



US 20050276711A1

(19) **United States**

(12) **Patent Application Publication**
Marshall et al.

(10) **Pub. No.: US 2005/0276711 A1**

(43) **Pub. Date: Dec. 15, 2005**

(54) **MUFFLER SYSTEM FOR A COMPRESSOR**

Related U.S. Application Data

(75) Inventors: **Steven Edwin Marshall**, Abingdon, VA (US); **David Rex Gilliam**, Bristol, VA (US); **David Turner Monk**, Bristol, VA (US); **Benjamin Alan Majerus**, Bristol, VA (US)

(63) Continuation-in-part of application No. 10/441,306, filed on May 19, 2003, now Pat. No. 6,935,848.

Publication Classification

(51) **Int. Cl.7** **F04B 39/00; F04B 53/00**

(52) **U.S. Cl.** **417/540; 417/312**

Correspondence Address:
MCNEES, WALLACE & NURICK LLC
100 PINE STREET
P.O. BOX 1166
HARRISBURG, PA 17108-1166 (US)

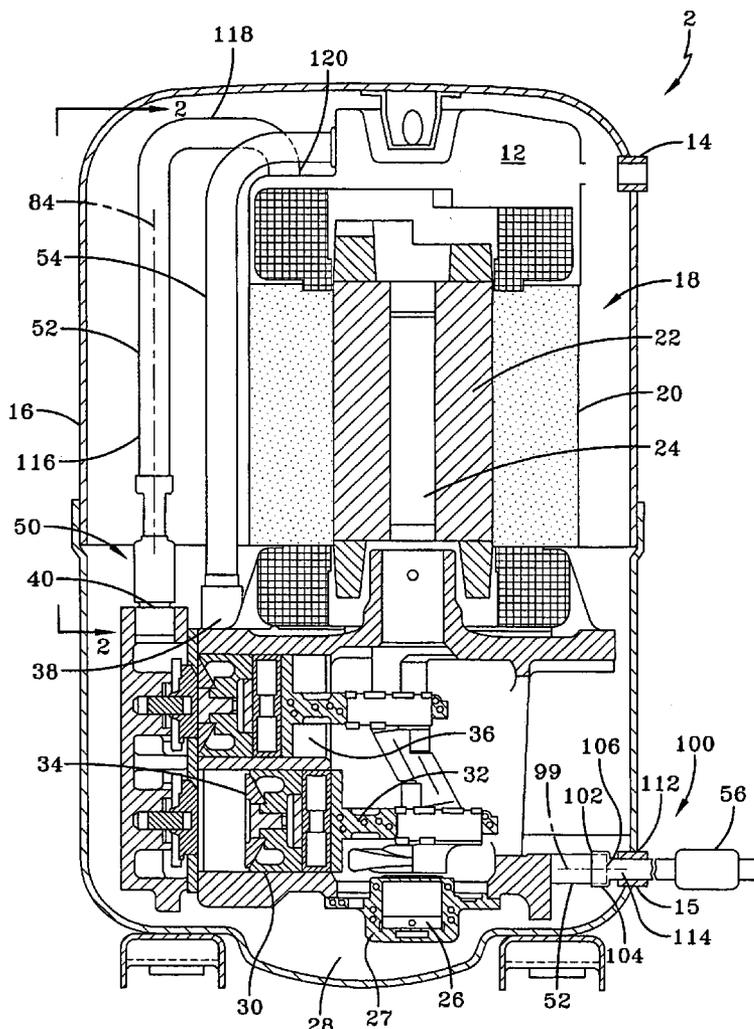
(57) **ABSTRACT**

A muffler system for a compressor includes an expansion chamber muffler for reducing pressure pulses at the compressor's fundamental pulsation frequency and a side-branch muffler for filtering high-frequency pressure pulses. The expansion muffler is positioned along the compressor discharge stream at a location that maximizes pulsation reduction at the compressor's fundamental pulsation frequency. The side-branch muffler is tuned to the frequency at which the pulsation reduction for the expansion muffler is at a minimum.

(73) Assignee: **BRISTOL COMPRESSORS, INC.**,
Bristol, VA

(21) Appl. No.: **11/189,527**

(22) Filed: **Jul. 26, 2005**



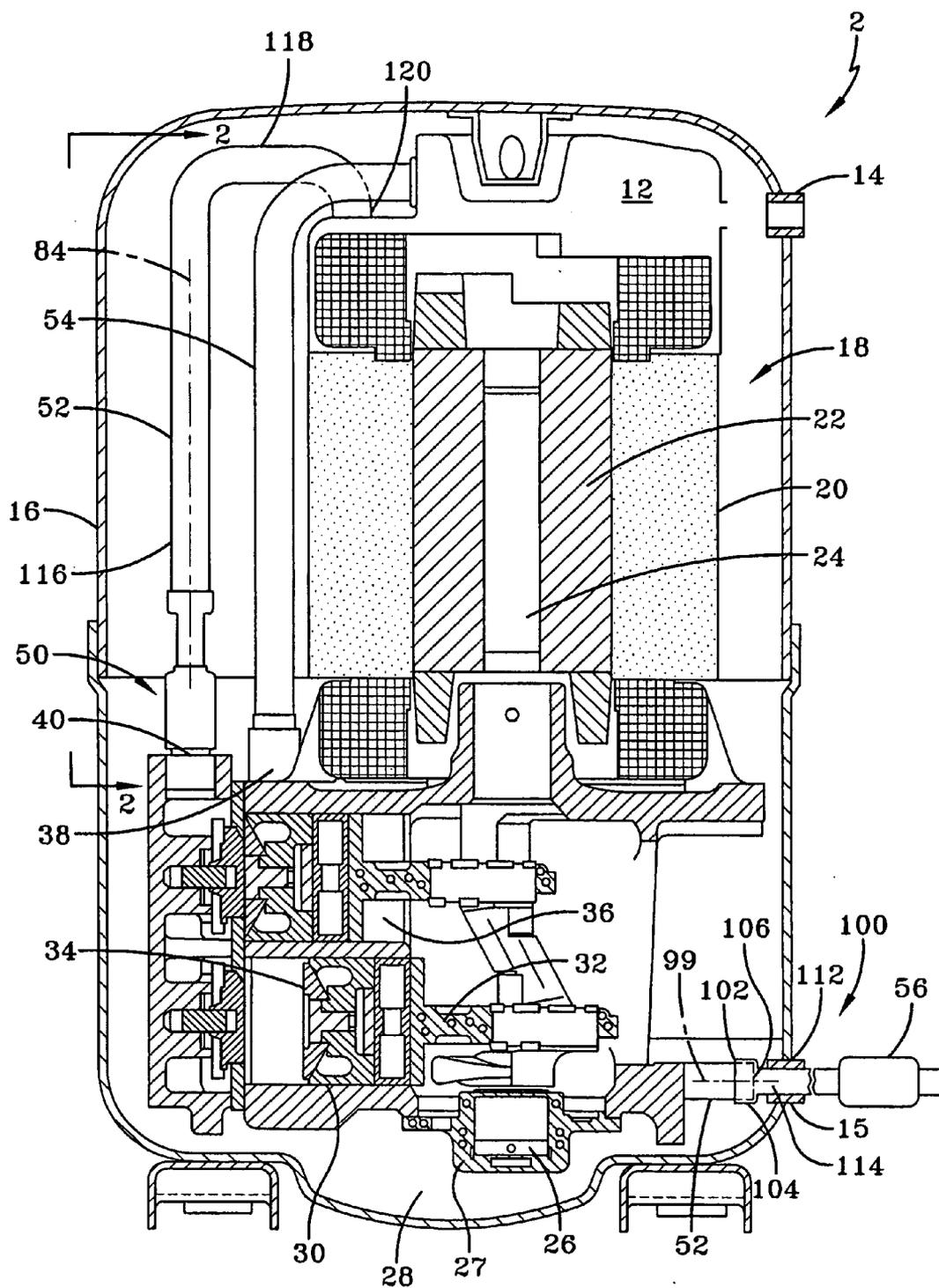


FIG-1

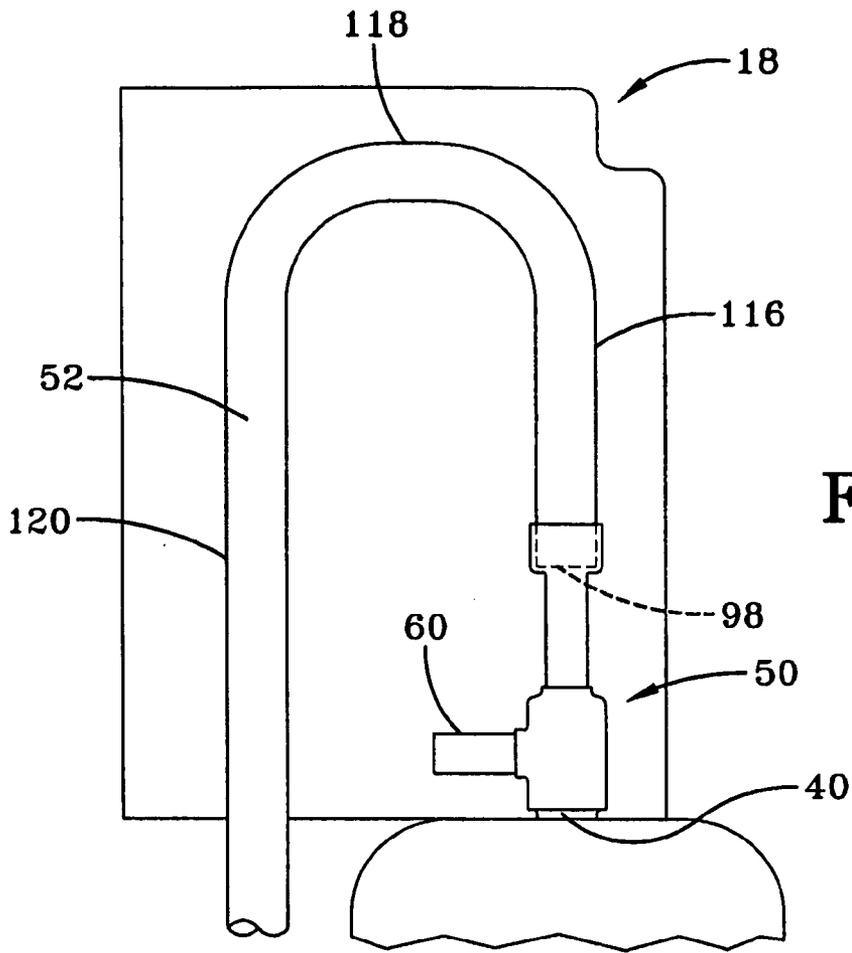
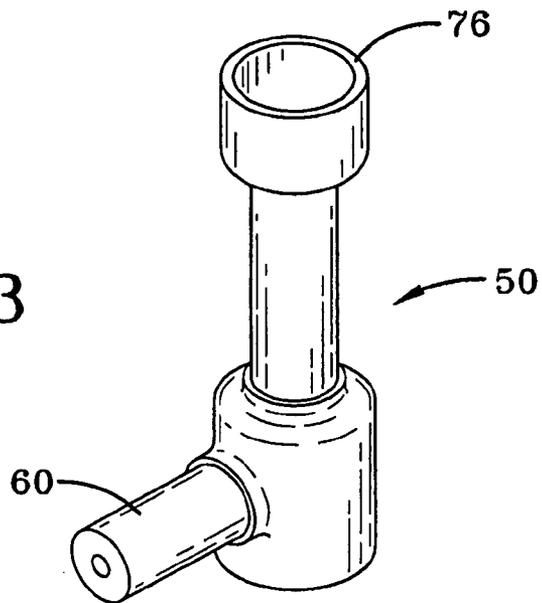


FIG-2

FIG-3



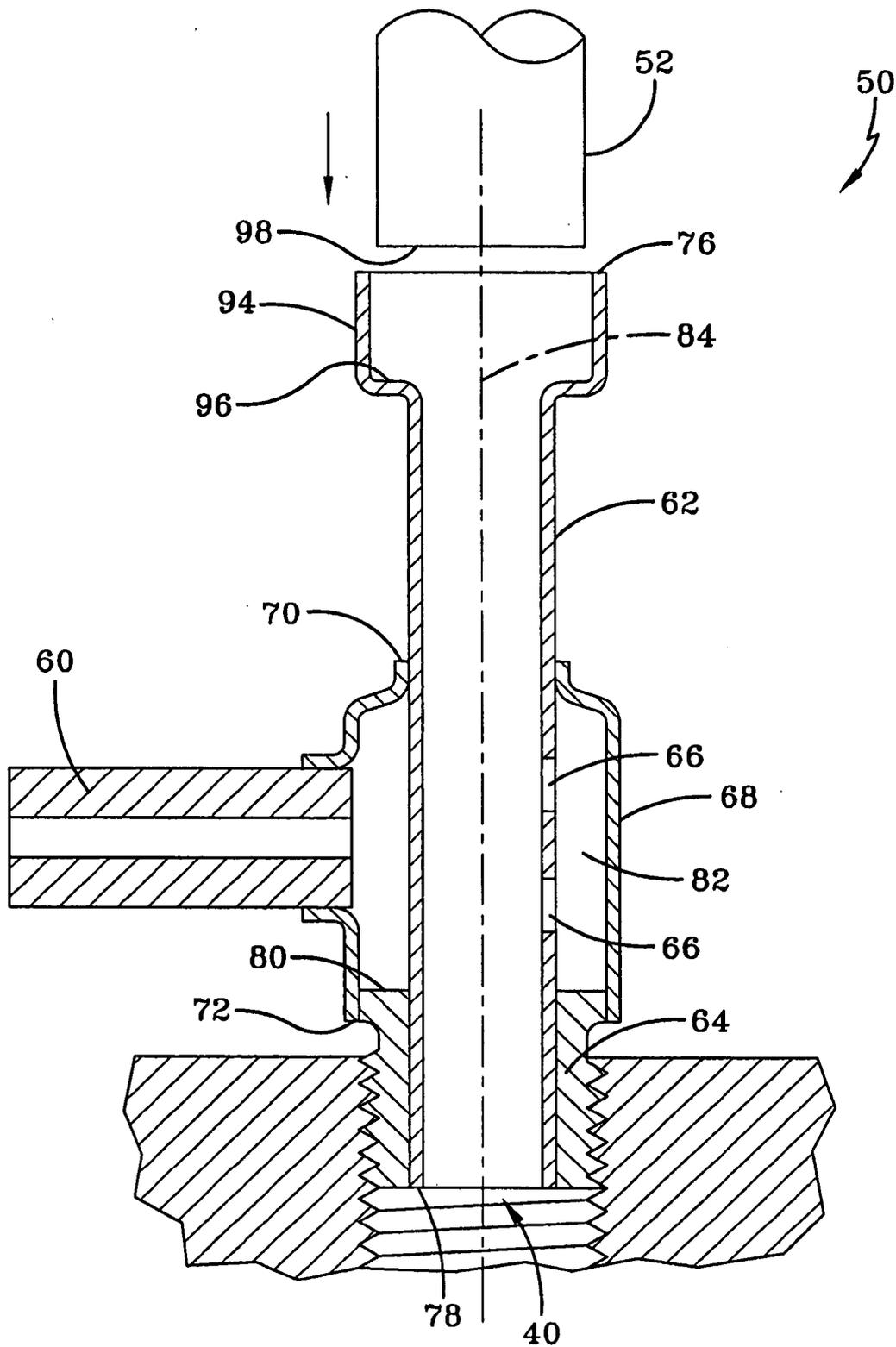


FIG-4

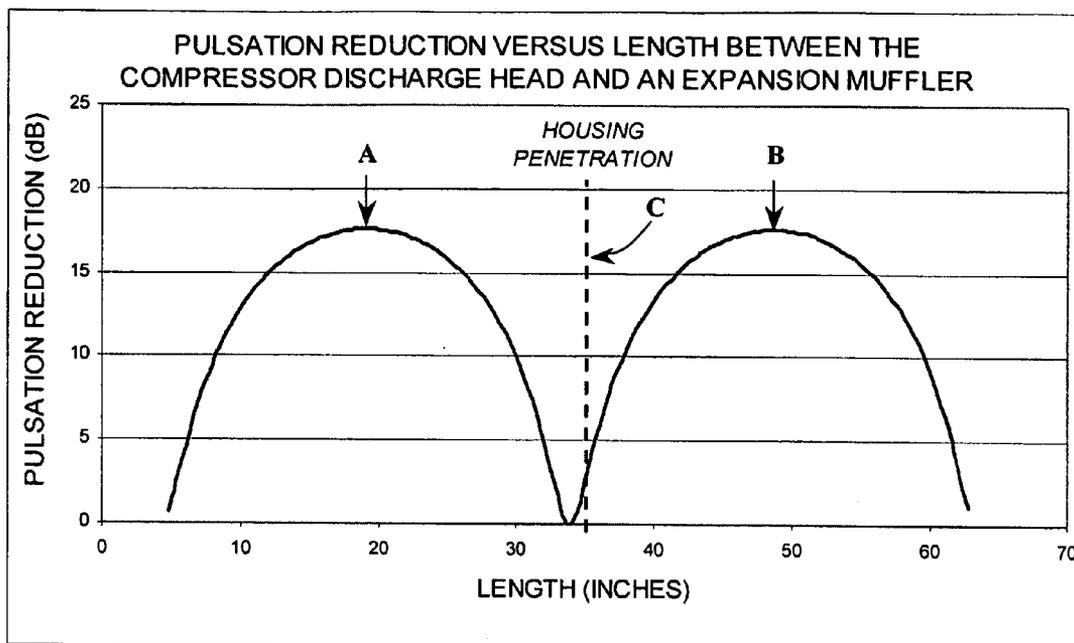


FIG. 5

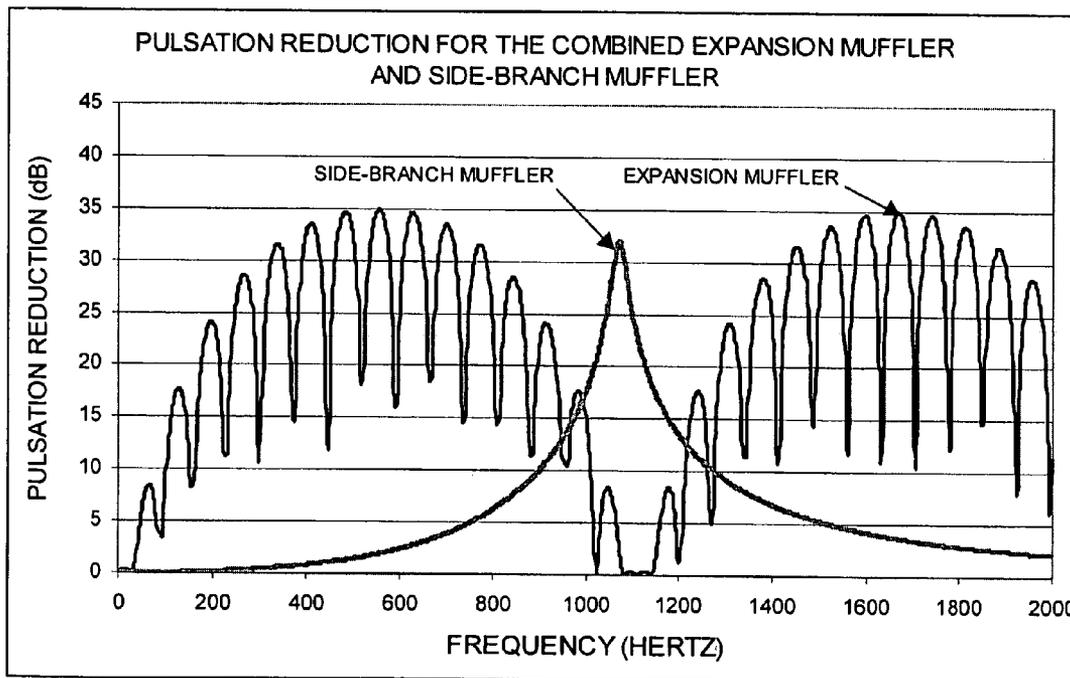


FIG. 6

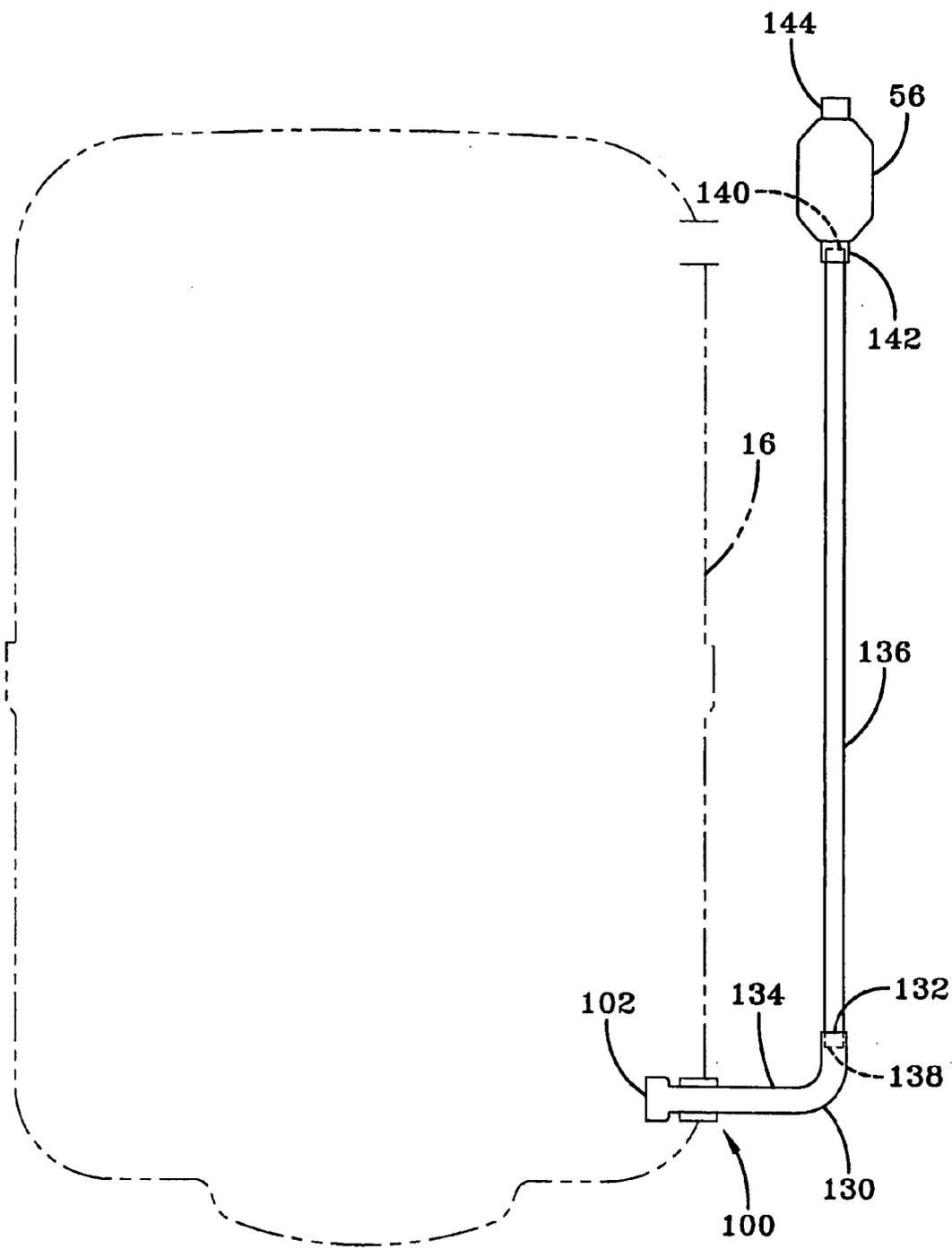


FIG-7

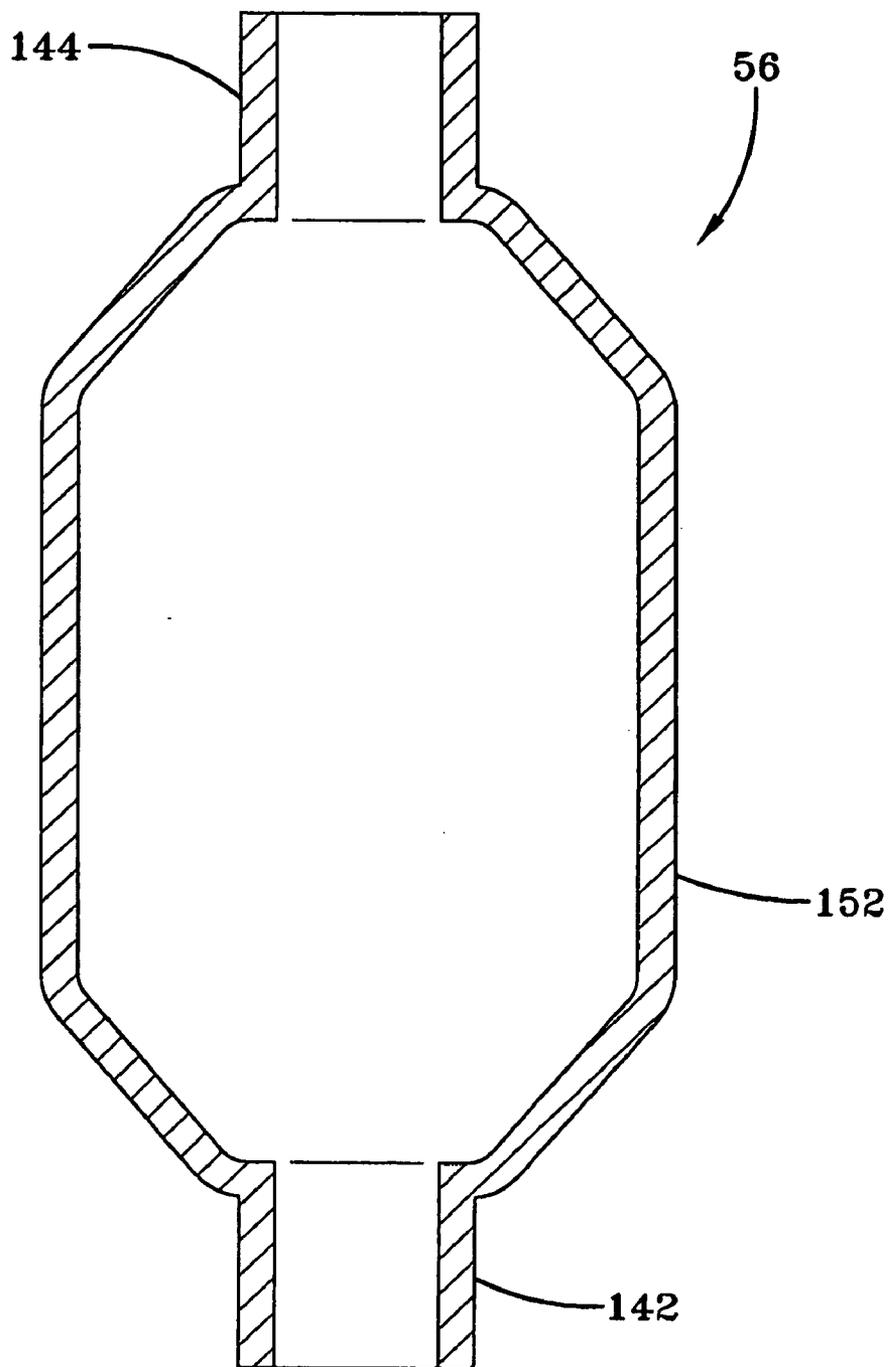


FIG-8

MUFFLER SYSTEM FOR A COMPRESSOR

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This Application is a continuation in part of application Ser. No. 10/441,306, filed May 19, 2003.

FIELD OF THE INVENTION

[0002] The present invention is directed to a muffler system for use with a compressor, and more specifically to a muffler system having an internal muffler and an external muffler for use with the high-pressure discharge side of a compressor used in refrigeration, cooling and heating systems.

BACKGROUND OF THE INVENTION

[0003] Compressors are one of several components in cooling and heating systems. They are an important component as the compressor is used to compress refrigerant gas used in the system, raising the pressure and the temperature of the gas. The compressor is typically used in combination with a condenser, expansion valves, an evaporator and blowers to heat or cool a space. Depending on the direction of the refrigerant flow upon exiting the compressor, the system can be used to remove heat from a preselected space or provide heat to a preselected space.

[0004] The compressor itself typically is a hermetically sealed device that has an intake port and a discharge port. The hermetically sealed device typically is a metallic shell that houses an electric motor and a mechanical means, such as pistons or other mechanical portion, for compressing gas. For most compressor designs, the gas cavity enclosed by the housing serves as a reservoir of low-pressure gas to be drawn into the mechanical section of the compressor. The electric motor is connected to a power source that provides line power for operation. The motor in turn drives the mechanical means for compressing gas. Compressors are typically categorized by the mechanical means used to compress the gas. For example, compressors using a scroll compression device to compress refrigerant gas are referred to as scroll compressors; compressors using a piston device to compress the refrigerant gas are referred to as reciprocating compressors; compressors using rotating cams to compress a refrigerant gas are known as rotary compressors. While there are differences among the compressors as to how refrigerant gas is compressed, the basic principles of operation as set forth above are common among the compressors, i.e., gas is drawn in through the gas intake when the motor is energized, the gas is compressed in the mechanical portion of the compressor and the highly compressed gas is discharged through an outlet port.

[0005] While different compressor designs may result in different noise generation mechanisms and overall different noise profiles, there are common sources of noise for the various types of compressors. One common source of noise originates in the exhaust gas at the discharge where the noise takes the form of a pressure pulsation. Pressure pulsation in the exhaust gas typically generates discrete narrowband tones at the harmonics of the operating speed. The pulsation propagates from the compressor discharge mechanism downstream in the refrigerant gas. The pressure pulsation can transmit noise through the compressor housing at the

point of discharge tube penetration, or can propagate further downstream and induce noise upon contacting other components of the refrigeration system. As can be seen, this sound is particularly undesirable when the system is located within, adjacent to or near a living area or a work area.

[0006] Various mufflers have been attempted to eliminate, reduce or otherwise attenuate pressure pulsation and compressor noise. For piston-driven compressors, mufflers are typically positioned inside the compressor housing on the discharge side of the cylinder head, also referred to as a discharge head. While a muffler having an expansion chamber located adjacent to the discharge head can prevent pressure pulsation from propagating downstream, it has been found that placement of an expansion chamber muffler adjacent the discharge head reduces operating efficiency of the compressor, while also increasing the overall size of the compressor.

[0007] What is needed is a compressor muffler system that sufficiently attenuates pressure pulsation generated by compressor operations without adversely affecting the compressor operating efficiency.

SUMMARY OF THE INVENTION

[0008] The present invention relates to a muffler system for a compressor having a compressor shell and a compressing device with a gas discharge port, the muffler system including a side-branch muffler, the side-branch muffler to be disposed within a compressor shell and in fluid communication with a gas discharge port upon installation of the side-branch muffler. An expansion muffler is disposed exterior to the compressor shell at a predetermined distance from the gas discharge port for maximizing pulsation reduction at a fundamental pulsation frequency of a compressing device upon installation of the expansion muffler. An exhaust system connects the side-branch muffler and the expansion muffler; and the side-branch muffler is tuned to a frequency at which pulsation reduction for the expansion muffler is at a minimum.

[0009] The present invention further relates to a compressor system including a housing having an exhaust port and a compression means for compressing a refrigerant fluid, the compression means being disposed within the housing, the compression means having a discharge port for exhausting compressed refrigerant fluid from the compression means. An expansion muffler is disposed exterior to the housing a predetermined distance from the exhaust port and in fluid communication with the exhaust port, the expansion muffler being configured and disposed to maximize pulsation reduction at a fundamental pulsation frequency of a compressing device. A side-branch muffler is disposed within the housing and in fluid communication with the discharge port, the side-branch muffler being in fluid communication with the exhaust port. The side-branch muffler is tuned to a frequency at which pulsation reduction for the expansion muffler is at a minimum.

[0010] An advantage of the present invention is the inclusion of an expansion chamber muffler exterior of the compressor housing for attenuating pressure pulses from propagating downstream in the refrigeration circuit, reducing the overall size of the compressor housing, while not adversely affecting the compressor operating efficiency. The side-branch muffler, while able to be located inside the compres-

sor housing due to its small volume, serves to reduce pressure pulsation at the frequency not addressed by the expansion muffler, thus reducing sound radiation from the compressor housing and preventing pressure pulsation from propagating downstream in the refrigeration circuit.

[0011] Other features and advantages of the present invention will be apparent from the following more detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a cross-section of a refrigerant compressor that incorporates the muffler system of the present invention;

[0013] FIG. 2 is a partial elevation view of the side-branch muffler discharge tube of the present invention taken along line II-II from FIG. 1;

[0014] FIG. 3 is a perspective view of a muffler of the present invention;

[0015] FIG. 4 is a cross-section of the muffler being joined to the discharge tube of the present invention;

[0016] FIG. 5 is a graph illustrating pressure pulsation reduction at the fundamental pulsation frequency versus expansion chamber location from the discharge head;

[0017] FIG. 6 is a graph illustrating pressure pulsation reduction versus pulsation frequency for the combination of the expansion muffler and a tuned side-branch muffler;

[0018] FIG. 7 is an elevation view of an embodiment of the present invention showing the position of an external muffler; and

[0019] FIG. 8 is a cross section of the external muffler of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0020] One embodiment of a compressor that incorporates the muffler system of the present invention is depicted in FIG. 1. Compressor 2 is connected to a conventional refrigeration or heating, ventilation and air conditioning and refrigeration (HVAC&R) system (not shown), such as may be found in a refrigerator, home or automobile. The HVAC&R system has a condenser, expansion device and evaporator in fluid communication. Compressor 2 is preferably a reciprocating compressor connected to an evaporator (not shown) by a suction line that enters the suction port 14 of compressor 2, although the muffler system may be used with any compressor, including, for example, a rotary, screw, or scroll compressor. Suction port 14 is in fluid communication with suction plenum 12. Refrigerant gas from the evaporator enters the low-pressure side of compressor 2 through suction port 14 and then flows to the suction plenum 12 before being compressed.

[0021] Compressor 2 includes an electrical motor 18. A standard induction motor having a stator 20 and a rotor 22 is shown. However any other suitable electrical motor may be used. A shaft assembly 24 extends through rotor 22. The bottom end 26 of shaft assembly 24 in this compressor 2 extends into a lubrication sump 28 and includes a series of

apertures 27. Connected to shaft assembly 24 below the motor is at least one piston assembly 30. Compressor 2 of FIG. 1 depicts two piston assemblies. A connecting rod 32 is connected to a piston head 34 which moves back and forth within cylinder 36. A cylinder head includes a gas inlet port 38 and a gas discharge port 40. Associated with these ports 38, 40 are respective suction valves and discharge valves (not shown) assembled in a manner well known in the art. Gas inlet port 38 is connected to an intake tube 54 which is in fluid communication with suction plenum 12.

[0022] Motor 18 is activated by a signal in response to a predetermined condition, for example, an electrical signal from a thermostat when a preset temperature is reached. Electricity is supplied to stator 20, and the windings in the stator 20 cause rotor 22 to rotate. Rotation of rotor 22 causes the shaft assembly 24 to turn. In the compressor shown, oil in the sump 28 is drawn through apertures 27 in bottom end 26 of shaft 24 and moved upward through and along shaft 24 to lubricate the moving parts of compressor 2.

[0023] Rotation of rotor 22 also causes reciprocating motion of piston assembly 30. As the assembly moves to an intake position, piston head 34 moves away from gas inlet port 38, the suction valve opens and refrigerant fluid is introduced into an expanding cylinder 36 volume. This gas is pulled from suction plenum 12 within compressor housing 16. This gas is pulled into intake tube 54 to gas inlet port 38 where it passes through the suction valve and is introduced into cylinder 36. When piston assembly 30 reaches a first end (or top) of its stroke, shown by movement of piston head 34 to the right side of cylinder 36 of FIG. 1, the suction valve closes. The piston head 34 then compresses the refrigerant gas by reducing the cylinder 36 volume. When piston assembly 30 moves to a second end (or bottom) of its stroke, shown by movement of piston head 34 to the left side of cylinder 36 of FIG. 1, a discharge valve is opened and the highly compressed refrigerant gas is expelled through gas discharge port 40. The highly compressed refrigerant gas flows from the gas discharge port 40 past a side-branch muffler 50 then through an exhaust or discharge tube 52, exiting the compressor housing 16 into a conduit connected to a condenser. An expansion muffler 56 positioned outside the compressor housing 16 is connected in fluid communication with the conduit between the compressor 2 and the condenser adjacent the compressor housing 16. This comprises one cycle of the piston assembly 30.

[0024] The placement of muffler 56 physically outside compressor housing 16 and at a specific distance along the conduit connecting compressor housing 16 and the condenser is useful in reducing the pressure pulsation at the fundamental pulsation frequency. For example, the fundamental pulsation frequency for a reciprocating compressor is the number of cylinders multiplied by the rotational speed of the motor. That is, a compressor with two cylinders operating at a rotational speed of 60 cycles per second (60 hertz) will produce a fundamental pulsation at a frequency of 120 hertz. For maximum pulsation reduction, muffler 56 must be placed at a specific distance from the gas discharge port 40 as determined by the wave speed and wavelength within the refrigerant gas at the operating conditions of pressure and temperature. Further, locating muffler 56 outside compressor housing 16 not only permits a reduction in size of the compressor housing 16, but enhances the effectiveness of muffler 56 without adversely affecting the efficiency of the

compressor 2 as will be discussed in further detail below. Side-branch muffler 50 additionally filters pressure pulsation at the frequency not affected by the expansion muffler that tend to radiate directly from compressor housing 16 as unwanted noise and propagate downstream in the refrigerant circuit. Side-branch muffler 50 preferably includes an internal pressure relief valve (IPRV), or pressure relief member 60 connected to a resonator volume 82 (FIG. 4) as further discussed in application Ser. No. 10/440,763, which is incorporated herein by reference.

[0025] Referring to FIGS. 2-4, muffler 50 preferably utilizes a side-branch resonator volume 82 tuned to a frequency for pressure pulsation unaffected by the expansion muffler 56 that generates noise at the discharge tube—compressor housing penetration and propagates downstream in the refrigeration circuit. Side-branch muffler 50 includes a tube 62 having opposed ends 76, 78. A threaded member 64 having a lip 80 at one end is positioned over end 78 of tube 62 for threadedly engaging the discharge head to maintain tube 62 in fluid communication with gas discharge port 40. Preferably, the end 78 of tube 62 and the end of threaded member 64 opposite lip 80 are substantially coincident to ensure the parts are sufficiently engaged therebetween. A housing 68 alternative includes opposed openings 70, 72 which permits opening 70 of housing 68 to be positioned over end 78 of tube 62 until opening 72 of housing 68 sufficiently contacts lip 80. Methods of securing tube 62, housing 68 and threaded member 64 in position to each other such as spot welding, soldering, brazing, or by press-fit are well known in the art. Housing 68 is preferably substantially cylindrical in profile and defines a resonator volume 82 between tube 62 and housing 68. Tube 62 and housing 68 are maintained in fluid communication by a pair of preferably axially aligned resonator throats 66 formed in tube 62. However, it is to be understood that more than two throats 66 may be used and that the throats 66 are not required to be in axial alignment. The flow area and distance between the resonator throats 66, as well as the size of the volume resonator 82 are specified such to 'tune' the side-branch resonator muffler to the pulsation frequency unaffected by expansion muffler 56 and most likely to excite noise at the discharge tube 52—compressor housing 16 penetration. Resonator volume 82 displaces significantly less volume than typically used mufflers that employ an expansion chamber. Although not necessarily drawn to scale in FIG. 4, between openings 70, 72, resonator volume 82 displaces a comparable volume as compared to tube 62. By virtue of both this lack of pronounced volumetric increase of resonator volume 82 that is adjacent the discharge port 40 and controlling the specific distance from the discharge head to the expansion chamber, compressor efficiency is maintained. Additionally, the small size of housing 68 of muffler 50 permits reduction in size of the compressor housing.

[0026] While preferred, it is to be understood that it is not required that muffler 50 be secured directly to the discharge head. That is, muffler 50 can be located anywhere within the compressor housing 16 downstream of the discharge head.

[0027] One end of discharge tube 52 is connected to muffler 50. The other end of discharge tube 52 is connected to the discharge outlet 15 of compressor 2. While a preferred embodiment of discharge tube 52 is of unitary construction, as previously discussed, if desired, discharge tube 52 may be segmented, such as to insert a discharge-side component

such as an IPRV 60. A portion of the discharge tube 52 adjacent muffler 50 preferably has a cane or inverted "J" shape, but can have any suitable shape. The shape of discharge tube 52 is primarily driven by the location and attitude of the two interface locations within the compressor housing 16 while maintaining sufficient spacing from compressor components. Thus, the path of the unitary discharge 52 tube typically follows a path adjacent the compressor housing 16, preferably including from an end 98, a substantially straight portion 116 which extends into a substantially curved portion 118 and similarly extends into a remaining portion 120 that terminates at end 106. Referring back to FIGS. 1, 2 and 4, both tube 62 of muffler 50 and a portion of discharge tube 52 share a coincident axis 84. The segment or portion of discharge tube 52 that extends along axis 84 is of an extended length which more evenly distributes prestresses along the collective axial length of tube 52. Additionally, the joint formed between discharge tube 52 and tube 62 of muffler 50 is also coincident with axis 84. In one embodiment, tube 62 of muffler 50 has an enlarged diameter portion 94 that extends into a shoulder 96 formed therein that is coincident with axis 84. To establish the joint between tube 62 of muffler 50 and discharge tube 52, end 98 of exhaust tube 52 is directed inside the enlarged diameter portion 94 of tube 62 past end 76 to the extent required to form the joint, up to "bottoming out" at the shoulder 96.

[0028] Discharge tube 52 connects in a similar way to discharge outlet 15. Discharge outlet 15 includes a fitting 100 that extends through an aperture 112 in the compressor housing 16. The fitting 100 is provided with a secure joint between itself and the compressor housing 16 that is both fluid tight and rigid, both to prevent the leakage of refrigerant through aperture 112 and avoid unnecessary flexure to the subsequent joints formed between both the fitting 100 and the discharge tube 52 inside the compressor housing 16 and between the conduit and the fitting 100 located outside the compressor housing 16. A fitting portion 114 of fitting 100 extends inside the compressor housing 16 which axially aligns along axis 99 with end 106 of tube 52. The portion of fitting portion 114 that is inside compressor housing 16 includes an end 102 having an enlarged diameter portion 104. To establish a joint between the discharge tube 52 and fitting portion 114, the end 106 of discharge tube 52 is directed past end 102 of fitting portion 114 along axis 99 into the enlarged diameter portion 104 until a joint is formed. The joint may be secured by soldering or other appropriate bonding method. Preferably, the joints for each end 98, 106 of discharge tube 52 is established prior to securing the joints. By virtue of the this variable, coincident insertion distance along enlarged diameter portion 94 between discharge tube 52 and tube 62 of muffler 50 and between discharge tube 52 and fitting portion 114, prestresses in the discharge tube 52 caused by non-alignment installation conditions may be further reduced, thereby improving the structural integrity of the compressor.

[0029] Referring to FIGS. 7, 8, fitting 100 extends outside compressor housing 16 into an extension 134 which further extends into a bend 130, preferably a right angle, that terminates at an upturned end 132. Alternately, fitting 100 could terminate immediately outside of compressor housing 16, if desired. A substantially straight conduit 136 has an end 138 that inserts inside of end 132 of fitting 100 for connection therewith. Conduit 136 extends substantially parallel to the compressor housing 16 in a substantially vertical direc-

tion by virtue of the right angle connection with end **132**, terminating at end **140** which, in one embodiment, is adjacent the top of the compressor housing **16**. Alternately, conduit **136** could be curved in shape and could extend in any direction or attitude with respect to fitting **100**. The second muffler member **56** is connected at inlet end **142** with end **140** of conduit **136** and has an opposed exhaust end **144** for connection with a conduit connecting with a condenser (not shown). Fitting **100**, conduit **136** and muffler **56** are in continuous fluid communication therebetween so that refrigerant fluid exhausting from compressor housing **16** sequentially flows through fitting **100** and conduit **136** before reaching muffler **56**.

[0030] Muffler **56** attenuates pressure pulses generated by operation of the compressor. Muffler **56** is provided with the inlet end **142** and the exhaust end **144** on opposed ends of muffler **56**. A preferably enlarged diameter housing **152** is interposed between inlet end **142** and exhaust end **144**. The gas volume enclosed by housing **152** serves to filter pressure pulsations propagating in conduit **136**. The ability for muffler **56** to filter pressure pulsations is extremely sensitive to the total distance between the discharge head and muffler **56**. In fact, maximum pulsation reduction at the compressor's fundamental pulsation frequency occurs when muffler **56** is located along the discharge path at a position as determined by the wave speed and wavelength within the refrigerant gas at the operating conditions of pressure and temperature. For example, a compressor with two cylinders operating at 60 cycles per second (60 hertz) rotational speed will produce a fundamental pulsation at a frequency of 120 hertz. If the speed of sound in the refrigerant gas is 7200 inches per second (the speed of sound for R22), then the wavelength at the fundamental pulsation frequency is 60 inches (7200 inches per second/120 cycles per second). Since each wavelength includes two maximum pressure points, the distance between maximum attenuation points is 30 inches for this case, FIG. 5. FIG. 5 provides a design guide to position the muffler such to achieve maximum reduction at the fundamental pulsation frequency, often the most troublesome frequency in a refrigerant compressor as will be discussed in additional detail below.

[0031] A compressor system using the novel combination of the side-branch muffler **50** mounted internally within the compressor housing **16** and expansion muffler **56** mounted adjacent but external to the compressor housing has been tested. Further referring to FIG. 5, pulsation reduction is illustrated as a function of distance from the discharge head of the compressor for the fundamental pulsation frequency at the operating condition of pressure and temperature. The attenuation provided by the muffler is shown in decibel reduction. The decibel reduction is given by 10 times the logarithm of the ratio of the input dynamic pressure to the output dynamic pressure. It is shown that significant pulsation reduction can be achieved with an expansion chamber muffler positioned approximately 15-20 inches from the discharge head, which is identified as region "A" on the attenuation curve. Region "A" is inside the compressor housing, the penetration which is identified by the vertical dotted line that is approximately 32 inches from the discharge head and additionally identified as "C". However, significant efficiency losses of at least two percent are attributable with the muffler being located within the compressor housing adjacent the discharge head as compared to being located further downstream. Also, the muffler requires

significant volume which is not always available inside the housing. Note, however, that further along the curve, approximately 45-50 inches from the discharge head, identified as region "B", the pulsation reduction is substantially identical to the level shown in region "A". Region "B" is located approximately 15-20 inches from the position of the housing. For purposes herein, the position of the compressor housing discharge port and the housing penetration (region "C") are substantially the same. In other words, by connecting the expansion muffler to the discharge port by a conduit of less than two feet in length, the compressor operates quietly and efficiently while gaining additional room within the compressor housing or permitting the volume of the compressor housing to be reduced and still achieving the same performance.

[0032] In addition to reduced compressor housing size and efficiency gains as previously discussed, by virtue of muffler **56** being used outside the compressor housing, the user has the opportunity to easily replace muffler **56**, if desired. Provided the replacement muffler is located at the same position from the discharge head, the performance of the side-branch muffler is unaffected. Typically, as compressor capacity increases, so does the amplitude of the pressure pulsations associated with its operation. Thus, different mufflers may be desirable for use with compressors having different operating capacities, although identical mufflers may be selected for use with compressors having different operating capacities to reduce inventory. With the present invention, the user need only replace an existing muffler with another configured to attenuate the increased amplitudes, since the existing muffler was already positioned within the range of lengths corresponding to substantially maximum attenuation levels.

[0033] While the expansion muffler **56** has been positioned for maximum pulsation reduction at the fundamental pulsation frequency, pressure pulsation at the harmonics of the fundamental frequency is also a concern. It is a physical property of expansion mufflers that while maximum pulsation reduction is achieved at one frequency for a specific muffler position, other frequencies may be unaffected by the muffler when located at that position. Therefore, in order to prevent higher frequency pulsation from transmitting sound at the housing penetration or from propagating downstream in the refrigeration circuit, a side-branch muffler has been added on the inside of the compressor housing as discussed above. Referring to FIG. 6, the pulsation reductions versus frequency for both the expansion muffler at the specified location and the side-branch muffler are illustrated. As shown, the pulsation reduction for the expansion muffler decreases to zero at about 1100 hertz. Therefore, the side-branch muffler has been tuned to this 'drop-out' frequency of the expansion muffler.

[0034] While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying

out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A muffler system for a compressor having a compressor shell and a compressing device with a gas discharge port, the muffler system comprising:

a side-branch muffler, the side-branch muffler to be disposed within a compressor shell and in fluid communication with a gas discharge port upon installation of the side-branch muffler;

an expansion muffler disposed exterior to the compressor shell at a predetermined distance from the gas discharge port for maximizing pulsation reduction at a fundamental pulsation frequency of a compressing device upon installation of the expansion muffler;

an exhaust system connecting the side-branch muffler and the expansion muffler; and

wherein the side-branch muffler is tuned to a frequency at which pulsation reduction for the expansion muffler is at a minimum.

2. The muffler system of claim 1 wherein the expansion muffler has an elongated chamber.

3. The muffler system of claim 1 wherein a portion of the exhaust system extends substantially vertically along the exterior of the compressor shell.

4. The muffler system of claim 3 wherein the expansion muffler is positioned adjacent to an upper portion of the compressor shell upon installation.

5. The muffler system of claim 1 wherein the side-branch muffler filters pressure pulses capable of transmitting noise to the compressor shell and capable of passing through the expansion muffler without attenuation.

6. The muffler system of claim 1 wherein the predetermined distance includes a range of about 45-50 inches.

7. The muffler system of claim 1 wherein the predetermined distance is about 48 inches.

8. A compressor system comprising:

a housing having an exhaust port;

a compression means for compressing a refrigerant fluid, the compression means being disposed within the housing, the compression means having a discharge port for exhausting compressed refrigerant fluid from the compression means;

an expansion muffler disposed exterior to the housing a predetermined distance from the exhaust port and in fluid communication with the exhaust port, the expansion muffler being configured and disposed to maximize pulsation reduction at a fundamental pulsation frequency of a compressing device;

a side-branch muffler disposed within the housing and in fluid communication with the discharge port, the side-branch muffler being in fluid communication with the exhaust port; and

wherein the side-branch muffler is tuned to a frequency at which pulsation reduction for the expansion muffler is at a minimum.

9. The muffler system of claim 8 wherein the expansion muffler is positioned adjacent to an upper portion of the housing.

10. The muffler system of claim 8 wherein the predetermined distance includes a range of about 45-50 inches.

11. The muffler system of claim 8 wherein the predetermined distance is about 48 inches.

12. The muffler system of claim 8 wherein the expansion muffler has an elongated chamber.

13. The muffler system of claim 8 wherein the side-branch muffler filters pressure pulses capable of transmitting noise to the housing and capable of passing through the expansion muffler without attenuation.

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