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

(11) EP 1 657 445 A2

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
17.05.2006 Bulletin 2006/20

(21) Application number: **05254751.0**

(22) Date of filing: **29.07.2005**

(51) Int Cl.:
F04C 29/06 (2006.01) ***F01N 1/02*** (2006.01)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK YU

(30) Priority: **21.10.2004 US 970613**

(71) Applicant: **INGERSOLL-RAND COMPANY**
Montvale NJ 07645 (US)

(72) Inventor: **Lucas, Michael J.**
Mooresville
North Carolina 28115 (US)

(74) Representative: **Holmes, Matthew Peter et al**
MARKS & CLERK,
Sussex House,
83-85 Mosley Street
Manchester M2 3LG (GB)

(54) **Compressor discharge pulsation dampener**

(57) A pulsation dampener comprising a first resonator tube having a first tube inlet in communication with a compressor outlet. The first resonator tube has an outlet located within a first resonator chamber. The first resonator tube has a length l_1 that is equal to $\lambda_1 / 4$ wherein λ_1 is the acoustic component wavelength passing through the first resonator tube and the first chamber has a length 1_2 that is within 20% of the length 1_1.

EP 1 657 445 A2

Description

BACKGROUND

[0001] The present invention relates to pulsation dampeners. More particularly, the present invention relates to a compressor discharge pulsation dampener.

[0002] The operation of a screw compressor consists of four processes, namely, "suction", "entrapment", "compression", and "discharge". As the rotors turn, a space is formed at the opening of the compressor for gas to become entrained between the opening formed by the two rotors. The space forms a pocket that entraps the gas between the rotors. As the rotors continue to turn, the volume of entrapped gas progressively reduces, and the entrapped gas is compressed as it moves towards the opposite end of the rotors. At the discharge of the compressor the entrapped gas is discharged out a port where it then enters the compressor piping system. Each discharge creates a pulse of pressurized fluid.

[0003] There are many reasons to reduce compressor discharge pulsations. Pressure pulsations in the flow path can cause mechanical components to vibrate, which may lead to mechanical failure. Check valves and air coolers are two examples of mechanical components that have been known to fail due to pressure pulsations. Noise from the compressor is another reason to reduce compressed air discharge pulsations. Pressure pulsations inside the compressor air gas stream radiates through the piping creating a very undesirable high pitch pure tone noise that is sound deafening.

[0004] Absorptive and reactive types of silencer are used to reduce pressure pulsations Absorptive silencers provide broad-band sound attenuation with relatively little pressure loss by converting the sound energy to heat through friction in porous or fibrous duct lining materials. Reactive silencers come in two types - reflective or resonator silencers. Reflective silencers provide single or multiple points of reflection through area changes in the cross-section of the duct. Reflective silencers rely on the mismatch of the acoustic impedance to cause some of the acoustic energy to be reflected at an area junction. Resonator silencers provide for sound attenuation by providing weakly damped resonator elements that dissipate the acoustic energy at specific frequencies. Helmholtz resonators and branch pipes are the most common types of resonator silencers. Resonator silencers arc used to attenuate a narrow band of frequencies, as such they must be tuned to effectively attenuate the sound energy. Dampening materials are sometimes added to the neck of the resonator to increase the filter bandwidth.

[0005] In practice, air compressor manufacturers try to avoid silencers made from fibrous duct materials. The environment at the discliarge of the compressors is extremely harsh with temperatures in excess of 400 degrees Fahrenheit and pressure pulsations that are often greater than 100 psi peak-to-peak. These environments are known to destroy the silencer, through the gradual deterioration of the fibrous material Once the fibrous material is gone, the silencer is no longer effective at reducing the pressure pulsation.

[0006] Reactive silencers with perforated tubes and expansion chambers are the preferred method for reducing the pressure pulsation. These designs are more robust than absorptive silencers, but require a thorough understanding of how to design the silencer to achieve the optimum performance. A venturi tube is another well-known device for attenuating pressure pulsation. In principle, a venturi tube is very similar to an expansion chamber, the difference being a gradual transition in volume rather than an abrupt change found in an expansion chamber, so as to reduce the pressure drop.

[0007] On most oil-free compressors the silencer is located right at the discharge port where the pulsation is greatest. The gas that is discharged into the silencer is in the form of slugs of fluid. The gas pulse that is discharged from the compressor can be decomposed into two components. An acoustic component that has a wavelength λ_a, that travels at the speed of sound, c, and a hydrodynamic component that has a wavelength, λ_g, that travels at the convective velocity of the gas, u_g. In most compressor applications the Mach number is less than 0.2, which requires the acoustic wavelength to be greater than the hydrodynamic instability wavelength ($\lambda_0 > \lambda_g$). When a gas pulse is discharged from the compressor discharge port most of the energy of the pulse is in the form of a hydrodynamic instability that can be described as a slug of fluid. As the pressure disturbance travels downstream from the compressor discharge port, the hydrodynamic instability wave transitions into an acoustic pressure wave. The role of the silencer is to attenuate the acoustic component of the pulse. Reactive type silencers are tuned to treat the acoustic part of the disturbance; thus the characteristic dimension used in sizing the silencer is λ_a.

[0008] In a specific application of oil-free compressors, a truck mounted air compressor is used to unload dry bulk goods from large container trucks. The technique involves pumping compressed air into one end of a container truck, while from the other end of the truck a valve is opened allowing the dry goods to be pumped out of the truck into a permanent storage container. Examples of dry products pumped out of container trucks using this technique are flour, wheat, cereal, cornstarch, and synthetic powder products. Noise from the compressor is a concern to the truck operators especially in situations where the trucks are used to unload dry goods in urban areas. One example of a noise problem is unloading flour to bakeries located in a residential area.

[0009] A significant amount of noise from the truck mounted air compressor is due to the pressure pulsations. Manufacturers of truck mounted air compressors use discharge silencers to reduce the pressure pulsations. Reducing the pressure pulsation reduces the noise radiated form the connecting piping, valves, and coolers. Different techniques have been tried, some silencers use perforated plates while other silencers use expansion chambers. Current silencer designs do not perform well over all the pressure pulsation frequency ranges and some silencers have high-pressure drops. Other silencers use absorptive material such as fiberglass. Truck operators prefer not to use absorptive type silencers because of the possibility of the absorptive material deteriorating causing contamination of the bulk products that are being pumped by the compressor.

SUMMARY

[0010] The present invention provides a pulsation dampener comprising a first resonator tube having a first tube inlet in communication with a compressor outlet. The first resonator tube has an outlet located within a first resonator chamber- The first resonator tube has a length l_1 that is equal to λ_1 / 4 wherein λ_1 is the acoustic component wavelength passing through the first resonator tube and the first chamber has a length l_2 that is within 20% of the length l_1.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Fig. 1 is schematic view of a pulsation dampener that is a first embodiment of the present invention.

[0012] Fig. 2 is a sectional view of a pulsation assembly incorporating the pulsation dampener of the first embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0013] The present invention will be described with reference to the accompanying drawing figures wherein like numbers represent like elements throughout. Certain terminology, for example, "top", "bottom", "right", "left", "front", "frontward", "forward", "back", "rear" and "rearward", is used in the following description for relative descriptive clarity only and is not intended to be limiting.

[0014] A pulsation dampener 30 that is a first embodiment of the present invention will be described with respect to Fig. 1. The preferred pulsation dampener 30 includes first and second resonator chambers 32 and 34. A first tube 40 extends in to the first resonator chamber 32. The tube 40 has an inlet 41 external to the resonator chamber 32 and an outlet 42 inside of the resonator chamber 32- The first tube outlet 42 is spaced from the center CC of the resonator chamber 32. The first resonator tube 40 has a length l_1 that is equal to λ_1 / 4 wherein λ_1 is the acoustic component wavelength passing through the first tube 40. The first resonator tube 40 will generally attenuate only a very narrow range of frequencies. However, the tube 40 and resonator chamber 32 are configured such that the frequency attenuated by the resonator tube 40 matches one of the quarter wavelength modes of the chamber 32. With such a configuration, the resonator chamber 32 acts as a broadband attenuation device. Such a relationship is established by providing a resonator chamber 32 having a length l_2 that is equal to or within approximately 20% of the length l_1 of the first tube 40. That is, the resonator chamber 32 has a length l_2 that is equal to λ_1 / 4 plus or minus 20% of λ_1/4.

[0015] In the preferred embodiment, the pulsation dampener 30 includes a second resonator tube 44 having an inlet 45 in the first resonator chamber 32 and an outlet 46 in the second resonator chamber 34. The second tube inlet 45 is spaced from the center CC of the first resonator chamber 32 and the outlet 46 is spaced from the center CC of the second resonator chamber 34. The second resonator tube 44 has a length l_3 that is equal to λ_2 / 4 wherein λ_2 is the acoustic component wavelength passing through the second tube 44. As with the previous tube 40, the second resonator tube 44 and resonator chamber 34 are configured such that the frequency attenuated by the resonator tube 44 matches one of the quarter wavelength modes of the second chamber 34. With such a configuration, the second resonator chamber 34 acts as a broadband attenuation device. Such a relationship is established by providing a resonator chamber 34 having a length l_4 that is equal to or within approximately 20% of the length l_3 of the second tube 44. That is, the resonator chamber 34 has a length l_4 that is equal to λ_2 / 4 plus or minus 20% of λ_2 / 4. It has been found that the pulsation dampener of the present embodiment attenuates the dynamic pressure pulsations by 40 dB or more such that fluid passing through the first and second tubes 40 and 44 and the chambers 32 and 34 to the exit 48 of chamber 34 is substantially free of extreme pressure pulsations. While the preferred pulsation dampener 30 is described having two resonator tubes 40, 44 and two resonator chambers 32, 34, more or fewer tubes and chambers may be utilized.

[0016] The pulsation dampener 30 may be utilized in various compressor applications, but will be described in reference to a truck mounted compressor application. Referring to Fig. 2, a truck mounted pulsation assembly 10 incorporating a pair of pulsation devices 30 and 30' according to the present invention is shown. The pulsation assembly 10 includes a body 12 configured for mounting on a truck (not shown). The body 12 includes opposed side walls 18 and 20 extending between opposed end walls 14 and 16. First and second pulsation dampeners 30, 30' are configured within the body 12. The first and second pulsation dampeners 30 and 30' are generally separated by a longitudinal wall 22 extending from end wall 14 to a first transverse wall 24 adjacent the other end wall 16. A shared fluid chamber 36 is defined by the side walls 18, 20, the end wall 16 and the first transverse wall 24. The shared fluid chamber 36 receives fluid from the exit 48, 58 of each pulsation dampener 30, 30' before the combined fluid travels through an exit port 60 through end wall 16. A second transverse wall 26 adjacent end wall 14, in combination with the longitudinal wall 22, defines inlet chambers 27 and 29 that are in communication with the outlet of the compressor (not shown).

[0017] The first pulsation dampener 30 extends between the first inlet chamber 27 and the shared chamber 36 and the second pulsation dampener 30' extends between the second inlet chamber 29 and the shared chamber 36. The first pulsation dampener 30 includes a first resonator chamber 32 defined by side wall 18, longitudinal wall 22, second transverse wall 26 and a third transverse wall 28 and a second resonator chamber 34 defined by side wall 18, longitudinal wall 22, third transverse wall 28 and first transverse wall 24. A first resonator tube 40 extends from the inlet 27 to the first chamber 32 with the first tube outlet 42 spaced from the center CC of chamber 32. A second resonator tube 44 extends between the first and second chambers 32, 34 with the second tube inlet 45 spaced from the center CC of the first resonator chamber 32 and the outlet 46 spaced from the center CC of the second resonator chamber 34. The first resonator tube 40 has a length l_1 that is equal to $\lambda_1 / 4$ wherein λ_1 is the acoustic component wavelength passing through the first tube 40 and the first chamber 32 has a length l_2 that is within 20% of the length l_1 of the tube 40- The second resonator tube 44 has a length l_3 that is equal to $\lambda_2 / 4$ wherein λ_2 is the acoustic component wavelength passing through the second tube 44 and the second chamber 34 has a length l_4 that is within 20% of the length l_3 of the tube 44.

[0018] The second pulsation dampener 30' includes a first resonator chamber 33 defined by side wall 20, longitudinal wall 22, second transverse wall 26 and third transverse wall 28 and a second resonator chamber 35 defined by side wall 20, longitudinal wall 22, third transverse wall 28 and first transverse wall 24. A first resonator tube 50 extends from the inlet 29 to the first chamber 33 with the first tube outlet 52 spaced from the center CC of chamber 33. A second resonator tube 54 extends between the first and second chambers 33, 35 with the second tube inlet 55 spaced from the center CC of the first resonator chamber 33 and the outlet 56 spaced from the center CC of the second resonator chamber 35. The first resonator tube 50 has a length l_5 that is equal to $\lambda_3 / 4$ wherein λ_3 is the acoustic component wavelength passing through the first tube 50 and the first chamber 33 has a length l_6 that is within 20% of the length l_5 of the tube 50. The second resonator tube 54 has a length l_7 that is equal to $\lambda_4 / 4$ wherein λ_4 is the acoustic component wavelength passing through the second tube 54 and the second chamber 35 has a length l_8 that is within 20% of the length l_7 of the tube 54.

[0019] The pulsation dampener 30 of the present invention reduces the pressure pulsations over a broad range of frequencies without the use of absorptive materials or perforated tubes or plates. The pulsation dampener has a very low static pressure drop while attenuating the dynamic pressure pulsations by 40 dB or more.

Claims

1. A pulsation dampener comprising:

a first resonator tube having a first tube inlet in communication with a compressor outlet and a first tube outlet located within a first resonator chamber, wherein the first resonator tube has a length l_1 that is equal to $\lambda_1 / 4$ wherein λ_1 is the acoustic component wavelength passing through the first resonator tube and the first chamber has a length l_2 that is within 20% of the length l_1.

2. The pulsation dampener of claim 1 wherein the first resonator chamber has a center and the first tube outlet is spaced from the first resonator chamber center.

3. The pulsation dampener of claim 1 wherein the first resonator tube and the first resonator chamber are configured such that the frequency attenuated by the first resonator tube matches a quarter wavelength mode of the first resonator chamber.

4. The pulsation dampener of claim 1 further comprising a second resonator chamber adjacent to the first resonator chamber and a second resonator tube having a second tube inlet located in the first resonator chamber and a second tube outlet located within the second resonator chamber, wherein the second resonator tube has a length l_3 that is equal to λ_2 /4 wherein λ_2 is the acoustic component wavelength passing through the second tube and the second chamber has a length l_4 that is within 20% of the length l_3.

5. The pulsation dampener of claim 4 wherein the first and second resonator chambers each have a center and the first tube outlet and the second tube inlet are spaced from the first resonator chamber center and the second tube outlet is spaced from the second resonator chamber center.

6. The pulsation dampener of claim 4 wherein the first resonator tube and the first resonator chamber are configured such that the frequency attenuated by the first resonator tube matches a quarter wavelength mode of the first resonator chamber and the second resonator tube and the second resonator chamber are configured such that the frequency attenuated by the second resonator tube matches a quarter wavelength mode of the second resonator chamber.

7. A truck mounted pulsation assembly comprising:

a body configured for mounting on a truck, the body defining a fluid inlet configured to receive compressed fluid from a compressor, at least a first resonator chamber, and a fluid exit; and a first resonator tube supported by the body, the first resonator tube having a first tube inlet in the communication with the fluid inlet and a first tube outlet positioned in the first resonator chamber; wherein the first resonator tube has a length l_1 that is equal to λ_1 / 4 wherein λ_1 is the acoustic component wavelength passing through the first resonator tube and the first chamber has a length l_2 that is within 20% of the length l_1.

8. The pulsation assembly of claim 7 wherein the first resonator chamber has a center and the first tube outlet is spaced from the first resonator chamber center.

9. The pulsation assembly of claim 7 wherein the first resonator tube and the first resonator chamber are configured such that the frequency attenuated by the first resonator tube matches a quarter wavelength mode of the first resonator chamber.

10. The pulsation assembly of claim 7 further comprising a second resonator chamber defined by the body adjacent to the first resonator chamber and a second resonator tube having a second tube inlet located in the first resonator chamber and a second tube outlet located within the second resonator chamber, wherein the second resonator tube has a length l_3 that is equal to λ_2 / 4 wherein λ_2 is the acoustic component wavelength passing through the second tube and the second chamber has a length l_4 that is within 20% of the length l_3.

11. The pulsation assembly of claim 10 wherein the first and second resonator chambers each have a center and the first tube outlet and the second tube inlet are spaced from the first resonator chamber center and the second tube outlet is spaced from the second resonator chamber center.

12. The pulsation assembly of claim 10 wherein the first resonator tube and the first resonator chamber are configured such that the frequency attenuated by the first resonator tube matches a quarter wavelength mode of the first resonator chamber and the second resonator tube and the second resonator chamber are configured such that the frequency attenuated by the second resonator tube matches a quarter wavelength mode of the second resonator chamber.

13. The pulsation assembly of claim 10 further comprising a third resonator chamber defined by the body and a third resonator tube having a third tube inlet located in communication with the fluid inlet and a third tube outlet located within the third resonator chamber, wherein the third resonator tube has a length l_5 that is equal to λ_3 /4 wherein λ_3 is the acoustic component wavelength passing through the second tube and the second chamber has a length l_6 that is within 20% of the length l_5.

14. The pulsation assembly of claim 13 wherein the third resonator chamber has a center and the third tube outlet is spaced from the third resonator chamber center.

15. The pulsation assembly of claim 13 wherein the third resonator tube and the third resonator chamber are configured such that the frequency attenuated by the third resonator tube matches a quarter wavelength mode of the third resonator chamber.

16. The pulsation assembly of claim 13 further comprising a fourth resonator chamber defined by the body adjacent to the third resonator chamber and a fourth resonator tube having a fourth tube inlet located in the third resonator chamber and a fourth tube outlet located within the fourth resonator chamber, wherein the fourth resonator tube has a length l_7 that is equal to λ_4 / 4 wherein λ_4 is the acoustic component wavelength passing through the fourth tube and the fourth chamber has a length l_8 that is within 20% of the length l_5.

17. The pulsation assembly of claim 16 wherein the third and fourth resonator chambers each have a center and the third tube outlet and the fourth tube inlet are spaced from the third resonator chamber center and the fourth tube outlet is spaced from the fourth resonator chamber center.

18. The pulsation assembly of claim 16 wherein the third resonator tube and the third resonator chamber are configured such that the frequency attenuated by the third resonator tube matches a quarter wavelength mode of the third resonator chamber and the fourth resonator tube and the fourth resonator chamber are configured such that the frequency attenuated by the fourth resonator tube matches a quarter wavelength mode of the fourth resonator chamber.

19. The pulsation assembly of claim 16 wherein the second resonator chamber and the fourth resonator chamber each have an exit in fluid communication with the fluid exit.

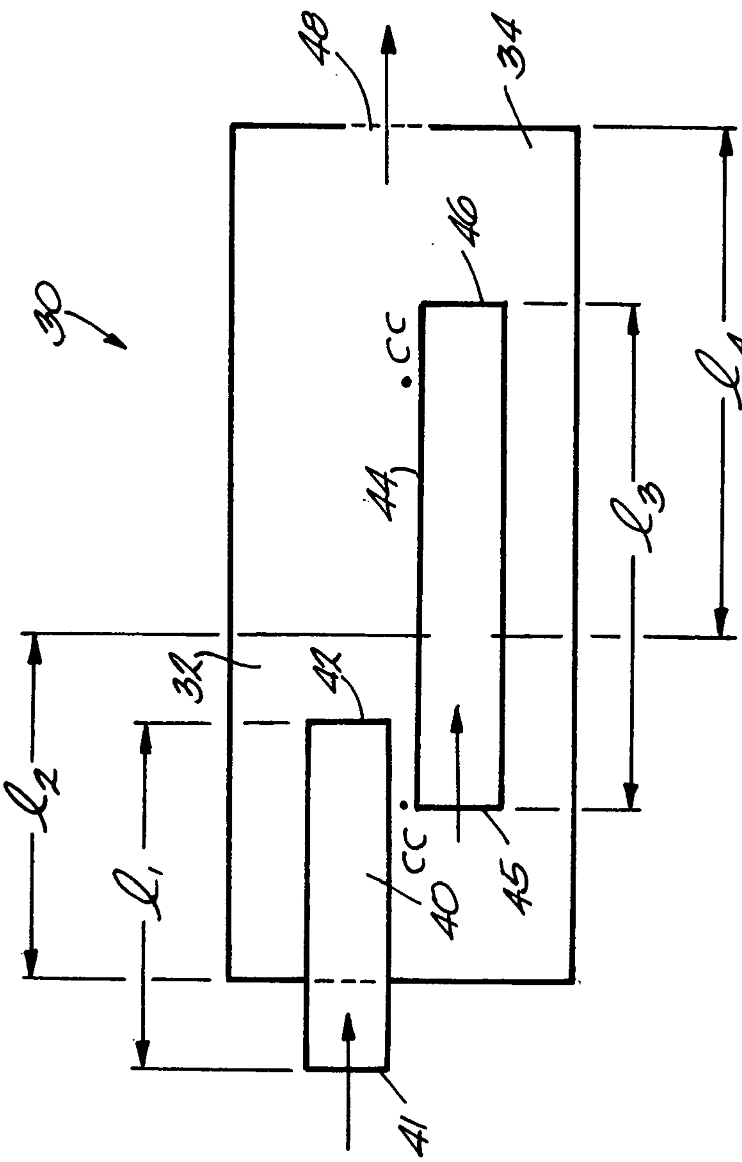

Fig. 1

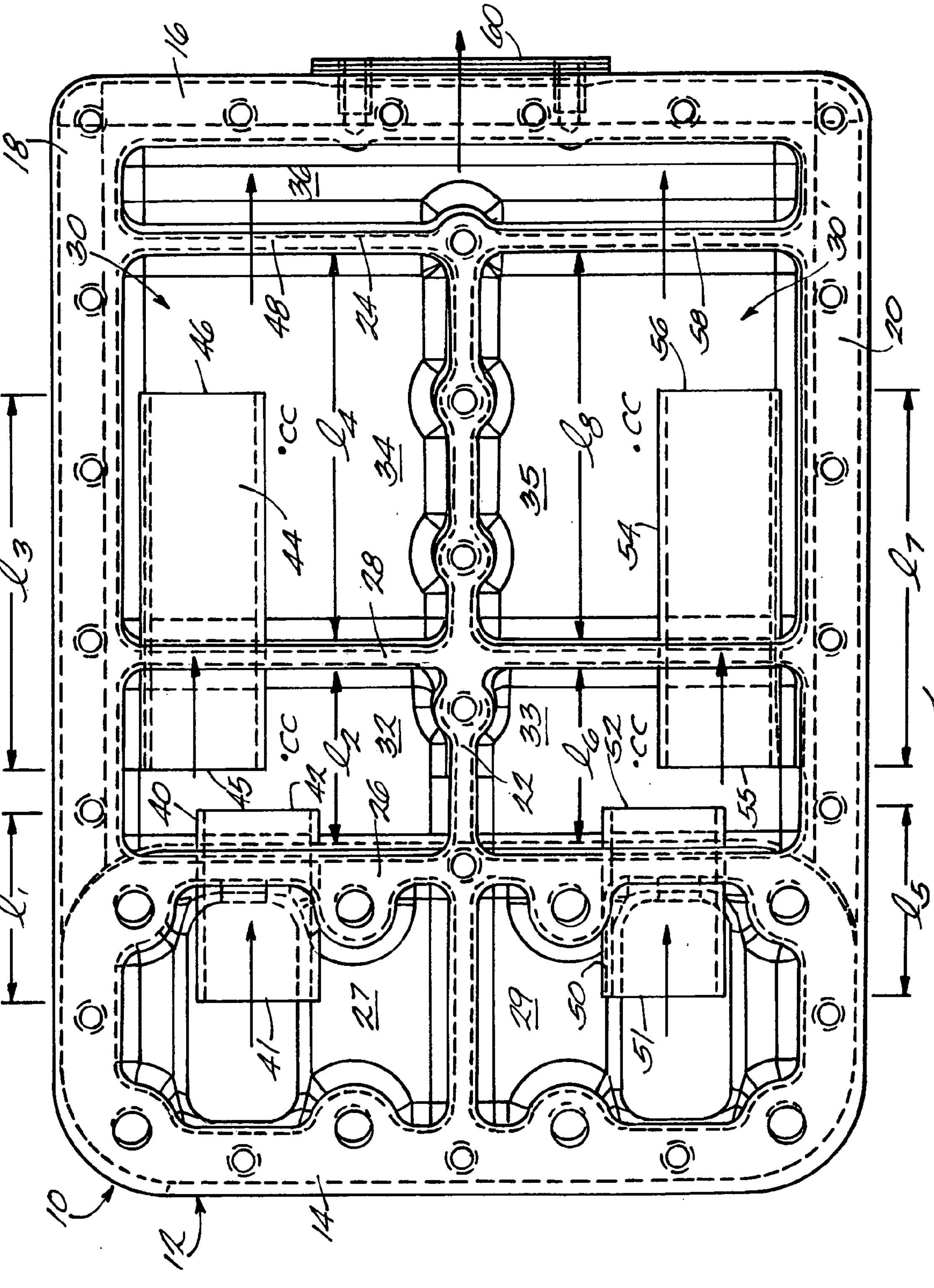

Fig. 2