(19) DANMARK

(10) **DK/EP 2245392 T3**

Patent- og Varemærkestyrelsen

(12) Oversættelse af europæisk patentskrift

(51) Int.Cl.: ***F 25 B 1/10 (2006.01)*** ***F 25 B 9/00 (2006.01)*** ***F 25 B 49/00 (2006.01)***
F 25 B 41/04 (2006.01)

(45) Oversættelsen bekendtgjort den: **2019-12-09**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2019-09-18**

(86) Europæisk ansøgning nr.: **08727825.5**

(86) Europæisk indleveringsdag: **2008-01-17**

(87) Den europæiske ansøgnings publiceringsdag: **2010-11-03**

(86) International ansøgning nr.: **US2008051303**

(87) Internationalt publikationsnr.: **WO2009091397**

(84) Designerede stater: **AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR**

(73) Patenthaver: **Carrier Corporation, One Carrier Place, Farmington CT 06034, USA**

(72) Opfinder: **ASPROVSKI, Zvonko, 7730 Treeline Drive, Liverpool, NY 13090, USA**
DURAISAMY, Suresh, 4046 Plum Yew Circle, Liverpool, NY 13090, USA

(74) Fuldmægtig i Danmark: **Plougmann Vingtoft A/S, Strandvejen 70, 2900 Hellerup, Danmark**

(54) Benævnelse: **TRYKAFLASTNING I HØJTRYKSKØLESYSTEM**

(56) Fremdragne publikationer:
WO-A1-2005/066556
WO-A1-2006/118573
WO-A1-2007/086871
JP-A- 2006 183 940
US-A- 6 044 655
US-A1- 2006 236 708
US-B1- 6 178 759

DESCRIPTION

Technical Field

[0001] This invention relates generally to transport refrigeration systems and, more particularly, to a method and apparatus for relief of high pressure in a CO_2 vapor refrigeration system exposed to high ambient temperature conditions.

Background of the Invention

[0002] In transport refrigeration systems, such as refrigerated trucks, truck-trailers or refrigerated containers, during periods when the compressor is operating to compress the refrigerant in the system, substantial pressures can build up on the discharge (i.e. high pressure side) of the system. The vapor compression circuit is therefore designed to safely contain these pressures. It is recognized, however, that situations may arise where the pressures will tend to exceed what is considered a safe level. Accordingly, it is necessary to provide design features which will relieve these pressures before they become excessive.

[0003] In accordance with one established protocol, three levels of safely are provided on the high pressure side of the refrigeration system. The three levels are applied sequentially and in a prioritized fashion as follows. The first level is implemented in software and is based on pressure transducer readings. That is, when a predetermined pressure level is sensed, action is taken to limit the refrigerant flow, shut off the compressor or the system, or temporarily shut off the system and restart it after the pressure drops within a tolerance range.

[0004] A second level is implemented by way of a mechanical pressure switch which responds to sensed pressures to shut the system off or temporarily shutting the system off and restart it after a period of time.

[0005] A third level is implemented by way of a mechanical relief device which responsively opens to at least partially allow the refrigerant to be released to the atmosphere in the event that prescribed pressure levels are exceeded.

[0006] Recently concerns have arisen about the environmental effects of the release of commonly used refrigerants to the atmosphere by way of leakage and the like. One approach to addressing this problem is the use of a more benign refrigerant, CO_2, in place of the traditional refrigerants such as Freon. With such a refrigerant, however, it is necessary to operate at substantially higher pressures, and therefore compressors have been designed specifically for the compression CO_2. With these higher pressures in the circuit, it is even more important to continuously sense these pressures and when they become excessive, provide relief in a safe manner. For that purpose, the three level protocol as described above has been found to be satisfactory to control the operating pressures on the high pressure side during operation of the system.

[0007] With the use of CO_2 as the refrigerant, the applicants have recognized that, in addition to the occurrence of excessive pressures during periods of operation, system pressures may also become excessive during periods of shipping and storing. That is, when a charged system at rest is exposed to excessive ambient temperature conditions, such as may occur in a warehouse in the summertime or when a system is exposed to direct sunlight at midday, the pressures are likely to rise to undesirable levels. Under these conditions, the three level safety protocol will be useful in relieving pressure on the high pressure side, but, unlike systems with conventional refrigerants in these situations, a CO_2 system will be susceptible to excessive pressure conditions on the low pressure side as well.

[0008] What is needed is therefore a method and apparatus for relieving pressures on the low pressure side of a CO_2 system which is exposed to high ambient temperature conditions during shut down.

[0009] JP 2006/183940 A and US 2006/236708 A1 have been deemed to disclose the features of the preamble of claim 1, and WO 2006/118573 A1 is further prior art.

Disclosure of the Invention

[0010] According to a first aspect of the present invention, there is provided a method as claimed in claim 1. According to a second aspect of the present invention, there is provided a CO_2 vapor compression system as claimed in claim 2.

[0011] At least one pressure relief device is provided on the low pressure side of a CO_2 vapor compression system such that, during periods in which the system is shut down but exposed to relatively high temperatures, the pressure on the low pressure side will be relieved before they reach unacceptably high levels.

[0012] In the drawings as hereinafter described, one embodiment is depicted; however, various other modifications and alternate constructions can be made thereto without departing from the scope of the invention.

Brief Description of the Drawings

[0013]

FIG. 1 is a schematic illustration of a CO_2 vapor compression system with the present invention incorporated therein.

FIG. 2 is a graphic illustration of the pressures inside a CO_2 system as a function of ambient temperature and charge levels.

Detailed Description of the Invention

[0014] Referring now to FIG. 1, the CO_2 refrigerant vapor compression system 10 includes a compression device 11 driven by a motor 12 operatively associated therewith, a refrigerant heat rejecting heat exchanger 13, a refrigerant heat absorbing heat exchanger 14, also referred to herein as an evaporator, all connected in a closed loop refrigerant circuit in series refrigerant flow arrangement by various refrigerant lines 16, 17 and 18. Additionally, the refrigerant vapor compression system 10 includes a filter drier 19 and a flash tank receiver 21 disposed in refrigerant line 4 of the refrigerant circuit downstream with respect to refrigerant flow of the refrigerant heat rejecting heat exchanger 13 and upstream with respect to refrigerant flow of the evaporator 14, and an evaporator expansion device 22, operatively associated with the evaporator 14, disposed in refrigerant line 4 downstream with respect to refrigerant flow of the flash tank receiver 21 and upstream with respect to refrigerant flow of the evaporator 14.

[0015] The compression device 11 functions to compress and circulate refrigerant through the refrigerant circuit as will be discussed in further detail hereinafter. The compression device 11 may be a single multi-stage compressor having at least a first low pressure compression stage 11A and a second high pressure compression stage 11B, such as for example a scroll compressor or a reciprocating compressor, as illustrated in FIG. 1, wherein partially compressed refrigerant from the first compression stage 11A passes to the second compression stage 11B internally within the compression mechanism of the multiple stage compressor 11. It is to be understood, however, that in another embodiment, the compression device 11 may comprise a pair of compressors 11A and 11B, such as for example a pair of reciprocating compressors or scroll compressors, having a refrigerant line connecting the discharge outlet port of the first compressor 11A in refrigerant flow communication with the suction inlet port of the second compressor 11B. In the case of a single multiple stage compressor, both compression stages would be driven by a single motor 12 operatively associated in driving relationship with the compression mechanism of the compressor 11. In the case of a pair of compressors constituting the compression device 11, each compressor will be driven independently of the other by its own dedicated motor operatively associated in driving relationship with its compression mechanism.

[0016] The refrigerant vapor compression system 10 further includes a compressor unloading circuit 23 comprising a refrigerant line 24 that interconnects an intermediate pressure point in the compression process with refrigerant line 18 of the refrigerant circuit of a point downstream with respect to refrigerant flow of the evaporator 14 and upstream with respect to refrigerant flow of the suction inlet 26 of the compression device 11, and an unloading valve 27 disposed in the refrigerant line 24 that is operative to control the flow of refrigerant through the refrigerant line 24 of the compressor unloading circuit 23. In the exemplary embodiment of the refrigerant vapor compression system depicted in FIG. 1, wherein the compression device 11 is a single compressor having at least a low pressure compression stage 11A and a high pressure compression stage 11B, refrigerant line 24 of the compressor unloading circuit 23 taps into the compression device 11 at a location 28 opening into an intermediate pressure point of the compression process, that is at a refrigerant pressure higher than the refrigerant pressure at the suction inlet to the compression device 11 and lower than the refrigerant pressure at the discharge outlet 29 of the compression device 11, and taps into the refrigerant line 18 at suction pressure.

[0017] The CO_2 refrigerant vapor compression system 10 is designed to operate in a subcritical cycle. Thus, the refrigerant heat rejecting heat exchanger 13 is designed to operate as a refrigerant condensing heat exchanger through which hot, high pressure refrigerant vapor discharge from the compression device 11 passes in heat exchange relationship with a cooling medium to condense the refrigerant passing therethrough from a refrigerant vapor to refrigerant liquid. The refrigerant heat rejecting heat exchanger 13, which may also be referred to herein as a gas cooler or a condenser, may comprise a finned tube heat exchanger, such as, for example, a fin and round tube heat exchange coil or a fin and flat mini-channel tube heat exchanger. In transport refrigeration system applications, the typical cooling medium is ambient air passed through the condenser 13 in heat exchange relationship with the refrigerant by means of fan(s) 31 operatively associated with the condenser 13.

[0018] The evaporator 14 constitutes a refrigerant evaporating heat exchanger which, in one form, may be a conventional finned tube heat exchanger, such as, for example, a fin and round tube heat exchange coil or a fin and mini-channel flat tube heat exchanger, through which expanded refrigerant, having traversed the expansion device 22, passes in heat exchange relationship with a heating fluid, whereby the refrigerant is vaporized and typically superheated. The heating fluid passed in heat exchange relationship with the refrigerant in the evaporator 14 may be air passed through the evaporator 14 by means of fan(s) 32 operatively associated with the evaporator 14, to be cooled and also commonly dehumidified, and thence supplied to a climate controlled environment which may include a perishable cargo, such as, for example, refrigerated or frozen food items, placed in a storage zone associated with a transport refrigeration system.

[0019] During normal operation, the compression device 11 is driven by the motor 12 to compress the CO_2 gas to an intermediate pressure by the first stage 11A and to a high pressure by the second stage 11B. This high pressure, which is in the normal range of 300psi to 2250psi (2MPa to 15.5MPa), is maintained throughout the entire high pressure side which includes the condenser 13, the filter drier 19, and the flash tank 21 and terminates at the expansion valve 22 where the pressure is substantially reduced. That section between the expansion device 22 and the suction inlet 26 is known as the low pressure side and includes an evaporator 14 and the downstream side of the unloading valve 27.

[0020] The expansion device 22, which is normally an electronic expansion valve, operates to control the flow of refrigerant through the refrigerant line 33 to the evaporator 14 in response to the refrigerant suction temperature and pressure sensed by the sensors (not shown) on the suction side of the compression device 11. A bypass valve 34 is provided to supplement the refrigerant flow through the expansion device 22 when higher mass flow is required by the refrigeration system.

[0021] The unloading valve 27 is selectively operated by a control (not shown) to control the flow of refrigerant through the refrigerant line 12. The unloading valve 27 is a fixed flow area valve such as, for example, a fixed orifice solenoid valve which is selectively operated in response to the refrigerant discharge temperature and pressure sensed at the discharge outlet 29. Thus the compression device 11 can be unloaded as necessary to control the refrigeration capacity of the refrigeration vapor compression system 10 by selectively opening or closing the unloading valve 27. With the unloading valve 27 in the opened position, refrigerant vapor flows out of an intermediate stage of the compression process through the compressor unload bypass line 24 to the refrigerant line 18, rather than proceeding onward to be further compressed in the high pressure compression stage 11B. Refrigerant vapor passing through the unload circuit refrigerant line 24 returns directly to the suction side of the compression device 11, thus bypassing the high compression stage 11B and thereby unloading the compression device 11. This unloading of the compressor 11 through the compressor unload circuit 23 may be implemented in response to a high compressor discharge refrigerant temperature, or for capacity reduction or compressor power reduction.

[0022] During such operation as just described, provision is generally made to prevent the occurrence of excessive pressures on the high pressure side of the system. This is generally accomplished with a three tiered successively implemented system which includes first a software approach of responding to unusually high sensed pressures to take proper actions such as shutting down the system. If, for some reason, that does not cause a proper reduction of pressure in the high pressure side, a high pressure switch 36 comes into play to responsively take appropriate action such as shutting down the system. If the high pressure conditions still persist, the third level of safety measures is implemented by way of a pressure relief device 37 which relieves the high system pressure between the compressor discharge port 29 and the expansion valve 22. A relief device typically takes the form of a rupture disc or a pressure relief valve which simply allows a portion or the entire high pressure refrigerant vapor to escape to ambient.

[0023] It should be recognized that the three levels of measures to be taken during operation of the system relate only to the high pressure side of the system since the low pressure side is maintained at a relatively low pressure (i.e. in the range of 100psi to 1055psi (0.7MPa to 7.3MPa) as long as the compression device 11 is operating.

[0024] A problem, however, arises on the low pressure side of the system, not during operation but during periods in which the system is shut down but exposed to relatively high temperature conditions. This will be more clearly understood by reference to Fig. 2 wherein it is shown that the pressures within a closed CO_2 system (which is true of the low pressure side when the system is at rest), can become excessive as the temperatures are increased.

[0025] The Fig. 2 data is based on the assumption that the total internal volume is 600 cubic inches (9.8 litres). The red lines represent ambient temperatures, and the black lines represent the level of charge of CO_2 in Ibm (mass pounds). It will thus be seen, for example, that at 70°F (21°C), for any of the charge levels 2 Ibm to 8 Ibm (0.9 to 3.6 kg), the resulting pressures remain within an acceptable level. However, as the ambient temperature rises to 150°F (66°C), for example, which is quite possible when a unit is sitting in the sunlight on a hot summer day, then the pressure levels rise to unacceptable levels.

[0026] A summary of the values for 70°F (21°C) and 150°F (66°C) for charges 2 Ib_M to 8 Ib_M (0.9 to 3.6 Kg) are shown in Table I below. Please note that 1 Ibm is equal to 0.45 kg, and 1 psi is equal to 6.9 kPa.

Table 1

CO_2 Charge (lbm)	Pres at 70°F Ambient (psi)	Pres at 150°F Ambient (psi)
2	550	700
4	820	1150
5	850	1350
6	850	1490
8	850	1710

[0027] It will thus be seen that the maximum pressures that will be reached when the ambient temperature is at 70°F (21°C) is 850 psi (5.9 MPa) which is acceptable for such a system. However, when the temperature rises to 150°F (66°C), the pressures rise from 700 psi (4.8 MPa) for 2 Ibm (0.9 kg) to 1710 psi (11.8 MPa) for 8 Ibm (3.6 kg) such pressures are considered to be too high. In this regard, since the low pressure side of the system is normally constructed to operate at the relatively low range of 100psi to 1055psi (0.7MPa to 7.3MPa), it is preferable to not exceed 1055psi (7.3MPa) on the low pressure side.

[0028] Referring now back to Fig. 1, let us consider the operation of various components, specifically the unloading valve 27 and the expansion device 22.

[0029] For purposes of reliability and safety, the unloading valve 27 is a normally closed valve such that, when the system is shut down, the valve 27 is closed. At the same time during shut down, the first and second stages 11A and 11B are both non-operational and therefore in their closed positions. The result is that, that part of the circuit between the first stage 11A and the second stage 11B, including the upstream side of unloading valve 27, is a closed space with CO_2 refrigerant trapped therein and subject to the high pressure phenomenon as discussed hereinabove with respect to Fig. 2 and Table I. For illustrative purposes, this section is delineated by the line 38 in Fig. 1.

[0030] Considering now the expansion device 22 and its bypass valve 34, when the system is shut down, these two are in a closed position to prevent refrigerant migrating to the evaporator coil and the suction side of compressor which would affect the reliability and reduce the compressor useful life. Accordingly, there is another section, i.e. between the expansion device and the suction inlet 26 that is now a closed space that is subject to the high pressure phenomenon as discussed hereinabove. For illustrative purposes, this section is delineated by the line 39. Finally, because of the closed condition at the discharge outlet 29 on the one end and the expansion device 22 on the other end, the section therebetween, a delineated by line 40, is also a closed section that is susceptible to elevated pressures when exposed to high temperatures. However, it should be recognized that this is the high pressure side which already includes provisions for relief of high pressure in the way of the high pressure relief device 37. Accordingly, no special provision needs be made to that section. However, the sections shown at 38 and 39 do require the addition of features that would not ordinarily be included. Thus, a high pressure relief device 41 is placed in line 43, upstream of the unloading valve 27 and a high pressure relief device 42 is placed in line 44 upstream of the suction inlet 26 as shown. The relief device 41 and 42 can be in the form of rupture discs or pressure relief device which, when exposed to excessive temperatures will rupture and release the high pressure gas to the atmosphere. In this way, the high pressure relief device 41 will act to relieve any excessive pressure in the section of the circuit shown at 38 and the relief device 42 will act to relieve any excessive pressure that may exist in that portion of the circuit shown at 39. As an example, an appropriate pressure level that the relief devices 41 and 42 might be designed to open would be in the range of 1300psi to 2500psi (9MPa to 17.2MPa).

[0031] In addition to the high pressure relief device 42, that section shown at 39 would preferably also include a high pressure switch 46 that would take precedent over the relief device 42 such that the high pressure switch 46 would open before the relief device 42 would open.

[0032] Although the present invention has been particularly shown and described with reference to one embodiment as illustrated in the drawings, it will be understood by one skilled in the art that various changes in detail may be made thereto without departing from the scope of the invention as defined by the claims.

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP2006183940A **[0009]**
- US2006236708A1 **[0009]**
- WO2006118573A1 **[0009]**

PATENTKRAV

1. Fremgangsmåde til forebyggelse af forekomst af uønskede høje tryk i et CO_2-dampkompressionssystem (10), når det er eksponeret for høje omgivende temperaturbetingelser under nedlukning, hvor CO_2-dampkompressionssystemet (10) indbefatter mindst én kompressor (11) og et kompressoraflastningskredsløb (23), der fluidmæssigt forbinder et mellemtrin (28) for den mindst ene kompressor (11) med et lavtrykspunkt mellem en varmeabsorberende varmeveksler (14) og et sugeindløb (26) til den mindst ene kompressor (11), hvilket lavtrykssugepunkt er på nedstrømssiden af den varmeabsorberende varmeveksler (14) og på opstrømssiden af sugeindløbet (26) til den mindst ene kompressor (11), hvilket kompressoraflastningskredsløb (23) indbefatter en aflastningsventil (27), hvilken fremgangsmåde omfatter:
tilvejebringelse af en trykaflastningsanordning (41), der er placeret mellem aflastningsventilen (27) og mellemtrinnet (28) for dampkompressionssystemet (10), hvilken trykaflastningsanordning (41) er tilpasset til at åbnes, når trykket i kompressoraflastningskredsløbet (23) på opstrømssiden af aflastningsventilen (27) når et forudbestemt niveau i tidsrum, hvori systemet (10) ikke er i drift, men er eksponeret for relativt høje temperaturbetingelser.

2. CO_2-dampkompressionssystem (10), der omfatter:
et kølemiddelkredsløb med i et serielt strømforhold mindst én kompressor (11) for komprimering af CO_2-damp som et kølemiddel, en varmeafvisende varmeveksler (13), en ekspansionsanordning (22) og en varmeabsorberende varmeveksler (14);
et kompressoraflastningskredsløb (23), der fluidmæssigt forbinder et mellemtrin (28) for den mindst ene kompressor (11) med et lavtrykspunkt mellem den varmeabsorberende varmeveksler (14) og et sugeindløb (26) til den mindst ene kompressor (11), hvilket lavtrykspunkt er på nedstrømssiden af den varmeabsorberende varmeveksler (14) og på opstrømssiden af sugeindløbet

(26) til den mindst ene kompressor (11), hvilket kompressoraflastningskredsløb (23) indbefatter en aflastningsventil (27); og
en trykaflastningsanordning (41) placeret mellem aflastningsventilen (27) og mellemtrinnet (28) af kølemiddelkredsløbet for aflastning af tryk i kompressoraflastningskredsløbet (23) på opstrømssiden af aflastningsventilen (27) i tidsrum, hvori systemet (10) ikke er i drift, men er eksponeret for relativt høje temperaturbetingelser.

3. Fremgangsmåde ifølge krav 1, eller CO_2-dampkompressionssystem ifølge krav 2, hvor den mindst ene kompressor (11) indbefatter to trin (11A, 11B).

4. Fremgangsmåde ifølge krav 1, eller CO_2-dampkompressionssystem ifølge krav 2, hvor den mindst ene kompressor (11) omfatter to serielt forbundne kompressorer.

5. Fremgangsmåde ifølge et hvilket som helst af krav 1, 3 eller 4, eller CO_2-dampkompressionssystem ifølge et hvilket som helst af krav 2 til 4, hvor trykaflastningsanordningen (41) omfatter en brudskive.

6. Fremgangsmåde ifølge et hvilket som helst af krav 1, 3 eller 4, eller CO_2-dampkompressionssystem ifølge et hvilket som helst af krav 2 til 4, hvor trykaflastningsanordningen (41) omfatter en trykaflastningsventil.

7. Fremgangsmåde ifølge et hvilket som helst af krav 1 eller 3 til 6 eller CO_2-dampkompressionssystem ifølge et hvilket som helst af krav 2 til 6, hvor aflastningsventilen (27) omfatter en normalt lukket ventil.

8. CO_2-dampkompressionssystem ifølge et hvilket som helst af krav 2 til 7 og som indbefatter en højtrykskontrakt (46), der er placeret på kølekredsløbets lavtryksside, hvilken højtrykskontrakt (46) er designet til at åbnes ved et tryk, der er lavere end det tryk, hvorved trykaflastningsanordningen (41) er tilpasset til at frigive tryk.

Fremgangsmåde ifølge et hvilket som helst af krav 1 eller 3 til 7 og som indbefatter det yderligere trin med installation af en højtrykskontakt (46) på kølekredsløbets lavtryksside, hvilken højtrykskontrakt (46) er tilpasset til at åbnes ved et tryk, der er lavere end det tryk, hvorved trykaflastningsanordningen (41) er tilpasset til at frigive tryk.

DRAWINGS

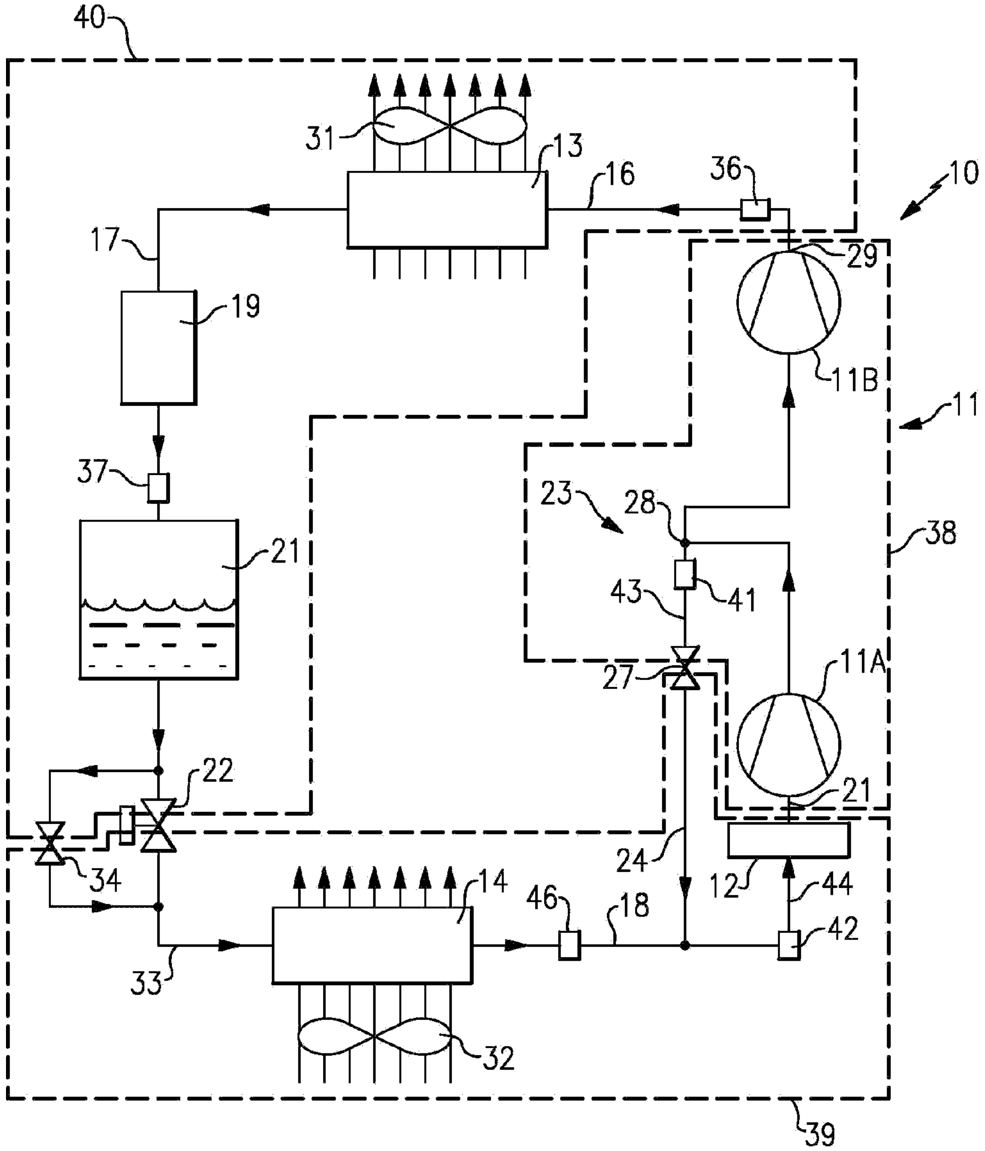

FIG.1

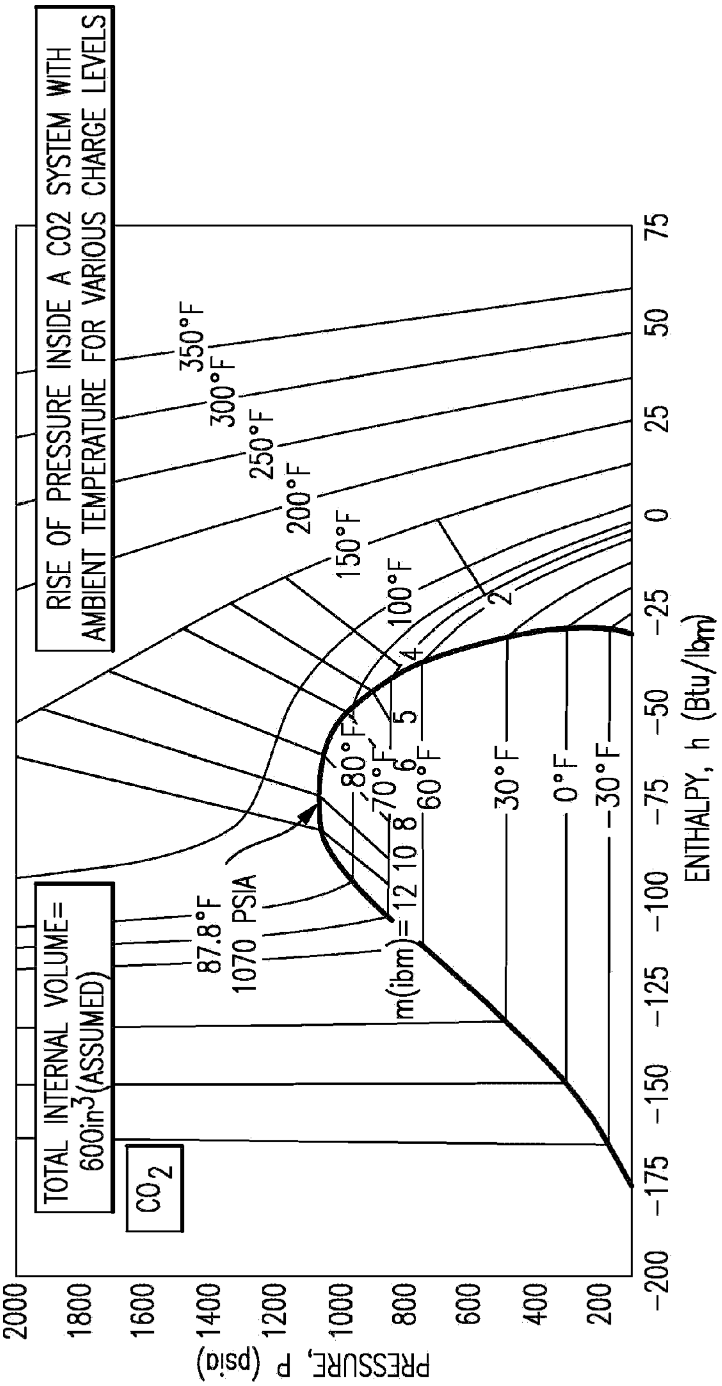
RISE OF PRESSURE INSIDE A CO2 SYSTEM WITH AMBIENT TEMPERATURE FOR VARIOUS CHARGE LEVELS
TOTAL INTERNAL VOLUME= 600in³(ASSUMED)
CO2
87.8°F
1070 PSIA
m(ibm)=12 10 8 6 5 4 2
350°F
300°F
250°F
200°F
150°F
100°F
80°F
70°F
60°F
30°F
0°F
-30°F
PRESSURE, P (psia)
2000
1800
1600
1400
1200
1000
800
600
400
200
ENTHALPY, h (Btu/lbm)
-200
-175
-150
-125
-100
-75
-50
-25
0
25
50
75

FIG.2