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Inside This Issue

General

Suction Modulation (Stepper Motor Valves)

Suction modulation has been used for many years as a means to regulate the flow of refrigerant in the system to match the evaporator capacity to that of the total heat load within a container box. Traditionally, a coil and plunger type valve that used pulse width modulation (PWM) to create a variable magnet field to open/close the valve was used in the container product. For this type of valve, plunger position is controlled by a PWM signal, varying the magnet field of the coil producing a proportional force on the plunger, which is counteracted by a spring. Power to the valve coil must always be present in order to maintain plunger positioning for this type of valve.

Carrier's 69NT40-511-200 series, and up model units, are equipped with a new type of suction modulation valve (SMV). Technological advances in refrigeration valve and motor design now make it possible to use step motor valves that offer extremely fine open/close control, open/close position repeatability, and increased torque and efficiency with regard to the drive motor size verses the power input for the valve port plunger.

Stepper Motor Theory

Step motors, like most motors, are based on the principle that opposite magnetic poles attract and like magnetic poles repel. However, while traditional motors continuously rotate as long as power is applied, stepper motors will only rotate a fixed amount, or arc, then stop. When power is removed and reapplied, the motor will rotate another fixed amount and stop. These arcs or "steps" are what give the motor its name. The "steps" can be repeated infinitely in either direction—within the mechanical limits of the valve design. The number of steps can be remembered by a controller and are used to return the valve to any previous position at any time. Thus, giving this type of valve almost absolute repeatability and precise control (resolution) of refrigerant flow.

Features and Benefits

In the older PWM system configuration for 69NT40 type units, there were two suction refrigeration control valves, the SMV and an SSV (suction solenoid valve). The SSV acted as a secondary refrigerant flow valve when operating parameters called for additional refrigeration capacity in frozen mode or pull-down, under certain conditions.

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Feature Article

CA — Control Functions (Conclusion)

CALIBRATION MODE

This concludes our basic series on the EverFresh™ controlled atmosphere (CA) system—its components and how they operate. Look for future articles on CA pre-trip steps, alarms, and our upcoming new two-purity CA system in subsequent newsletters. At the end of this article is a listing of all previously related issues.

The CA system can perform anyone of four calibration sub-functions to readjust the O_2 and CO_2 sensors. The sensors can read from any one of four sampling sources: (1) the controlled space, (2) the membrane supply, (3) the outside air, or (4) a calibration gas bottle. The calibration sub-functions can be accessed by either keypad operations (including pre-trip testing), communications requests, or software embedded timers and provides the following functionality:

*Calibration will not function if the CA system is in Standby (CA Lockout) or **VENT** mode.*

Oxygen Sensor Zero (Gas) Calibration

Allowing calibration gas, (95% N_2, 5% CO_2) containing a known 0% oxygen mixture, to flow through the gas sensing chamber of the O_2 sensor this function will set and store the O_2 zero point value. Initiation of this test is done through either: Pre-trip (P4-1) testing, Communications request, or Keypad selection—Cd11 and holding the "enter" key for 5 seconds.

The display will show "P4-1" and a count down timer or "gAS" "CAL" depending on the function used to initiate the calibration. After the first minute the display will rotate through readings of the O_2 and CO_2 sensors and the above display outputs. After a minimum of six minutes if stability of the sensor is achieved the calibration will end. If stability of the sensor is not achieved the calibration will end at a maximum of twelve minutes. If stability is not achieved, a failure will be indicated by either a flashing **AL41** (O_2 Gas Calibration Failure) or in the case of pre-trip, "FAIL" in the display.

If AL48(Oxygen Sensor Voltage Failure) is active this calibration is skipped. The test is aborted if the compressor turns off or the O_2 sensor goes outside its valid operating range during the test. If the calibration does not complete or fails the previous calibration value is retained.

Oxygen Sensor Span Calibration

When initiated, this function adjusts the O_2 sensor profile curve by allowing outside air, via the Air Calibration Solenoid Valve (ASV), to flow through the gas sensing chamber of the O_2 sensor. This test can be initiated by either:

- Pre-trip (P3-0) testing.
- Communications request.
- User selection via the keypad, Cd10 and holding the "enter" key for 5 seconds.
- Automatically after a power-up—as long as the air heater has been energized for 2 hours and there are no shutdown alarms active—and the unit is not in Standby mode.
- Automatically once every 24 hours.

When initiated through a pre-trip, function code selection, or communications request the time-based (2 and 24 hour) calibrations are not affected (i.e., timers not reset).

The display will show "P3-0" and a count down timer or "AIR" "CAL" depending on the function used to initiate the calibration. After the first minute the display will rotate through readings of the O_2 and CO_2 sensors and the above display outputs. After a minimum of two minutes if stability of the sensor is achieved the calibration will end. If stability of the sensor is not achieved the calibration will end at a maximum of eight minutes. If stability is not achieved a failure will be indicated by either a flashing **AL42** (O_2 Air Calibration Failure) or in the case of pre-trip, "FAIL" in the display.

Depending on the calibration value determined, the service LED or Oxygen Sensor Failure (AL34) may also be activated.

CO_2 Zero Calibration

This calibration function causes a sample of the membrane stream, via the Nitrogen Solenoid Valve (NSV), to flow through the gas sensing chamber of the CO_2 sensor.

The membrane filters out most of the CO_2 in the air, providing a nearly "zero point" for the CO_2 sensor.

This test is initiated by either:

- Pre-trip (P4-0 and/or P6-0) testing.
- User selection via the keypad, N_2 test.
- Automatically 2 hours after a power-up, as long as the air compressor has been energized continuously.
- Automatically 24 hours after the last calibration.
- Automatically whenever the return temperature has changed more than 5ºC (9ºF) since the last calibration.

For pre-trip and N_2 test the time-based (2 and 24 hour) calibrations are not affected (i.e., timers not reset).

The display will show "P4-0" or "P6-0" (as appropriate) and a count down timer or "CO2Z" "CAL" depending on the function used to initiate the calibration. After the first minute the display will rotate through real time readings of the O_2 and CO_2 sensors and the above display outputs. If the calibration attempt fails or is not completed the current calibration value will continue to be used.

If the compressor turns off during the test it is aborted. Any unsuccessful, non-pre-trip, attempt will be retried every 15 minutes until a successful calibration is achieved or until 10 unsuccessful attempts are made (3 1/2 hours). After 10 unsuccessful attempts a CO_2 sensor alarm (AL35) will be activated. The pre-trip calibration will repeat once upon failure according to normal pre-trip testing rules.

CO_2 Sensor Span Check

Allowing "Cal-Gas," containing a known 5% CO_2 mixture, to flow through the gas sensing chamber of the CO_2 sensor this function checks the sensor span (min to max range). Initiation of this calibration is done through pre-trip (P4-2) testing. The display will show "P4-2" and a count down timer. After the first minute, the display will rotate through this and readings of the O_2 and CO_2 sensors.

If the compressor turns off the test is aborted. This calibration is a pre-trip check function only. No value is stored or used by the control function.

Nitrogen Test

This test allows the N_2 rich stream, from the membrane, to flow through the gas sensing chamber of the O_2 sensor to determine the current N_2 concentration and operating pressure. This test is initiated by either a pre-trip (P5-0) test or by user selection via the Nitrogen Check key. If initiated by the keypad, the air compressor must have been on for at least 2 continuous hours or the test request will be postponed until the time requirement is met. A test request via pre-trip is initiated immediately. The display will show "P5-0" and a count down timer or "ntest" (alternating between "ntest" and "rslts") and "   " depending on the function used to initiate the test.

After the first minute the test will show the N_2 percentage value. Since there is no actual N_2 sensor this value is calculated from the O_2 sensor value. After a minimum of two minutes if N_2 stability is achieved the test will end. If stability is not achieved the test will end at a maximum of eight minutes. If the N_2 concentration is out of range the previous value will continue to be used. A failed test will not indicate any alarm condition, but if initiated by pre-trip will cause "FAIL" to be displayed.

Upon completion of an N_2 test initiated by the N_2 Check key a CO_2 Zero Calibration will be attempted. If AL34, AL41, AL42, or AL 48 are active the test is skipped. The test will also be aborted if the compressor turns off or the oxygen sensor becomes invalid during the test.

Refer to the following for past articles covering the CA basics:

- February/March 1997 (Vol. 2, No. 2) — *What is Controlled Atmosphere?*
- May/June 1997 (Vol. 2, No. 4) — *Controlled Atmosphere – A Continued Discussion*
- June 1999 (Vol. 4, No. 1) — ***EverFresh™*** *Controlled Atmosphere System*
- July 1999 (Vol. 4, No. 2) — *CA System Components & Operation*
- August 1999 (Vol. 4, No. 3) — *CA - Condenser Section Components & Operation*
- September 1999 (Vol. 4, No. 4) — *CA – The Membrane Separator* and *How a Membrane Separator Works*
- October 1999 (Vol. 4,No. 5) — *CA – Oxygen and Carbon Dioxide Sensors*
- November 1999 (Vol. 4, No. 6) — *CA Miscellaneous Components*
- December 1999 (Vol. 4, No. 7) — *CA – Electronics & Control Functions*
- January/February 2000 (Vol. 5, No. 1) — *CA – Control Functions (Continued)*

❑ *N. LaCount*

General

Training School Schedule

Here is a brief look at some of the upcoming container training being offered around the world. Refer to the *2000 Worldwide Customer Training* brochure (62-03198-26) for program descriptions, enrollment details, fees, and a complete schedule of remaining schools.

Date	Program	Location	Class I.D.	Language
MAY				
1 - 2	2-Day Container	Seoul, Korea	465	Korean
1 - 2	2-Day Container	Oakland, CA	466	English
3 - 4	2- Day C.A.	Christ Church, NZ	467	English
8 - 12	1-Week Container	Shanghai, China	468	English/Mandarin
15 - 19	1-Week Container	Pusan, Korea	471	English/Korean
15 - 19	1-Week Container	Bremerhaven, Germany	472	English
22 - 24	3-Day Container	Aarhus, Denmark	473	English
25 - 26	2-Day C.A.	Aarhus, Denmark	477	English/Danish
JUNE				
1 - 2	2-Day Container	Syracuse, NY	478	English
7 - 8	2-Day Container	Chile	480	English/Spanish
12 - 16	1-Week Container	Ecuador	481	Spanish
13 - 14	2-Day C.A.	N. Calif. @ UC Davis	483	English
19 - 30	2-Week Container	Syracuse, NY	484	English

Continued from page one – Suction Modulation (Stepper Motor Valves)

Operation of a stepper SMV unit will be different in that there is only one valve that can now handle all system capacity issues. Thus actual valve position will typically register as further closed because of the relative larger bore and stroke overall.

Some valve and motor specifications for this valve are:

Motor Type:	2 coil, bipolar*, 2 phase permanent magnet
Supply Voltage:	12 vdc
Phase Resistance:	75 ohms/winding [±10% @ 72°F (22°C)]
Number of Steps:	6000+
Step Resolution (Control):	0.0000783 inches/step (0.002 mm/step)

Another unique feature, unlike the older style PWM modulation valve that looses its position when power is removed, stepper motor valves remain in the last known position.

Refer to the unit service manual (generally found within section 6) for more information on valve operation and checking.

❑ *M. Parekh / N LaCount*

* Type of step motor that is powered by signals that change polarity. Current flow changes direction by alternating the two coil leads between positive and negative during each step.

TECH UNIT	X	=	ENGLISH UNIT	X	=	SI UNIT
Area						
cm^2	0.1550		in^2	645.2		mm^2
m^2	10.76		ft^2	929		cm^2
Energy						
kcal	3.968		Btu	1.055		kJ
kg_f·m	7.233		ft·lb	1.356		J
kW·h	3412		Btu	1.055×10^{-3}		MJ
Length						
mm	0.03937		in	2.54		cm
cm	0.03281		ft	0.3048		m
Mass						
g	0.03527		oz	0.02835		kg
kg	2.205		lb	0.4536		kg
ton (Long) (2240 lb)	1.12		US ton (2000 lb)	0.9072		tonne, Mg (Metric)
Power						
kcal/h	3.968		Btu/h	0.293		W
cal/s	14.286		Btu/h	3.927×10^{-4}		HP
HP metric	0.9863		HP	0.7457		kW
Mcal/h	0.3307		Ton* (Refrig.)	3.517		kW
Pressure						
mm Hg @ 0°C	0.03937		in Hg @ 32°F	3.386		kPa
kg_f/cm^2	14.22		Psia	6.895		kPa
Bar	14.504		Psia	0.6897		N/cm^2
Specific Enthalpy						
Kcal/kg	1.8		Btu/lb	2.326		kJ/kg

TECH UNIT	X	=	ENGLISH UNIT	X	=	SI UNIT
Specific Heat						
kcal/kg·°C	1.0		Btu/lb·°F	4.187		kJ/kg·°C
Velocity						
m/s	3.281		ft/s	0.3048		m/s
m/s	196.9		ft/min	0.00508		m/s
Temperature Interval						
°C				1.0		K
°C	1.8		°F	0.5556		°C
Volume (Liquid)						
cm^3	0.06102		in^3	0.01639		L
L	0.03531		ft^3	0.02832		m^3
m^3	1.308		yd^3	764.6		L
US gal	3.785		L	1000		mL, cm^3
US gal	8		US pint	16		US oz
Thermal Conductivity						
kcal/m·h·°C	8.064		Btu·in/ft^2·h·°F	0.1442		W/m·°C
kcal/m·h·°C	0.6720		Btu·ft/ft^2·h·°F	1.731		W/m·°C
Heat Transfer Coefficient						
kcal/m^2·h·°C	0.2048		Btu/ft^2·h·°F	5.678		W/m^2·°C
Flow						
L/s	15.85		gal/min	63.09		cm^3/s
cm^3/s	3.531×10^{-5}		CFS (ft^3/s)	28.317		L/s
CMS (m^3/s)	35.315		CFS (ft^3/s)	1.7		CMM (m^3/min)
CMM (m^3/min)	2118.88		CFH (ft^3/h)	0.01667		CFM (ft^3/min)
CFM (ft^3/min)	1.7		CMH (m^3/h)	35.315		CFH (ft^3/h)

B. Hernandez

Temperature Conversion

K = °C + 273.15
°F = (°C x 1.8) + 32
°C = (°F - 32) ÷ 1.8

Frictional Pressure Loss:

Compressed Air Piping	1 psi / 1000 ft
Water Piping	1 psi / 100 ft (98.1 Pa / m)

Prefixes

M	mega-	10^6
k	kilo-	10^3
c	centi-	10^{-2}
m	milli-	10^{-3}

Units

BTU	British Thermal Unit
cal	calorie
cm	centimeters
ft	foot
h	hour
HP metric	Metric Horsepower (PS, CV, ch)
in	inch
J	Joule
K	Kelvin (temperature)
kg / kg_f	kilogram (mass / force)
L	Liter
lb	pound
m	meter
mm	millimeters
mm Hg	millimeters of Mercury
N	Newton (force)
oz	ounce
Pa	Pascal
psia	pounds per square inch absolute
s	second
tonne	Ton Metric (1000kg)
W	Watt

* A ton of refrigeration is equal to 12,000 Btu/h

Carrier TRANSICOLD

Mechanical Refrigeration (The Basics)

The basic function of a mechanical refrigeration system is to contain and repetitively capture, compress, and cool to a liquid state again, a vaporized refrigerant for the purpose of absorbing heat from a space where it is not wanted and rejecting it to a place where it is unobjectionable.

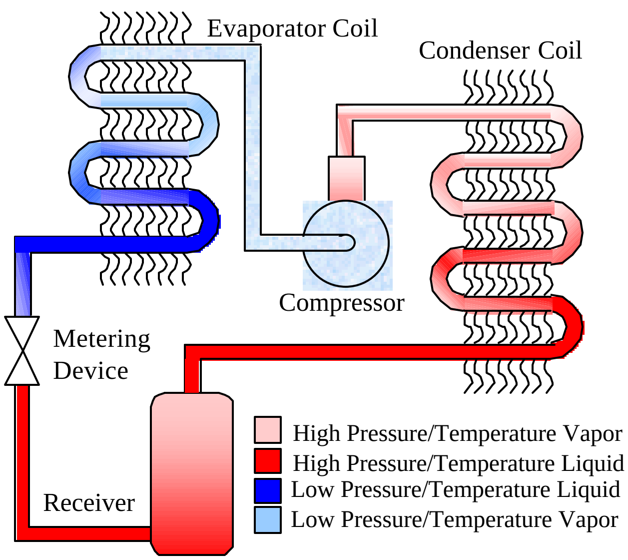
There are four basic components that make up any mechanical refrigeration/air conditioning system. They are the evaporator, compressor, condenser, and metering (control) device. All other components are added to generally help improve the overall system efficiency, capacity, temperature control, and reliability. As a result of the heightened awareness regarding atmospheric release of refrigerants, we will add a fifth component, the receiver. **For illustrative purposes we will start the cycle at the receiver, refer to the diagram below.**

A typical refrigeration system can be seen as two distinct sections or sides. A low pressure side (low-side) and a high pressure side (high-side). The separation of this pressure difference occurs at the metering device and the compressor.

The receiver, located in the high-side of the system, is nothing more than a storage reservoir used to hold excess liquid refrigerant. The amount of liquid contained within the receiver at any given time depends on several system and ambient (environment) conditions.

The volume of the receiver not taken up by the high pressure liquid will contain high pressure vapor as the liquid refrigerant flashes off—remember refrigerants boil at very low temperatures.

The receiver fulfills many jobs within a refrigeration system. When used in a system, it makes the refrigerant charge less critical because of the extra volume and storage area available for the base system charge. During some types of system servicing, it allows for the storage of this charge rather than needing it to be reclaimed. It also insures that the liquid line feeding the evaporator metering device is free of flash gas and contains only liquid refrigerant. On units with only air-cooled condensers (with no sub-cooling circuits) too much liquid refrigerant in the condenser coil can cause a loss in coil efficiency and system capacity. The receiver provides the extra room needed, in system volume, to prevent this from occurring.



Basic Components of a Refrigeration System

From the receiver, high pressure liquid refrigerant is fed through the metering (control) device to the low pressure evaporator coil. There are several types of metering devices available for use in mechanical refrigeration systems, but the most common used in a reefer container is the thermostatic expansion valve (TEV or TXV), of which there are also numerous types. The metering device not only allows refrigerant to flow, but, as mentioned earlier, it is also one of the separation points between the low-side and the high-side. The TXV/TEV does not regulate the low-side pressure; the compressor pumping action establishes this. It just controls the filling of the evaporator with liquid refrigerant and insures that only refrigerant vapor leaves the coil.

We will discuss in greater detail the operation of the TXV/TEV in a future article.

The evaporator coil is used to absorb heat from the refrigerated space into the refrigeration system; thus it is referred to as a heat exchanger. As the high pressure (thus high temperature) liquid refrigerant passes through the metering device into the coil, the liquid is subjected to a much lower pressure/temperature. In this low pressure/temperature state within the evaporator the refrigerant will boil or evaporate as it absorbs heat, turning from a low pressure liquid into a low pressure vapor.

The low pressure vapor is drawn, or sucked, from the coil into the suction side of the compressor where it is reduced in volume as it is compressed in the discharge side. As the low pressure/temperature vapor is compressed, its pressure/temperature is significantly raised, effectively adding heat energy to the refrigerant. This added energy allows for the system to force the heat to flow "uphill," or from low to high verses its natural tendency to flow "downhill," high to low temperatures. As you can see, the compressor discharge and suction sides also form the other system separation point between low and high pressure.

The increased pressure resulting from the refrigerant being compressed raises its boiling point, turning it into a high temperature/pressure, superheated, vapor, which is fed to the condenser coil. The condenser coil is also a heat exchanger, but it is used to reject heat from the system. As the superheated vapor passes through the condenser coil it begins to cool down as it gives up its heat to its surroundings, and condenses back into a liquid state. Once in the liquid state, any further cooling that occurs results in sub-cooling the refrigerant.

From the condenser coil the liquid refrigerant flows back into the receiver, and the cycle is repeated over and over until the desired temperature is reached within the container space—at which time the electrical/electronic controls determine what the system should do next.

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