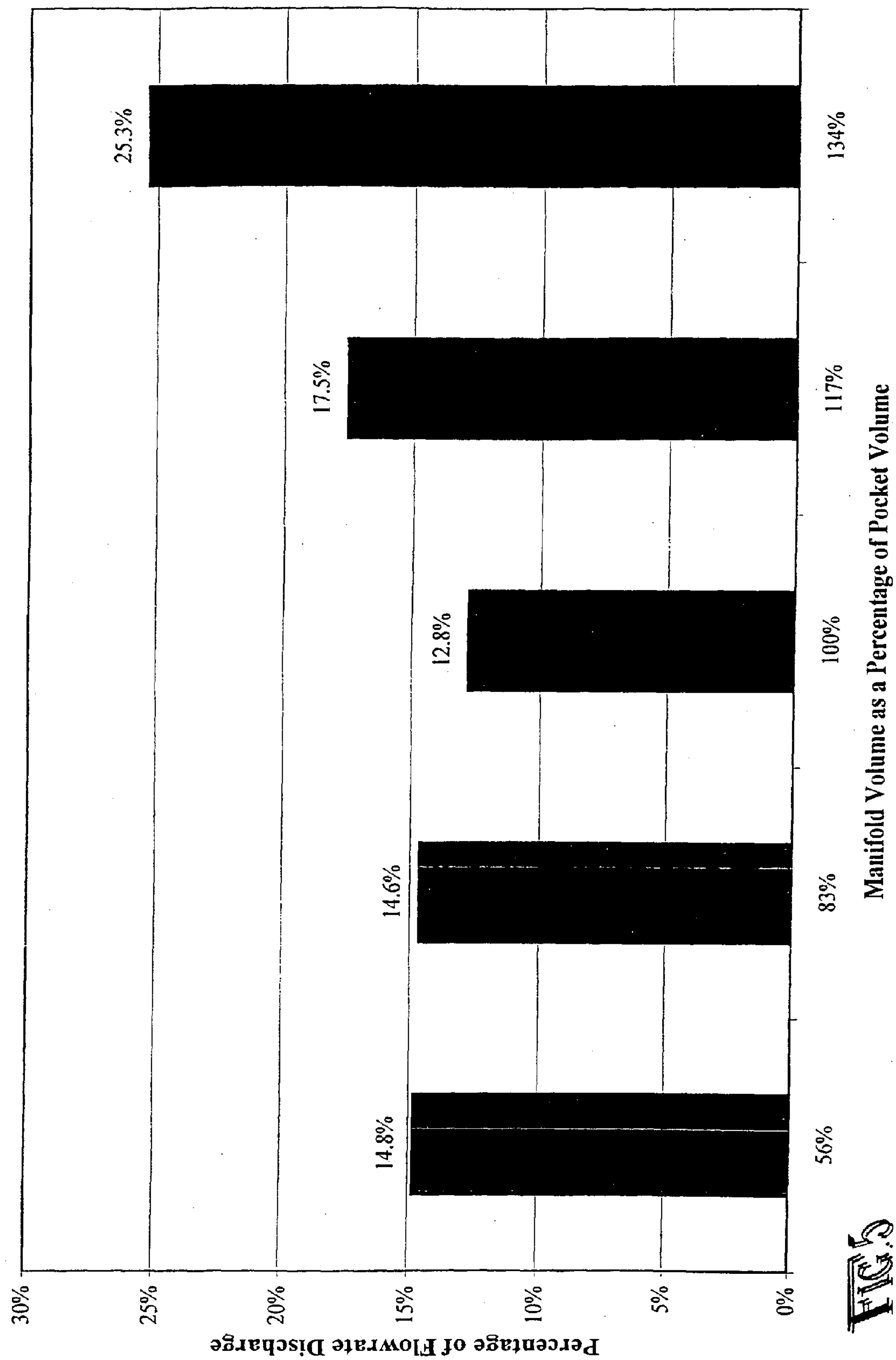
Percentage of Flowrate Discharge
0%
5%
10%
15%
20%
25%
30%
Manifold Volume as a Percentage of Pocket Volume
56%
83%
100%
117%
134%
14.8%
14.6%
12.8%
17.5%
25.3%

FIG. 5

## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description

- US 5702240 A, O'Neal **[0009] [0013] [0044]**