CASCADE REFRIGERATION

Revised by: Frank Fulkerson, CMS
Adapted from materials originally provided
By: Charles C. E. Harris

INTRODUCTION

This section is devoted entirely to cascade systems, which are generally accepted for temperatures in the -58°F to -200°F (-50°C to -127.7°C) range. We will aim our interests toward the smaller units, up to about 25 cubic feet, or 1 hp, as they outnumber the larger units many times over.

The use of the cascade system today has a wide variety of applications, ranging from chilling of tools and parts for assembly, to the storage of hi-tech adhesive compounds used in various industries.

In the medical profession cascade refrigeration will be found in the storage of blood plasma, vaccines, specimens, bone banks, biological fluids storage; the list goes on and on.

Most, if not all of the smaller systems use the capillary tube as a metering device. It is inexpensive to manufacture and in general gives little trouble during the life of the unit. The larger cascade systems employ the thermostatic expansion valve, which, with the state of the art today, is very reliable.

The experienced commercial service technician should have little trouble in troubleshooting and servicing a cascade refrigeration system if he has a thorough understanding of the basics of the refrigeration cycle and its underlying principles.

In the ultra low temperature field today the use of a compound system has given way to the cascade system almost 100%.

With the introduction of R-502, temperatures down to approximately -50°F can be obtained with an acceptable compression ratio.

A single stage system capable of reaching these temperatures left little room or need for the compound compression system, as a cascade system can take over at these temperatures.

As there are very few of these systems in use today, we will consider the cascade system only.

Some of the refrigerants listed in Table 1 may not be familiar to all service technicians, while others will be old friends.

Table 1 — LOW TEMPERATURE REFRIGERANTS

REFRIGERANT	BOILING POINT at ATMOSPHERIC PRESSURE °F	°C
12	–21.6	–29.8
22	–41.4	–40.8
13	–114.6	–81.4
503	–126.1	–87.8
170	–127.5	–88.6
1150	–155.0	–103.9
14	–198.4	–127.7

A word of caution to the service technician not familiar with all of these refrigerants: R-13, R-14, R-503, R-170, R-1150 all are at high pressure even at room temperature (400 psig to over 700 psig). TREAT THEM WITH RESPECT! While in addition to the high pressures, Ethane, (R-170) Ethylene, (R-1150) and

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Propane, (R-260) are all FLAMMABLE. Care must be taken when servicing equipment using these refrigerants. A trend away from the use of these refrigerants has taken place in recent years. Institutions purchasing equipment usually require that the unit not contain a refrigerant that is flammable.

R-22 has replaced Propane, while R-13 has replaced R-170. With the availability of R-503 in recent years it has replaced R-1150, which eliminates the use of another flammable refrigerant.

R-22 has lost some of its popularity in recent years as a first stage refrigerant in the smaller units, being replaced with either R-12 or R-500 on air cooled units, which are very popular. With the replacement of the hydrocarbon refrigerants, (R-170, R-1150) some new problems have been created, namely oil return. With the use of either R-170 or R-1150, oil return was not a problem as they would mix well with the oil and aid in its return.

However with fluorocarbon refrigerants it is a different story.

The miscibility of the oil in R-13, R-14, and R-503 is poor at the very best, leading to possible, if not probable, oil restrictions in the colder portions of the system. To overcome this condition an additive such as R-12, R-260 or Pentane must be added to help relieve this condition.

The purpose of these additives is to keep the oil in a fluid state so that it will move back to the compressor freely, without creating a restriction.

Follow the manufacturer's recommendations as to the amounts to be added to any system. As a rule (on the smaller units) the amount is on the order of 1 to 1.5 oz. (liquid) being added to the second and third stages only. In most if not all cascade units the first stage will not require this additive as the evaporator does not reach temperatures below the floc point of the oil.

With separate refrigerant circuits and the choice of several low temperature refrigerants available, maximum capacities can be provided for almost any temperature between -50° and -200°F with the cascade system.

NOMENCLATURE

As the various stages in cascade refrigeration are sometimes referred to as primary and secondary and also as 1st and 2nd stage and 1st, 2nd, and 3rd where 3 stage is concerned, the following terms will be used to avoid any confusion

High Stage The complete high temperature system.

Low Stage The complete low temperature system.

Intermediate Stage The second stage, when a 3 stage system is involved.

Interstage Condenser The heat exchanger between two systems as shown in Figure 2, where the low side of the high stage system provides the condensing medium for the low temperature refrigerant.

High Side As normally used, this refers to the motor, compressor, condenser, etc., of any system.

Low Side The evaporator, plate coils, refrigerated liner, etc., of any system.

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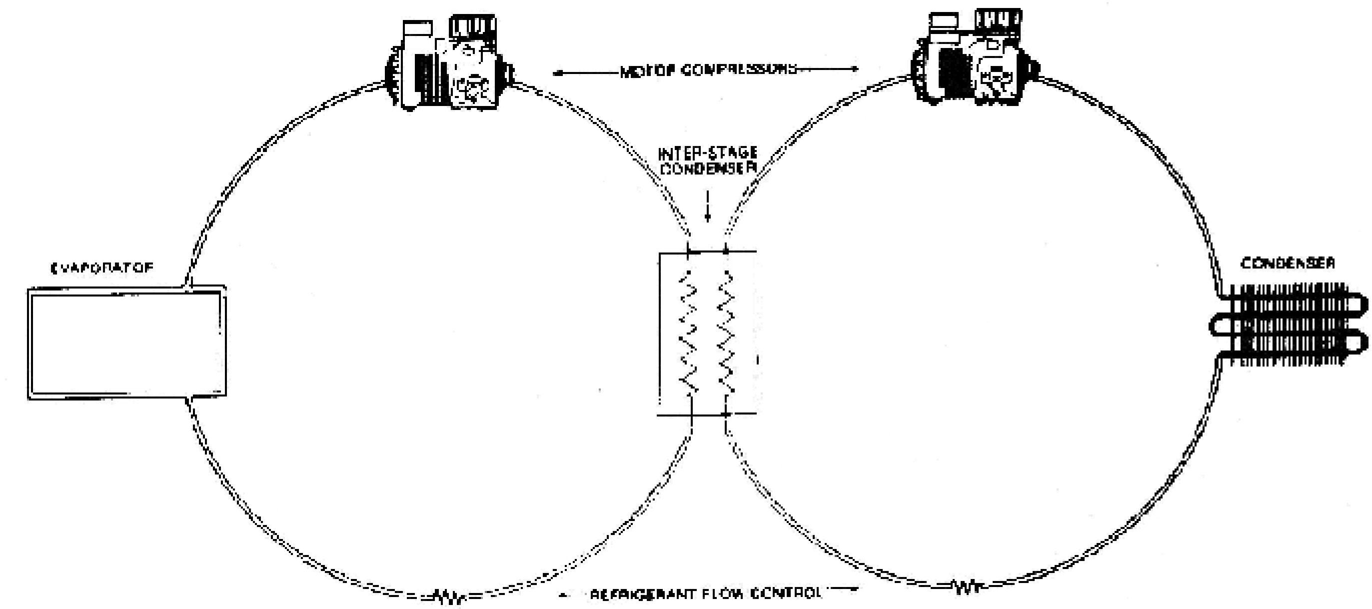

Figure 2

Simplified Drawing Showing Piping Arrangement of a Two-Stage Cascade System

PRECAUTIONS

High Pressure

R-13, R-503, R-170, and R-1150 in a cylinder at room temperature will have a pressure of 500 to 700 psig and R-14 will be higher still. When charging a unit, it is advisable to use a pressure reducing regulator to protect flexible charging lines and gauges and to eliminate the hazard of such pressures reaching the compressor crankcase.

Safety Devices

The low and intermediate stages of all cascade systems will have a relief valve or rupture disc to protect the system against excessive pressures. These should be piped to the outside of the building and kept away from open flames when flammable refrigerants are involved. Even a system using nonflammable refrigerants should be piped outside, as the safety will blow between 300 to 400 pounds pressure and the noise could cause alarm, if not panic.

Flammability

When ethane, ethylene, or any flammable refrigerant is being used, care should be used in purging. Disconnect the line from the rupture disc and use this to purge outdoors. This is an easy and safe procedure, but do not fail to reconnect the line and safety valve when purging is completed.

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If brazing or soldering by torch is necessary in any part of an ethane or ethylene system, purge all gas and flush the system with dry nitrogen before such repairs are attempted.

CAUTION:

As just mentioned, ethane and ethylene are flammable, but unless the unit you are working on is in a very small room or flammable materials are close by, the major hazard is that of receiving burns yourself. Purge the gas outside the building and do not smoke while doing this!

SYSTEM COMPONENTS

Low Temperature Refrigerants

Table 1, beginning with R-12, lists the low temperature refrigerants currently available. The use of R-12 in the first stage and R-13 or R-170 in the second stage is very rare today. However, there are many older units operating today containing these refrigerants. One should be aware of their characteristics. This combination of refrigerants will give you temperatures of -75°C to -85°C, with head pressures between 75 psig and 140 psig and suction pressures from 2 psig to as low as 16" vacuum.

The availability of R-503 has changed the design of new equipment to some extent in the last few years. By using R-500 in the first stage and R-503 in the second stage, temperatures as low as -90°C are commonplace in today's units, with operating pressures in the same ranges.

On some of the new 3 stage units on the market today, temperatures of -120°C are common. These units are similar in design to the -90°C systems, but have a 3rd stage added using R-14, which accounts for the low temperature. These units have operating pressures similar to the units mentioned above, with favorable compression ratios.

Refrigerant Controls

Dependable thermostatic expansion valves designed for low temperature refrigerants will be found on larger cascade systems. Normal procedure is used in applying and adjusting these, except that a little more care must be exercised. A low superheat is desirable to return oil from the low side, but a slug of low temperature liquid can not be allowed to reach the compressor. The expansion valve bulb must be firmly attached and positioned, and insulated as specified by the low temperature equipment manufacturer.

Capillary tubes will be found on most systems up to 1 hp. As a rule the capillary is sized correctly by the manufacturer and no further "engineering" of the cabinet is needed. In cases where oil problems occur often, check with the manufacturer for his recommendations.

Pressure Controls

With the exception of a reverse acting control, the pressure controls will be standard, and used in the normal way. A high pressure control will usually be found on all second and third stages, and in some cases on the first stage. This protects the system against excessive pressures during pull-down, or if there is a failure of the first stage system. The control may cycle a few times at the start. A high pressure control with a 100 pound differential (to allow pressures to equalize) is sometimes used rather than a back pressure regulator.

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Where continuous operation at the lowest temperature is desired, the high pressure control only is used on the low stage. Where control of the low side or fixture temperature is desired, a thermostat, connected in series with the high pressure control, is used. In special applications and on older units, a liquid line solenoid may be used with a low pressure control on the low stage. (A solenoid for such an application requires a waterproof coil in a well sealed housing.)

The addition of a reverse acting pressure control provides automatic operation even when starting warm. With the interstage condenser at room temperature, a pressure of 700 pounds or more would be required to condense the low temperature refrigerant, therefore the low stage compressor cannot be allowed to start until the high stage has lowered the temperature in the interstage condenser to operating temperatures. This has been accomplished in several ways, such as a thermostat sensing the temperature of the heat exchanger, or pressure controls with reverse acting contacts which open on pressure increase and close on a decrease. This control would be connected to the low side of the high stage. Some manufacturers have even used time delays for this purpose, but these offer no protection to the system if a failure occurs. The third stage will have a similar control system.

Low Sides

The usual variety of evaporators will be found from liners built up with freezer plates or wrapped with tubing, to fin-type coils. Finned coils should have a minimum of 1/4 in. fin spacing and a relatively high air velocity. When replacing a low side, an exact replacement is desirable. Otherwise, the circuiting and gas velocity must be carefully considered to insure the best possible oil return.

Interstage Condenser

Many types of these will be encountered, the simplest (found in many of the small cabinets) being a tube within a tube in the insulation around the cold chamber or coiled underneath. In larger installations, a shell and tube condenser will be found in either a vertical or horizontal application.

Miscellaneous

In general most items needed to repair a cascade system will be familiar to the service technician, the one exception being the type of dryers used in these systems. Due to the increased moisture capacity of a molecular sieve dryer, this is the recommended type; or a solid core dryer made by a reputable company. *NEVER USE A LOOSE FILL DRYER.*

DIVERSIFIED APPLICATIONS OF EQUIPMENT

Control Of High Pressure Equipment

Up until a few years ago, most cascade equipment used expansion valves and a low temperature refrigerant charge of at least 3 to 5 pounds which necessitated an interstage condenser receiver capable of holding the refrigerant pressure at 500 to 700 psi so that the charge could be contained there. To put the system in operation, the high stage had to be started and the inlet and outlet valves of the interstage condenser receiver opened when it was down to the working temperature. Any power failure or loss of refrigeration due to any failure in the high stage meant the loss of the low temperature refrigerant charge through the relief valve or rupture disc. The system could not be shut down until the low stage was pumped down and the charge locked in the interstage condenser receiver.

Small self-contained systems using less than 2 pounds of the low temperature refrigerants can be made completely automatic, if space is available to provide expansion tanks of sufficient volume to store the

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refrigerant in the vapor stage at or below 200 pounds pressure. Some of the small chest type units for temperatures down to -130°F using capillary tubes and hermetic compressors can hold the charge in the low side, oil separators, heat exchangers, etc., plus the dome or shell of the unit. As the size of the low side is increased and more refrigerant is required, one or more expansion tanks are required for automatic operation. Good practice limits the maximum pressure to 150 or 200 pounds.

In some cases, the connection to the expansion tank may be a capillary tube. When the unit is shut down, the rise in pressure is slow and most of the charge is stored in the tank. This capillary tube is sized so that the charge in the tank is fed slowly into the system during a pull-down from room temperature. In larger installations where a pull-down imposes a severe load on the motor and compressor, the charge may be admitted to the expansion tanks through a check valve and returned through a pressure reducing valve which can be adjusted to the capacity of the unit during such periods.

Water Cooling Circuitry

The condenser of a high stage does not always receive the incoming water first.

Water is used to remove superheat from the compressed low stage refrigerant before entering the interstage condenser and is also used in some motor cooling jackets. If it were also used on the compressor heads, the flow would be inadequate when the water regulator reduced the flow according to the demand of the high stage. By feeding the condenser last, an adequate flow is maintained at all times.

Frost Suppressors

While not so common today, these will be found on some units in the form of a heat exchanger between the low temperature suction line and the low temperature hot gas line before it enters the interstage condenser.

Liquid Line Accumulator

On some small units using capillary tubes in both systems, a small liquid accumulator may be found in the liquid line of the high stage. This is required, as the capillary tube is sized for continuous operation at low temperature, and during a start-up it can not pass the volume of refrigerant condensed by the unit at high temperatures, thus filling the condenser and causing excessively high pressures. The accumulator or reservoir prevents this pressure during the few minutes required to cool the interstage condenser.

SYSTEM CLEANUP

Cleanup is required any time a system has to be opened, for whatever reason, excluding the addition of refrigerant. Recover the charge according to EPA-approved procedures, and remove the dryer, disconnect the suction line from the compressor, and backflush the entire system with solvent to remove any contaminants or oil from the system. This is most important when replacing a compressor.

Any time a compressor is replaced the oil separator should be replaced also, since the oil separator contains a large quantity of oil that may be contaminated and would ruin the new compressor. It may cost more money, but look at it as an insurance policy for the job. Remember there are no short cuts to a good job, particularly on a cascade system; they show you no sympathy. If you don't have time to do the job right the first time, you certainly won't have time to do it over.

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SERVICE

With a large percentage of the equipment available today being self contained, you will find a majority of the manufacturers supplying an instruction and maintenance manual in some form or other and until you are thoroughly familiar with the operation and performance of such systems, it is recommended that these instructions be followed closely.

Until you have gained experience and knowledge of the operating characteristics of both stages of a system, it is advisable to check the high stage first. Since the high stage provides the cooling for the interstage condenser for low stage operation, any malfunction, especially a faulty expansion valve, plugged capillary tube, or a slight shortage of refrigerant, will cause high head pressure in the low stage. The high stage using R-12, R-22, or R-500 should present no problems.

The low stage should not present any real problems either if you will remember you are working with a high pressure refrigerant and sometimes a flammable one. Refer frequently to the notes under "PRECAUTIONS."

Figure 2 illustrates a two-stage cascade system. Each stage is a separate and simple refrigeration circuit, the only connection being the interstage condenser which is the low side of the high stage and the condenser of the low stage.

Figure 5 is a typical flow chart of a two stage system showing water cooling the low stage desuperheater, compressor heads, both motor jackets and then the high stage condenser, in that order. The heat exchanger with R-22 liquid going through the R-22 suction line also has the low stage hot gas (from the desuperheater) around the R-22 suction line.

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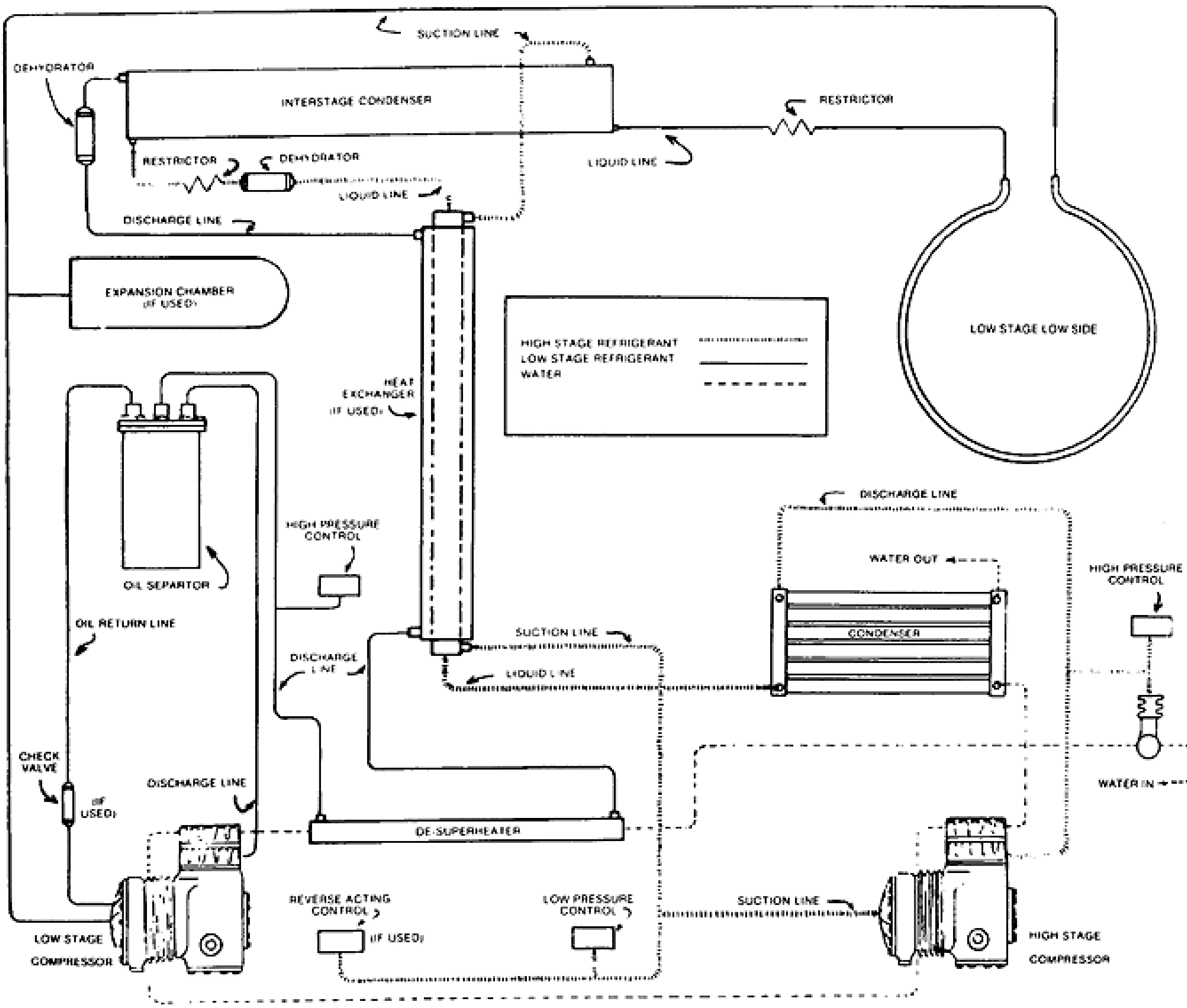

Figure 5

Flow Chart for Two-Stage Cascade System

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Figure 6 is a typical wiring diagram of the system shown by the flow chart, Figure 5. If J.I.C. (Joint Industrial Conference) wiring had been specified, the wiring diagram would probably be in the form shown in Figure 7. This ladder diagram shows exactly the same wiring. Many manufacturers use this type of diagram.

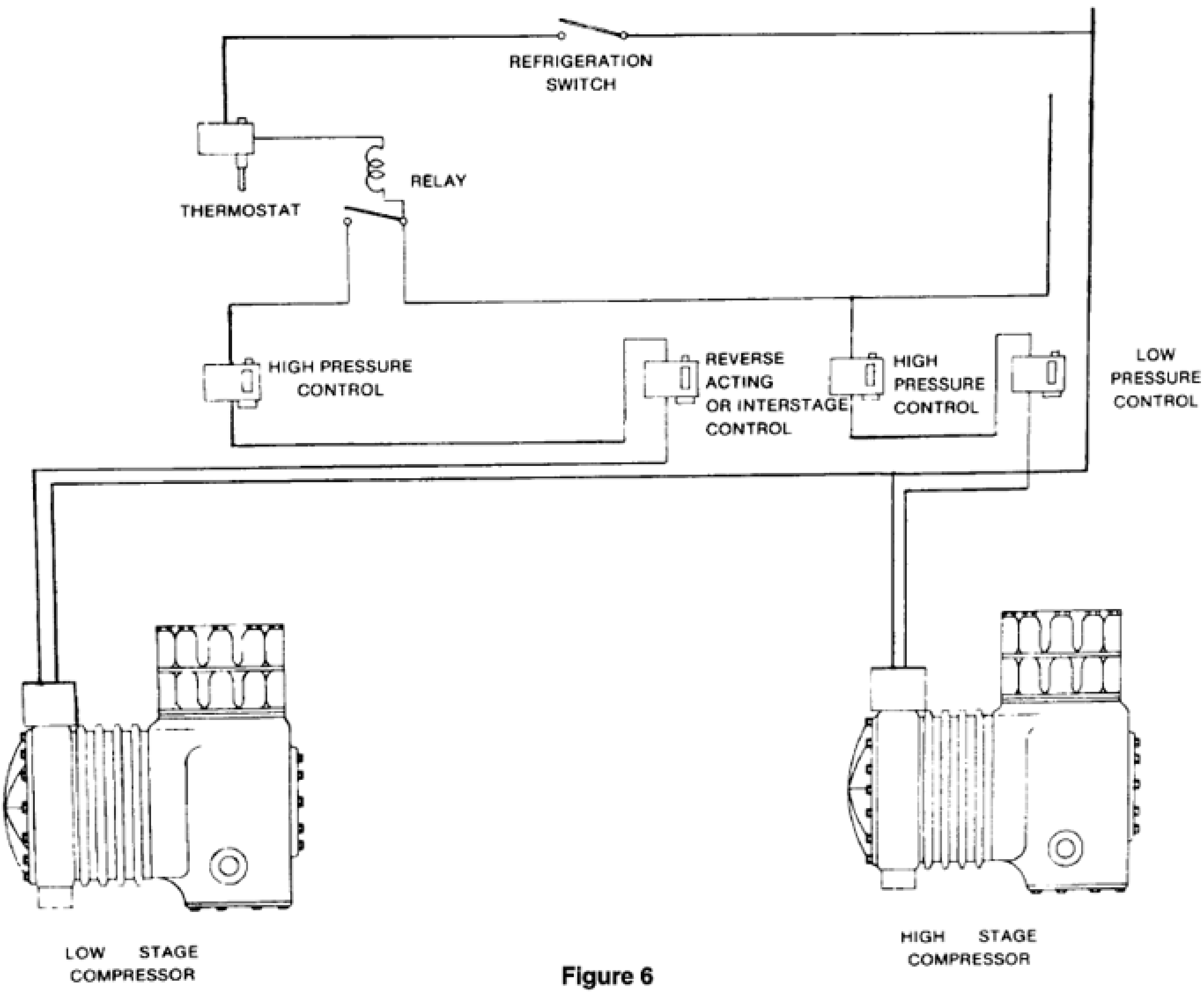

Figure 6

Schematic Wiring Diagram for Two-Stage Cascade System

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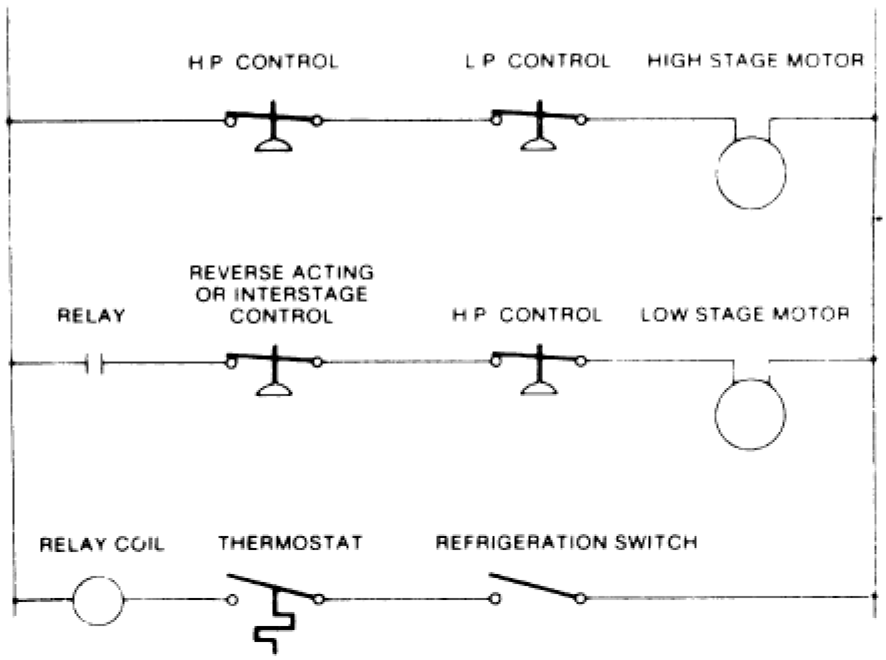

Figure 7

Same Control System as Shown Above Using J.I.C. Wiring Diagram

START-UP

When such a system is started, the contacts in the interstage control are open and, being in series with the low stage starter solenoid, the low stage compressor cannot start. When the interstage condenser is down to a low enough temperature, this control closes, putting the low stage in operation.

With the low side at room temperature, the load will raise the temperature in the interstage condenser but the head pressure in the low stage will rise rapidly and may operate the high pressure control several times before the system is able to handle the load. If the low side is large and cycling of the low stage continues for more than a few minutes, the temperature of the interstage condenser and the back pressure in the high stage will be raised to the point where the interstage control will open and stop the low stage system until the interstage condenser is again down to the required temperature. When the motor compressor is sized for continuous operation at the lowest temperatures, and especially where a convection fluid is involved, a crankcase pressure regulator is used. This is adjusted in the usual way so that current drawn by the motor during a warm start is within the specified rating.

REFRIGERANT LEAKS

Finding a leak in the system using R-12, R-22, R-13, R-500 or R-503 normally present little difficulty. Finding a leak in a system containing R-170, R-1150 or R-14 can be very difficult. The use of the old reliable liquid soap would be one answer, and more likely you may have to recover the charge and install another halocarbon, with the pressure increased with dry nitrogen to about 150 psig. Continue the leak check using an electronic leak detector. In most cases, you can find the leak by this method.

In some severe cases, you may have to resort to removing the compressor and the oil separator from the system, increase the pressure in the other components to a higher pressure, install a pressure gauge, let the unit sit for 24 hrs, and watch for a drop in pressure. This method works well for locating a leak in areas that are hard to reach. Further teardown of the unit may be necessary if a leak is found. Contact the manufacturer for the correct pressures to use.

The electronic leak detector is a fine and valuable instrument; however, it has its limits. Table 2 will help you with leak detection. Using R-12 as a reference of 1, you will have to have a leak rate approximately as much larger as shown in the third column, to be able to read it on the leak detector.

Table 2

DESIGNATION	CHEMICAL FORMULA	LEAKAGE RATE BY VOLUME
R–12	CCl_2F_2	1
R–22	$CHClF_2$	1
R–13	$CClF_3$	33
R503*	Azeotropic mixture	25
R–14	CF_4	75 — 100 approx.
* Azeotropic mixture of R–23 (CHF_3) and R–13 ($CClF_3$)		

With this information in mind, a great deal of care must be taken in locating leaks in systems containing the less common refrigerants. With systems containing R-14, it is going to be tough to find a small leak.

EVACUATION

The proper evacuation of any system is in all probability the single most important phase of the repair. It is even more important to give any cascade system a thorough and complete evacuation, as the success of the repair depends upon this most important phase.

Any time a system has been entered or a leak occurs and has been repaired, there is a good possibility that moisture and some noncondensables have entered the system, and they must be removed. Most low sides on cascade systems operate in a vacuum and if a leak occurs on this side of the system you can have a very real problem with moisture. Most second and third stages of a cascade system will not operate properly if the moisture content of the system is above 2-3 parts per million. *THE SYSTEM MUST BE DRY:*

The triple evacuation method is preferred, rather leaving the system on a vacuum pump over night. It can be accomplished in less time, and other phases of the repair can be done while evacuation is in progress. Furthermore, you are there on the job, should a problem occur with the pump or any of the other components involved with this procedure. If this procedure is left unattended overnight, there are too many unknowns that can cause a failure of the repair.

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A couple of reminders:

1. Heat may be used on the various components of the system to help in the evacuation.
2. When setting up for this type of evacuation, all material that enters the system *MUST PASS THROUGH A DRYER* of sufficient capacity to thoroughly dehydrate the material entering the system. A 5 cu. in. dryer would be large enough. Use it for one job and dispose of it.

ADDING REFRIGERANT

When charging a unit, follow the manufacturer's recommended charges and procedures. Normally the static charge method works well and is dependable, requiring no additional tools or equipment. The only caution here is to make certain that the unit and the ambient temperature are in the manufacturer's specified range. After unit is charged, start it and allow it to come to specified temperature. In some cases you may have to fine tune the charge by adding or purging small amounts of refrigerant. Refrain from this if at all possible. When you start this procedure one is "flying by the seat of his pants" and it is very easy to over- or under-charge the system and create more problems.

The frostback on a system can be used as an indicator of the charge in most cases, normally about 4 to 6 inches from the compressor. But do not depend upon this indication wholly, as the temperature of the returning refrigerant gas is extremely cold.

REFRIGERANT OIL

Some manufacturers supply their compressors and oil separators with oil of the correct amount and type for the unit. Always use the manufacturers' recommendations as to the type of oil to use in their equipment. The synthetic refrigeration oils normally have a lower floc point which is ideal for low temperatures.

On most small systems it is impossible to check the oil after the system has been assembled and started. One must be sure that the oil is correct before installation. On larger units that have visual oil level indicators, a check should be made after a few hours of operation.

CASCADE UNIT ASSEMBLY

Figure 8 shows a two-stage unit assembly on the base for a 10 cu. ft. cabinet which might be used for metal treating (light duty) or biological storage at -120°F. It is air cooled and, except for this, the flow chart in Figure 2 could apply. A small water cooled condenser is incorporated in case of high ambient temperatures, and an extra fan is used to give more air circulation over both compressors. In this case the low stage hot gas desuperheater is a coil of tubing in front of the auxiliary fan. This is the base assembly ready for mounting in the cabinet.

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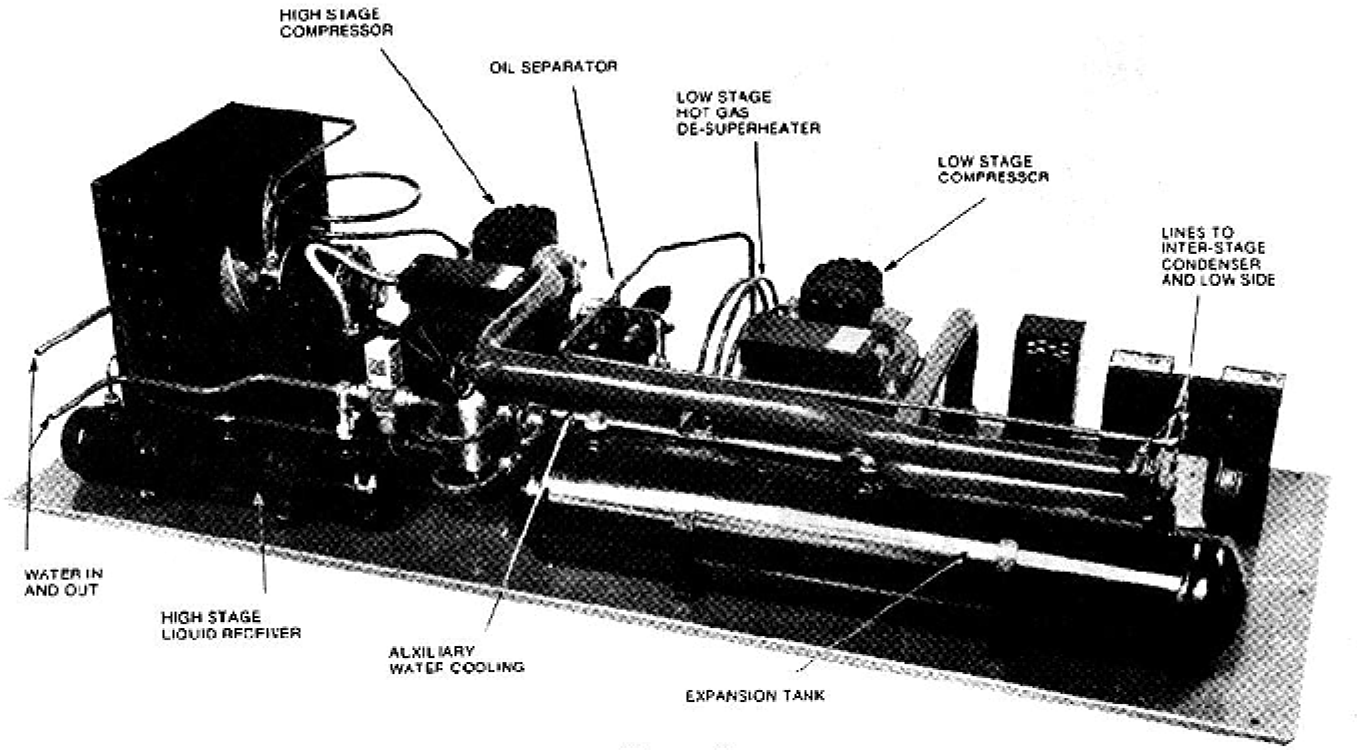

Figure 8
Two-Stage Cascade Unit Assembly

Courtesy of Harris Manufacturing

TROUBLESHOOTING

Don't panic! When you first look at a cascade system, it may seem complicated, and it very well may be. However, with a little study of this type of system the experienced refrigeration service technician should be able to diagnose the problem and repair it.

First, some preliminary checks: Remember you are looking at a unit that has 2 or 3 separate refrigeration systems. *CHECK ONE SYSTEM AT A TIME.*

ELIMINATE ALL POSSIBLE ELECTRICAL PROBLEMS FIRST. Check the power requirements of the unit, to see if they match the power available.

Check the voltage and current at the outlet and at the compressors, to be sure that they are correct. Normally the amperage drawn by each compressor will be approximately the same. Check all electrical components if necessary. Check with the user and get as many facts as possible. Find out how much product has been put in the freezer, and at what temperature.

Also check and find out the usage rate of the freezer (number of door openings per day) if you can. Many users overload their units, either by putting too much product in it at high temperatures, or by repeated door openings.

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Another item to look for is the placement of the unit. If it is in a room with other high heat-producing devices, such as autoclaves, this will increase the ambient temperature of the room.

As the ambient temperature increases, the head pressure increases (in both systems), causing the systems to work harder. This also will affect the internal temperature and operating characteristics of the unit.

Most low temp units manufactured in late years are designed to operate in an ambient of 90°F, but even these units have their limitations, so the service engineer must be on the lookout for high ambient conditions. If this is found, the unit will have to be moved to a cooler location, or the owner will have to install adequate cooling at the present location.

In placing the unit, another point to consider is the location of the room air conditioning discharge ducts, particularly the high velocity type. If the discharge duct is located directly in line with the door or lid of the unit, the stream of air from the duct will force cold air out of the unit when it is open.

Be certain the unit rests evenly on the floor, and is reasonably level. This is important as it will affect the door or lid alignment. Also check the condition of the sublids or inner doors. All are vital to proper operation.

As Father Time begins to take his toll, the integrity of the door gasket and the sublids deteriorates to the point of leakage. This includes both water vapor and heat.

Failure of the above will let in moisture-laden air that must be cooled, thus adding more load to the compressors, not to mention a heat gain and a frost problem.

One more preliminary check must be made: if the unit has an air-over condenser, be sure that it is free of dirt and lint, and kept clear of obstructions. This is where the heat is rejected to the atmosphere. Be sure the customer is aware that this must be cleaned on a regular basis.

Inspect the outside of the unit for evidence of frost or condensation. This condition will indicate that the insulation has become saturated with water and has frozen. Then the insulation becomes an excellent conductor of heat. This will cause 100% run time, and the unit will not maintain design temperature.

The only two known cures for this condition are as follows:

1. Reinsulate the unit, if insulated with fiberglass.
2. If insulation is foam, replace the unit.

Always consult the manufacturer for his recommendations on this type of repair.

This moisture will enter the cabinet through any opening, such as a void in the seals where tubing or electrical wiring enters the cabinet. Even a screw that was not replaced during a previous repair will let moisture in.

Many service technicians do not realize the importance of sealing the openings.

A quick rundown as to what causes this condition:

As the interior of the cabinet is cooled, what water vapor there is in the insulation will freeze out on the outside of the evaporator. This reduces the moisture content of the insulation. With no way for more water vapor to enter the insulation cavity, all is well. But, if there is a void in the seals around the tubing or a screw hole, the vapor pressure being greater on the outside of the cabinet will force moisture into the insulation cavity, and in a short time wet insulation will be the result.

CHECK ONE SYSTEM AT A TIME

DO NOT INSTALL A SERVICE MANIFOLD SYSTEM UNTIL YOU HAVE MADE THE FOLLOWING TESTS.

Get cabinet temperature and ambient temperature, record these and check with the manufacturer's specifications. Check and record the temperature of the heat exchangers, if accessible. Compare this temperature with manufacturer's specifications. If unavailable, compare with the TP chart, to see if the temperature is cold enough to condense the refrigerant vapor in the next stage. If the temperature is not correct further tests will be necessary, which are as follows:

Disable the second and third stage compressors and let the first stage compressor operate for approximately 8 minutes if system has been operating. If unit is at ambient temperature let the first stage operate for 12 to 15 minutes, then check the temperature of the heat exchanger.

Normally with no load on this system the heat exchanger temperature should be between -30°F and -50°F. Check the manufacturer's spec's, if available.

If these temperatures are found to be correct, in all probability the stage is alright, the problem with the unit is elsewhere. If the temperatures are found to be much warmer than those mentioned above, so, -10°F or so, you have trouble with the first stage. Further tests must be made on the first stage system.

If both compressors are operating and the unit is not at temperature, the following procedure may be used: Obtain the temperature of the interstage heat exchanger. On some units this is accessible through the interstage control well. On units that use a timer or pressure switch to control the second stage it may not be accessible.

Obtain this temperature and record it. In a normal healthy unit that is at specified temperature, this will be in the range of -30°F to -38°F. Compare these two readings.

If your readings are warmer than the above, you will find the problem in the first stage.

The problem will be either a short charge of refrigerant, a low capacity compressor, or possibly a restriction, any of which can be determined by installing a service manifold and reading the pressures.

If you have readings colder than the ones above, the problem is in the second stage. The colder temperatures indicate that the second (or third) stage is not loading the first stage to its capacity.

As with any refrigeration systems, inspect for leaks. Check all welded joints, safety valves, rupture discs and control switches.

At this point the technician will have to install a service manifold and make further tests to find the problem.

CASCADE REFRIGERATION

Revised by: Frank Fulkerson, CMS
Adapted from materials originally provided
By: Charles C. E. Harris

NOTE:

***THIS APPLIES TO ALL SYSTEMS:* Before entering a system (installing a service manifold), purge the manifold and all interconnecting lines with refrigerant of the type that is in the system. *THIS IS OF EXTREME IMPORTANCE!* As most cascade systems operate near or in a vacuum, care must be taken not to contaminate the system with noncondensables.**

If service valves are present on the system, the service manifold can be attached at this point. If only process tubes are present, install line taps on both high and low sides.

A WORD OF CAUTION WHEN INSTALLING LINE TAPS: Shut the system down and let it stand idle for at least 5 minutes to allow pressure equalization within the system before installing line taps. Extreme care must be taken, as the system still may be in a negative pressure condition.

Restart the unit and check the operating pressures. Consult the manufacturer for correct operating pressures; if these are unavailable, use your TP chart as a guide for approximate figures.

If the head pressure is lower than normal and the suction pressure is higher than specs, this would indicate a low capacity compressor which would also include leaking valves. If a deep vacuum is shown on the low side gauge and a lower than normal head pressure, this would indicate a probable restriction in the system. Discretion must be used at this point to determine the exact problem. If a low capacity compressor is suspected, use the following test to prove it:

Front seat the suction line valve on the compressor, if so equipped, or pinch off the suction line upstream of the process tube where the manifold is connected.

Operate the compressor for 4 minutes and record the suction pressure. If the compressor does not pull at least 20" vacuum in this length of time, scrap it.

A further test of the valves may be made at the same time. At the end of 4 minutes stop the compressor and wait 1 minute, then check the vacuum gauge for any loss of vacuum. If you lose vacuum, the valves are leaking.

The above test may be used on any compressor, and with a little modification it may be used on the bench.

When using this test the compressor should be operated against a head pressure of 100 psig to 125 psig to give it a load. The pressures on an average system usually fall within this range. This is a valid test for any reciprocating compressor.

A compressor that will pull a 20" vacuum may operate alright on other systems, but will prove to be questionable on a cascade system. In most cascade systems the compressors are operating near their capacity. The 20" vacuum is used as a guide to help determine the compressor's condition. Even though the operating pressures of most systems are not as low as 20", the compressor is of marginal capacity at that point.

By following this troubleshooting guide, Table 3, it should be relatively simple to find the cause of a problem and repair it.

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TROUBLESHOOTING CHART

SYMPTOMS	CAUSE	REMEDY
A. Compressor will not start.	Motor line open.	Close starting switch. Check 208 / 220 / 3 or 230 / 1 etc., power source.
	Fuse blown.	Replace fuse.
	Tripped overload.	Check thermal overload on motor.
	Pressure control stuck open.	Repair or replace.
	Piston stuck.	Remove motor compressor head. Look for broken valve and jammed parts.
	Frozen compressor or motor bearings.	Repair or replace.
B. Unit short cycles during normal operation.	Control differential set too closely.	Widen differential.
	Discharge valve leaking.	Correct condition.
	Motor compressor overload cutting out.	Check for high head pressure, tight bearings, stuck pistons, clogged air or water cooled condenser or water shutoff.
	Shortage of refrigerant.	Repair leak and recharge.
	Refrigerant overcharge.	Remove excess.
	Cycling on high pressure cut-out.	Check water supply.
	Discharge or suction shut-off valve not fully open.	Correct condition.
C. Compressor will not run; hums intermittently (cycling on over-load).	Improperly wired.	Check wiring against diagram.
	Low line voltage.	Check line voltage — determine location of voltage drop.
	Relay contacts not closing.	Check by operating manually. Replace relay if defective.
	High discharge pressure.	Eliminate cause of excessive pressure. Make sure discharge shutoff valve is open.
	Tight compressor.	Check oil level — correct binding.
	No power on one phase.	Check fuses and wiring.
D. Compressor starts, runs slow.	Low line voltage.	Correct condition.
	Improperly wired.	Check wiring.
	High discharge pressure.	Check discharge shutoff valve. Check pressure.
	Tight compressor.	Check oil level. Check binding.
E. Contactor burn — out	Low line voltage.	Increase voltage to not less than 10% under compressor motor rating.
	Excessive line voltage.	Reduce voltage to maximum of 10 %

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		over motor rating.
	Short cycling.	Reduce number of starts per hour.
	Relay vibrating.	Mount relay in rigid location.
	Shorted relay coil.	Replace relay.
F. High stage operates continuously when the low stage is shut down.	Shortage of refrigerant.	Repair leak and recharge.
	Control contacts frozen.	Clean points or replace control.
	Dirty condenser.	Flush condenser.
	Air in system.	Purge.
	Compressor inefficient.	Check valves and pistons.
	Plugged capillary tube or expansion valves.	Clean or replace.
	Low pressure control not working.	Adjust or replace. See Note #1.
	Improper Ref. charge.	Recharge.
G. Low stage inefficient (cooling coil temperature too high).	Inefficient high stage system causing high pressure, inefficiency or cycling in low stage.	Check high stage. See F and H.
	Controls not working properly.	Adjust or replace.
	Dirty condenser.	Flush condenser.
	Air in system.	Purge.
	Plugged capillary tube or filter.	Clean or replace.
	Too much refrigerant.	Purge system until there is only a slight frost at compressor suction service valve.
	Refrigerant shortage.	Repair leak and recharge.
	False indication of temperature.	Check stems of thermometers or recorders.
	Controls out of adjustment.	Reset controls.
	System was not thoroughly evacuated before charging.	Evacuate fully and recharge.
	Compressor inefficient.	Check valves and pistons.
	Restricted gas lines or slow leak.	Clear restriction or repair leak.
	Low stage refrigerant not dry enough.	Triple evacuate, install new dehydrator, and recharge system.
H. High stage head pressure too high.	Refrigerant overcharge.	Purge.
	Air in system.	Purge.
	Dirty or scaled condenser.	Clean or replace.
	Insufficient cooling water.	Locate and correct.
I. Low stage head pressure	Inefficient high stage operation.	Correct trouble in high stage, See B, F

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too high.		and H.
	Refrigerant overcharge.	Purge.
	Air in system.	Purge.
J. Head Pressure too low.	Refrigerant shortage.	Repair leak and recharge.
	Compressor valves inefficient.	Clean or replace any leaky valves and plates.
K. Noisy unit.	Insufficient compressor oil.	Add oil to proper level.
	Loose mountings or hold-down fixtures failing.	Tighten mounting bolts and make sure compressor is riding free on the springs.
	Oil slugging or refrigerant flooding back.	Adjust expansion valve or adjust refrigerant charge in capillary tube system.
L. Low suction pressure. Little or no refrigeration.	Capillary tube or filter plugged, defective expansion valve or plugged strainer.	Clean or replace.
M. Cold compressor body.	Liquid carrying over from evaporator.	Check refrigerant charge and expansion valve.

Note:#1 When the low stage is shut down with the unit in standby operation or, in the case of a storage cabinet, cycling at the desired temperature, the high stage should cut out on the low pressure control shortly after the low stage stops. For example, if the low stage normally cuts out with the high stage back pressure at 6” vacuum, then the high stage low pressure control should be set to cut out at 8" to 10" vacuum. In other words, it should be as close to the 6" as practical, and yet, allowing enough range to ensure that the high stage does not stop while the low stage is running.

When in doubt, or if there are questions about the repair of a cascade system, contact the manufacturer of the equipment.