Inside This Issue

General
✓ Suction Modulation (Stepper Motors)
✓ Mechanical Refrigeration (The Basics)
✓ Conversion Chart
✓ Training School Schedule

Feature Article
● CA – Control Functions (Conclusion)

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.

Continued on last page
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\textsubscript{2} and CO\textsubscript{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\textsubscript{2}, 5% CO\textsubscript{2}) containing a known 0% oxygen mixture, to flow through the gas sensing chamber of the O\textsubscript{2} sensor this function will set and store the O\textsubscript{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\textsubscript{2} and CO\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{2} and CO\textsubscript{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\textsubscript{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.*
**CO₂ 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 CO₂ sensor.

*The membrane filters out most of the CO₂ in the air, providing a nearly “zero point” for the CO₂ sensor.*

This test is initiated by either:

- Pre-trip (P4-0 and/or P6-0) testing.
- User selection via the keypad, N₂ 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 N₂ 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 O₂ and CO₂ 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 CO₂ sensor alarm (AL35) will be activated. The pre-trip calibration will repeat once upon failure according to normal pre-trip testing rules.*

**CO₂ Sensor Span Check**

Allowing “Cal-Gas,” containing a known 5% CO₂ mixture, to flow through the gas sensing chamber of the CO₂ 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 O₂ and CO₂ 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 N₂ rich stream, from the membrane, to flow through the gas sensing chamber of the O₂ sensor to determine the current N₂ 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 N₂ percentage value. Since there is no actual N₂ sensor this value is calculated from the O₂ sensor value. After a minimum of two minutes if N₂ stability is achieved the test will end. If stability is not achieved the test will end at a maximum of eight minutes. If the N₂ 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 N₂ test initiated by the N₂ Check key a CO₂ 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.

<table>
<thead>
<tr>
<th>Date</th>
<th>Program</th>
<th>Location</th>
<th>Class I.D.</th>
<th>Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAY 1 - 2</td>
<td>2-Day Container</td>
<td>Seoul, Korea</td>
<td>465</td>
<td>Korean</td>
</tr>
<tr>
<td>1 - 2</td>
<td>2-Day Container</td>
<td>Oakland, CA</td>
<td>466</td>
<td>English</td>
</tr>
<tr>
<td>3 - 4</td>
<td>2-Day C.A.</td>
<td>Christ Church, NZ</td>
<td>467</td>
<td>English</td>
</tr>
<tr>
<td>8 - 12</td>
<td>1-Week Container</td>
<td>Shanghai, China</td>
<td>468</td>
<td>English/Mandarin</td>
</tr>
<tr>
<td>15 - 19</td>
<td>1-Week Container</td>
<td>Pusan, Korea</td>
<td>471</td>
<td>English/Korean</td>
</tr>
<tr>
<td>15 - 19</td>
<td>1-Week Container</td>
<td>Bremerhaven, Germany</td>
<td>472</td>
<td>English</td>
</tr>
<tr>
<td>22 - 24</td>
<td>3-Day Container</td>
<td>Aarhus, Denmark</td>
<td>473</td>
<td>English</td>
</tr>
<tr>
<td>25 - 26</td>
<td>2-Day C.A.</td>
<td>Aarhus, Denmark</td>
<td>477</td>
<td>English/Danish</td>
</tr>
</tbody>
</table>

| 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.
### TECHLINE

### CONVERSION CHART

<table>
<thead>
<tr>
<th>TECH UNIT</th>
<th>X = ENGLISH UNIT</th>
<th>X = SI UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cm²</td>
<td>0.1550</td>
<td>645.2</td>
</tr>
<tr>
<td>m²</td>
<td>10.76</td>
<td>929</td>
</tr>
<tr>
<td>Energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>kcal</td>
<td>3.968</td>
<td>1.055</td>
</tr>
<tr>
<td>kg·m</td>
<td>7.233</td>
<td>1.356</td>
</tr>
<tr>
<td>kWh</td>
<td>3412</td>
<td>1.055 x 10⁻³</td>
</tr>
<tr>
<td><strong>Length</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mm</td>
<td>0.03937</td>
<td>2.54</td>
</tr>
<tr>
<td>cm</td>
<td>0.03281</td>
<td>0.3048</td>
</tr>
<tr>
<td>Mass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>0.03527</td>
<td>0.02835</td>
</tr>
<tr>
<td>kg</td>
<td>2.205</td>
<td>0.4536</td>
</tr>
<tr>
<td>ton (Long)</td>
<td>1.12 (2240 lb)</td>
<td>0.9072 (US ton)</td>
</tr>
<tr>
<td>Power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>kcal/h</td>
<td>3.968</td>
<td>0.293</td>
</tr>
<tr>
<td>cal/s</td>
<td>14.286</td>
<td>3.927 x 10⁻⁴</td>
</tr>
<tr>
<td>HP metric</td>
<td>0.9863</td>
<td>0.7457</td>
</tr>
<tr>
<td>Mcal/h</td>
<td>0.3307</td>
<td>3.517</td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mm Hg @ 0°C</td>
<td>0.03937</td>
<td>3.386</td>
</tr>
<tr>
<td>kg/cm²</td>
<td>14.22</td>
<td>6.895</td>
</tr>
<tr>
<td>Bar</td>
<td>14.504</td>
<td>0.6897</td>
</tr>
<tr>
<td>Specific Enthalpy</td>
<td>1.8</td>
<td>Btu/lb</td>
</tr>
</tbody>
</table>

### 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- 10⁶
- k kilo- 10³
- c centi- 10⁻²
- m milli- 10⁻³

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

---

B. Hernandez

---

### 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 / kgf** kilogram (mass / force)
- **L** Liter
- **lb** pound
- **m** meter
- **mm** millimeters
- **mm Hg** millimeters of Mercury
- **N** Newton (force)
- **oz** ounce
- **Pascal** Pa
- **psia** pounds per square inch absolute
- **s** second
- **tonne** Ton Metric (1000kg)
- **W** Watt

---

*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.

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.

N. LaCount