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COMPOUND PAKS

1 INTRODUCTION

This type of compressor pak allows use of an environmentally acceptable refrigerant such as R22. It is particularly appropriate where control pressures of 4 psi are required to control the refrigeration of frozen food.

The pak incorporates internally compounded compressors, each driven by a three phase electric motor. The compressors are of the reciprocating type.

The basic function of the pak is to deliver clean refrigerant at a controlled pressure to the units on the shop floor. Returned gas from the units on the shop floor is processed by the pak before being re-cycled.

The controller needs a data input for the required configuration to be selected. This is achieved by setting the appropriate bit switches on the CPU board and using the hand held unit to force load the corresponding parameters into the controller.

2 FUNCTIONAL DESCRIPTION

The basic operation of the compound pak is to control the suction pressure of the refrigerant , by varying the combined speed of two compressors.

Compressor 1 is variable in speed from 750 to 1750 RPM.

Compressor 2 operates at a fixed speed of 1450 RPM.

Both compressors can be individually started and stopped by the system, as a function of the current conditions.

When the system is switched on, compressor 1 starts and attains 750 RPM.

The suction pressure is continuously monitored by a probe in the suction line. Compressor 1 increases speed up to a maximum of 1750 RPM or until the suction pressure has dropped to 4 psi.

If this pressure has not yet been reached, compressor 2 is turned on and runs up to a speed of 1450 RPM.

Compressor 1 then varies in speed until the suction pressure has dropped to 4 psi.

The compressor pak is controlled automatically by software in the electronic unit, which regulates compressor speed, and solenoid valves according to demand.

3 OPERATIONAL DESCRIPTION

Operation of the compound pak is described under the following main sub-headings:

(1) Refrigerant circuit
(2) Liquid injection circuit
(3) Combined refrigerant and liquid injection circuit
(4) Control and monitor panel (drawing SK351)
(5) Electronic unit
(6) Compressor sequencing
(7) Condenser fan operation

3.1 REFRIGERANT CIRCUIT

3.1.1 Suction header

The suction header has two or more inputs for gas from the units on the shop floor. The suction header passes gas to the two compressors.

3.1.2 Compressors

After the first stage of compression, the gas passes from the LP head, back into the compressor, and thence via the HP head to the common discharge line. This takes the compressed gas/oil mixture at high velocity to the oil separator.

The two compressors are controlled by the electronic system in accordance with the measured pressure in the suction line.

3.1.3 Oil separator

On entering the oil separator, the compressed gas/oil mixture is forced at high speed against the internal walls of the oil separator cylinder. Centrifugal force causes the mixture to rotate inside the cylinder of the oil separator. The oil drops to the bottom, and the gas is discharged to the condenser. The oil is returned to the compressors via the oil receiver.

3.1.4 Condenser

The condenser converts the incoming hot gas to a liquid, which then passes into the liquid receiver.

3.1.5 Liquid receiver

The liquid receiver stores the condensed liquid from the condenser, and passes the liquid on demand via the drier to the liquid header. The drier removes all traces of water vapour from the liquid refrigerant.

3.1.6 Liquid header

The liquid header supplies liquid refrigerant on demand to the various units on the shop floor.

3.1.7 Saturated gas header

The saturated gas header takes gas from the top of the liquid receiver for hot gas defrost.

3.1.8 Hot gas dump

If the back pressure falls to a dangerously low level, a solenoid valve is opened to allow saturated discharge gas to flow from the top of the liquid receiver into the suction header. This occurs with either compressor running, but not both. Hot gas dumping will continue until the required pressure is reached, then the solenoid valve will shut.

3.2 LIQUID INJECTION

3.2.1 Liquid injection to compressors

Whenever a compressor is started, a solenoid valve is opened on the liquid injection line for that compressor. A probe on the feed from the LP head to the HP side of the compressor senses the temperature of gas in the line. If this exceeds a preset value, a mechanically operated TEV in the liquid injection line is opened. This allows cool liquid vapour to be injected into both HP and LP heads in order to cool the compressor.

Each compressor has its own liquid injection system, fed from the common liquid line. The TEV on the liquid injection line to each compressor is controlled (both in terms of scaling and opening criteria) in accordance with design temperatures.

3.2.2 Common liquid injection

Liquid is injected into the main suction header from the common liquid line when suction solenoid valve SV3 is opened. This valve is opened only when gas dump is initiated and off when gas dump closes.

The amount of liquid injected into the main suction header is regulated by a TEV, which in turn is controlled by the temperature of the common suction line.

3.3 CONTROL AND MONITOR PANEL

The general layout of the panel is illustrated in drawing SK351.

3.3.1 Front panel display

The front panel display incorporates two digital displays, each of four digits indicating suction and discharge pressures, together with LEDs showing running and alarm condition states.

Processor fault indication

If a processor fault is present, then the display will flash 'help' alternately with the normal contents of the display.

3.4 ELECTRONICS HARDWARE

3.4.1 Hardware configuration

The electronic control system comprises the following set of common hardware cards:

(1) Mk 3 cpu card - 1 off.
(2) Common hardware motherboard - 1 off.
(3) Time and temperature cards for up to 8 temperatures - 2 off.
(4) Pressure sensor card - 1 off.
(5) Front panel driver and digital input card - 1 off.
(6) Front panel LED display card - 1 off.
(7) Digital output card - 2 off.
(8) Analogue driver card - 1 off.
(9) Digital input/output card - 1 off.

3.4.2 Digital inputs to electronic system

The following digital signals are sensed by the electronic control system:

(1) Liquid level alarm sensor.
(2) Compressor 1 fault chain.
(3) Compressor 2 fault chain.
(4) Fan fault.
(5) Low air flow - if required.
(6) Fan supply fault

3.4.3 Digital outputs from electronic system

The following digital signals are output by the electronic control system:

(1) Compressor 1 start.
(2) Compressor 2 start.
(3) Fan motor drive - 4 off.
(4) Solenoid valve 3 : liquid injection.
(5) Solenoid valve 4 : dump.

3.4.4 Analogue output from electronic system

Three analogue outputs are provided by the electronic system:

(1) Control signal to inverter driving the variable speed compressor; 0 to 10 volts.
(2) Control signal to fresh air dampers; 0 to 10 volts (if required).
(3) Control signal to recirc/supply dampers; 0 to 10 volts (if required).

3.5 COMPRESSOR SEQUENCING

3.5.1 Control sequence

The switching and control of the compressors is governed solely by measurement of the suction pressure. The system uses the variable speed compressor in conjunction with the fixed speed compressor to control the suction pressure about a given setpoint.

Compressor 1 operates over a band of 750 to 1750 RPM. When compressor 2 is also running at its fixed speed of 1450 RPM, the combined speed of the two compressors gives a band of 2200 to 3200 RPM.

The gap in capacity (1750 to 2200 RPM) between the two speed bands means that during changeover from one compressor to two compressors, the suction pressure drifts away from the setpoint. Drawing SK352 shows the behaviour of the system.

If the graph is traversed in the direction of increasing load on the system (left to right), then while the load lies in the 750 to 1750 RPM speed band, the suction pressure is maintained close to the setpoint.

As the load demand rises above 1750 RPM and enters the speed gap, the capacity of the pak remains constant, and the suction pressure begins to rise.

When the suction pressure passes through the switching setpoint 'A', compressor 2 is started (subject to timing delay restriction, see para 3.5.2). This causes the suction pressure to fall, and compressor 1 to reduce speed to 750 RPM.

As the load continues to increase the suction pressure rises again until the second variable speed band is entered, when it is again possible to maintain the pressure close to the control setpoint.

If the graph is traversed in the direction of decreasing load on the system (right to left), then while the load lies in the 2200 to 3200 RPM band, the suction pressure is maintained close to the setpoint.

As the load decreases below 2200 RPM equivalent and enters the speed gap (1750 to 2200 RPM) the suction pressure begins to fall. The pressure continues to fall until it passes through switching setpoint 'B', at which point compressor 2 (fixed speed) is switched off. The suction pressure then rises to approximately the same level as the control setpoint.

3.5.2 Compressor start timing restrictions

There is a minimum period of 7 minutes for consecutive starts of the same compressor. This period is defined by a parameter in the control software.

3.6 CONDENSER FAN OPERATION

3.6.1 Fan control strategy

The number of fans running depends on the discharge pressure level. The fans are turned on and off according to threshold levels. These levels are determined by an adjustable setpoint (F61) together with five pairs of differentials from that setpoint. The differentials are provided as hand held unit functions.

3.6.2 Condenser fan control parameters

(F71)	Condenser fan 1 turn ON
(F72)	Condenser fan 1 turn OFF
(F73)	Condenser fan 2 turn ON
(F74)	Condenser fan 2 turn OFF
(F75)	Condenser fan 3 turn ON

(F76) Condenser fan 3 turn OFF
(F77) Condenser fan 4 turn ON
(F78) Condenser fan 4 turn OFF

3.7 TEMPERATURE AND PRESSURE SENSING

Temperature and pressure sensors are as follows:

Abbreviation	*Function*
TS1	Common suction temperature
TLD1	Compressor 1 low stage discharge
THD1	Compressor 1 high stage discharge
THS1	Compressor 1 high stage suction
TLD2	Compressor 2 low stage discharge
THD2	Compressor 2 high stage discharge
THS2	Compressor 2 high stage suction
TL1	Liquid from condenser
TL2	Liquid main from receiver
TA1 *	Air on condenser
TA2 *	Air off condenser
TW1 *	Water in temperature
TW2 *	Water out temperature
PD1	Discharge pressure sensor
PS1	Suction pressure sensor
(* all switchable from hand held unit)	

3.8 COMMISSIONING

3.8.1 General instructions

Check for direction of rotation of condenser fans.

Check for direction of rotation of damper motors (if fitted).

Carry out functional tests on all solenoids, using bit switch settings given in Table 1.

TABLE 1 BIT SWITCH MAP

Board 1 input/output			Board 2 input/output		
Switch 1			Switch 2		
Bit 1	Valve shut down	-	Bit 8	-	-
Bit 2	Gas dump SV	OFF	Bit 7	-	-
Bit 3	Injection SV LIQ	OFF	Bit 6	-	-
Bit 4	1190 alarm	ON	Bit 5	-	-
Bit 5	-	-	Bit 4	C2 run	ON
Bit 6	Low level refrig lamp	OFF	Bit 3	-	-
Bit 7	-	-	Bit 2	-	-
Bit 8	C1 over ride pulse	OFF	Bit 1	-	-
Switch 1 not fitted			Switch 1		
Bit 1	n/a	-	Bit 8	-	-
Bit 2	n/a	-	Bit 7	Fan 1 run	ON
Bit 3	n/a	-	Bit 6	Fan 2 run	ON
Bit 4	n/a	-	Bit 5	Fan 3 run	OFF
Bit 5	n/a	-	Bit 4	-	-
Bit 6	n/a	-	Bit 3	C1 stop/start	OFF
Bit 7	n/a	-	Bit 2	-	-

Bit 8	n/a	-	Bit 1	-	-

Check the accuracy of the pressure transducers against quality service gauges.

Ensure all pressure switches are correctly set.

Ensure that sufficient refrigerant has been charged for run mode.

4 MAINTENANCE

Diagnostic maintenance is facilitated by the presence of indicator lamps on the control panels, and by use of the hand held unit. A full list of hand held unit functions is given at the end of this section.

4.1 SYSTEM ALARMS AND FAULT RESPONSES

The following paragraphs give details of operation in the event of a fault, together with the appropriate control responses and hand held functions.

4.1.1 Temperature sensor failure (F84)

Detection and reporting

A temperature sensor failure alarm (non critical) for the appropriate sensor is generated when either:

(1) The sensor has returned a reading less than -50 degs C for longer than two minutes, or;
(2) The sensor has returned a reading more than 150 degs C for longer than two minutes.

The alarm ceases to be generated when the fault condition is no longer present.

Control response

No control response is generated by this alarm condition.

4.1.2 High suction pressure alarm (F88)

Detection and reporting

A high suction pressure (critical) alarm is generated whenever the suction pressure is greater than the *High suction pressure alarm threshold.*

When the suction pressure is equal to or less than this value the alarm will cease to be generated.

The high suction pressure alarm threshold is variable between 10 and 40 psig, and has a default value of 35 psig.

Control response

If a High Suction - Low Level alarm is present for more than 35 minutes a dial out will be activated through the DES-E-1190 alarm panel.

4.1.3 Compressor faults

Detection and reporting

A compressor fault is reported (without a confirmation period) whenever its associated alarm chain is asserted.

If a compressor 1 failure alarm is generated, this is classified as a Critical alarm and will cause a dial out.

If a compressor 2 failure alarm is generated, this will only be classified as Critical if demanded to run.

Control response

The compressor will be shut down and dial out will be activated if a faulty compressor is demanded.

4.1.4 Liquid level alarm

Detection and reporting

This alarm (critical) will be reported whenever the low liquid level alarm input to the control system is asserted, and not otherwise reported.

Control response

The control system will take no action other than to report the alarm.

4.1.5 High discharge pressure

Detection and reporting

A high discharge pressure alarm (non-critical) will start to be generated when the discharge pressure rises through the High discharge pressure alarm setpoint.

The alarm will continue to be generated until the discharge pressure falls below the High discharge pressure alarm setpoint.

The High discharge pressure alarm threshold is variable between 260 and 300 psig, and has a default value of 290 psig.

Control response

In the event of a high discharge pressure alarm, all fans will be started. If no change occurs, the pak capacity is reduced, until the head pressure falls below its setpoint

4.1.6 Low pressure stage high discharge temperature

Detection and reporting

This alarm (non-critical) will be generated when the low pressure stage high discharge temperature (measured by DT1, DT2) is greater than the low pressure stage high discharge temperature alarm threshold.

The alarm will not be generated when the temperature is equal to or less than the threshold. Each compressor can generate its own alarm.

The low pressure stage high discharge temperature alarm threshold is variable between 60 and 100 degrees C, and has a default value of 90 degrees C.

Control response

The control response is read-only. If a thermistor is fitted the compressor will be shut down by the fault chain.

4.1.7 High pressure stage high discharge temperature

Detection and reporting

This alarm (critical) will be generated when the high pressure stage discharge temperature (measured by DT3, DT4) is greater than the High pressure stage high discharge temperature alarm threshold.

The alarm will cease to be generated when the temperature is equal to or less than the threshold. Each compressor can generate its own alarm.

The High pressure stage high discharge temperature alarm threshold is variable between 80 and 130 degrees C, and has a default +value of 100 degrees C.

Control response

The control response is read only.

4.1.8 Fan trip alarm

A fan trip alarm is generated whenever any fan trips on overload.

4.1.9 Low air flow alarm

Detection and reporting

A low air flow alarm is enabled or disabled via the hand held unit, if an air flow sensor is fitted. The alarm will only be asserted when all fans are running and air flow is below required volume.

Control response

The alarm is reported to the front end as a non critical alarm.

4.2 PROCESSOR ALARMS

The following processor alarms are reported:

(1) RAM failure
(2) PROM failure
(3) Program counter out of allowed range
(4) Background tasks not executing
(5) Back-up data checksum failure

4.3 ALARM REPORTING

Alarms are reported to the four devices listed below:

(1) Front end.
(2) Hand held unit.
(3) Front panel display (via front end).
(4) Shop services panel.

Compound pak HHU				
HHU	Descriptions	Type	Limits/Units	Defaults
00	Condenser air on temp TA1	D	deg C	
01	Condenser air off temp TA2	D	deg C	
02	Common suction line temp TS1	D	deg C	
03	Liquid from condenser temp TL1	D	deg C	
04	Liquid from receiver temp TL2	D	deg C	
05	TW1	D	deg C	
06	TW2	D	deg C	
07	Disable TW1/TW2	S		
08	Suction pressure PS1	D	psi	
09	Discharge pressure PD1	D	psi	
10	C1 run status	D	0=off, 1=run	
11	-			
12	C1 LO stage discharge temp TLD1	D	deg C	
13	C1 LO stage discharge temp TLD1	D	deg C	
14	C1 LO stage discharge temp TLD1	D	deg C	
15	Time before starting comp 1	D		
16	-			
17	Software version number	D		
18	Pass code CH.2	S		
19	Channel 2 gate	S		
20	C2 run status	D	0=off, 1=run	
21	-			
22	C2 LO stage discharge temp TLD2	D	deg C	
23	C2 HI stage suction temp THS2	D	deg C	
24	C2 HI stage discharge temp THD2	D	deg C	
25	Time before starting comp 2	D		
26	-			
27	-			
28	-			
29	-			
30	C1 alarm chain fault	A	0= OK, 1=alarm	
31	-			
32	-			
33	-			
34	-			
35	-			
36	C1 LO stage discharge temperature TLD1 fault	A	0= OK, 1=alarm	
37	C1 HI stage suction temperature THS1 fault	A	0= OK, 1=alarm	
38	C1 HI stage discharge temperature THD1 fault	A	0= OK, 1=alarm	
39	Hardware version number	D		
40	C2 alarm chain fault	A	0= OK, 1=alarm	
41	-			
42	-			
43	-			
44	-			
45	-			
46	C2 LO stage discharge temperature TLD2 alarm	A	0= OK, 1=alarm	
47	C2 HI stage suction temperature TLS2 alarm	A	0= OK, 1=alarm	

48	C2 HI stage discharge temperature THD2 alarm	A	0= OK, 1=alarm	
49	THS1/THS2 alarm level	S	30 to 60 deg C	50
50	Suction pressure setpoint	S	0 to 12 psi	4
D = DISPLAY S = SETTABLE A = ALARM				
Compound pak HHU				
HHU	Descriptions	Type	Limits/Units	Defaults
51	Differential above setpoint to load up	S	0 to 8 psi	2
52	Differential below setpoint to off load	S	0 to 8 psi	2
53	LO Stage HI discharge temperature alarm setpoint	S	30 to 90 deg C	60
54	HI Stage HI discharge temperature alarm setpoint	S	80 to 130 deg C	100
55	Discharge pressure to force capacity decrease	S	200 to 300 psi	275
56	LO suction alarm setpoint differential	S	0 to 9 psi	4
57	HI suction alarm setpoint differential	S	10 to 30 psi	16
58	Suction pressure setpoint to commence cabinet valve release	S	10 to 60 psi	30
59	System start/shutdown	S	0=shutdown, 1= start	
60	Number of fans demanded	D		
61	Fan control setpoint	S	100 to 250 psi	160
62	LO air flow enable	S	0=enable,1=inhibit	
63	Fan display timer	S	1 to 90 seconds	5
64	-			
65	-			
66	System gas dump injection	S	0 to 10 psi	2
67	D3 start pulse	S	0 to 10 seconds	3
68	-			
69	-			
70	-			
71	Fan 1 on differential from setpoint (F61)	S	-50 to +50 psi	
72	Fan 1 off differential from setpoint (F61)	S	-50 to +50 psi	
73	Fan 2 on differential from setpoint (F61)	S	-50 to +50 psi	
74	Fan 2 off differential from setpoint (F61)	S	-50 to +50 psi	
75	Fan 3 on differential from setpoint (F61)	S	-50 to +50 psi	
76	Fan 3 off differential from setpoint (F61)	S	-50 to +50 psi	
77	Fan 4 on differential from setpoint (F61)	S	-50 to +50 psi	
78	Fan 4 off differential from setpoint (F61)	S	-50 to +50 psi	
79	-			
80	-			
81	-			
82	Low refrigerant alarm	A	0= OK, 1=alarm	
83	-			
84	Temperature sensor fault	A	0= OK, 1=alarm	
85	-			
86	-			
87	Low suction pressure alarm	A	0= OK, 1=alarm	
88	High suction pressure alarm	A	0= OK, 1=alarm	
89	High discharge pressure alarm	A	0= OK, 1=alarm	
90	CPU fault	A	0= OK, 1=alarm	
92	-			
93	-			
94	-			
95	-			
96	-			

97	-			
98	-			
99	Set device number	S	0 to 999	800
D = DISPLAY S = SETTABLE A = ALARM				