INTRODUCTION

(Note: Throughout this text, the term “hermetic” also includes semi-hermetic compressor systems.)

Repeated compressor failures on the same hermetic system often can be attributed to an incorrect diagnosis of the initial failure. Improper system cleanup (after components have been replaced) also plays a large part in causing repeated problems. Acid, sludge, carbon, and loose metallic particles, if allowed to remain in a system, will lead to more trouble in the future. Correctly determining the cause of a failure, fixing the problems, and then performing a thorough system cleanup—these are the only ways to reduce the possibility of successive failures.

It is imperative that the cause of a motor failure (also called a motor burnout) be identified correctly. The effects on the system can vary a great deal depending on the cause, as can the methods used to clean up the system after this type of failure has occurred. The service technician first must determine if a motor failure has occurred, then how severe it is. Once that evaluation has been made, the technician must observe the proper guidelines for compressor replacement (if necessary) and system cleanup. This chapter offers a step-by-step procedure, presented in outline form, for the technician to follow.

I. FORWARD

The failure of a hermetic compressor that results in a motor burnout can pose a significant service problem. Merely replacing the compressor with a new unit does not ensure that the system will be restored to reliable service. Experience has demonstrated that if repeated failures are to be avoided, attention must be directed to the correction of any system faults that may have contributed to the original failure.

II. SCOPE OF THE PROCEDURE

The purpose of this procedure is to describe the basic requirements for restoring a system to reliable service. Note: This procedure is limited to positive-displacement systems. Even on these systems, any specific recommendations of the original equipment manufacturer should be given preference. The guidelines contained in this chapter are intended for use only when specific manufacturers’ recommendations are not available. This chapter will present the following information:

- How to determine if a motor failure has occurred
- How to determine the severity of a motor failure
- System failure indicators
- Methods of cleanup
- Background information

III. UNDERSTANDING THE CAUSES OF MOTOR FAILURE

In a hermetic refrigeration system, the compressor motor is located within the closed refrigerant circuit, enveloped by an atmosphere of refrigerant vapor. There is a very close interdependence between the hermetic motor and its surrounding atmosphere. Under normal conditions of operation, the motor relies on this vapor as a heat transfer medium to carry away the heat generated in the motor windings. The insulating action of the vapor also serves to sustain and augment the insulation of the motor.

The term “motor burnout” is used to describe a disabling failure in a motor’s electrical insulation.
Because this insulation system is distributed over multiple motor windings and is itself made up of several individual subsystems, insulation failures may occur in a variety of ways. As a result, the details of individual burnouts may vary greatly from case to case. When a motor failure occurs, there is usually a sudden release of electrical energy inside the motor housing at the point of insulation failure. This uncontrolled electrical discharge can generate very high localized temperatures—high enough to char or disintegrate electrical insulating materials, to chemically alter the system’s lubricant, or to thermally decompose refrigerant in the immediate area of the failure.

A. Causes of motor failure

Individual motor failures may result from any of a variety of different system malfunctions. Any condition that leads to abnormal stresses on the electrical insulation, or to a weakening of the insulation’s effectiveness, may trigger a motor failure. The insulating materials employed in motor windings are limited in their ability to withstand high operating temperatures, so high motor temperatures can lead directly to insulation damage and subsequent failure. Some specific operating faults that may contribute to motor failures include:

1. Supply voltage too high or too low
2. Failure of start capacitor or run capacitor in single-phase motors
3. Defective start relays in single-phase applications
4. High-voltage surges as a result of lightening strikes
5. Uneven system phase balance on three-phase systems
6. Unbalanced power supply voltage on three-phase systems
7. Single phasing (three-phase applications)
8. Short cycling
9. High compression ratios
10. Excessive suction superheat
11. Lack of proper motor cooling in air-cooled or water-cooled applications
12. Overloading of motor caused by
   a. Dirty or fouled condenser
   b. Overcharge of refrigerant
13. Damage to compressor caused by
   a. Contaminants in system
   b. Lubrication failure
   c. Breakage of internal parts (valves, etc.)

B. Results of motor failure

The first and most noticeable result of a motor failure is the failure of the motor to operate when properly connected to its normal power supply. A second but less obvious result may be the release of alien materials into the refrigerant circuit. All of the products formed as a result of motor failure should be regarded as contaminants as far as the refrigerant system is concerned. Some of these products may be very hazardous to the health of the service technician as well. These products include:

1. Loose debris from damaged insulation
2. Free carbon
3. Oil sludge
4. Acids
   a. Hydrofluoric (HCFCs and HFCs)
   b. Hydrochloric (HCFCs)
5. Acid reaction products
6. Heat reaction products (copper)

These contaminants, if left undisturbed in a system, can themselves contribute to future compressor failures by:

1. Physically or chemically damaging the insulation of the replacement motor
2. Causing short circuits at motor terminals
3. Causing mechanical problems
   a. Restricting oil supply passages
   b. Eroding or obstructing valves
   c. Clogging inlet and oil screens

In order to restore a system to proper operating condition, therefore, it is very important for all contaminants produced by a motor failure to be cleaned from a system.

IV. DETERMINING IF A MOTOR FAILURE HAS OCCURRED

A. Determining if the compressor has failed

The first task for the service technician is to determine if in fact the compressor has failed. This can be done in several ways. If the compressor will not start,
follow the service procedures provided by the equipment manufacturer. In the absence of manufacturer’s recommendations, you may follow the steps in the checklist below.

B. Checklist

After checking the fuses or circuit breakers and ensuring that the proper voltage is present at the unit, use the following checklist to make certain that the compressor, and not some other component, has failed.

1. Open all electric circuits (may have separate control circuits)

2. Check system components for condition using a reliable meter
   a. High-pressure switch
      Open or closed?
   b. Low-pressure switch
      Open or closed?
   c. Oil failure switch
      Open or closed?
   d. Motor protector
      Open?
   e. Capacitors
      Values OK?
   f. Start relays
      Values OK?
   g. Contactor
      Coil OK?
      Connections OK?
   h. Control circuit
      Voltage OK?
      Calling?
   i. Compressor terminals
      Grounded?
      Resistance correct for the type of motor?

The most common indicator of a compressor failure is that the motor has gone to ground. If this is the case, the service technician can be assured that there are hazardous materials in the unit. Always take the proper precautionary steps to protect yourself and your fellow workers.

Once you have determined that the compressor will have to be changed, there are several steps that must be taken in order to clean up the system. Follow the steps in the next section as a guideline to do the job properly.

V. REPLACING THE COMPRESSOR

A. No service valves in system

1. Recover the refrigerant from the system in accordance with current EPA regulations (install piercing valves if needed)
2. Remove the failed compressor
3. Purge excess lubricant from the system (nitrogen is an excellent product for this)
   Note: Be aware that there may be potentially harmful products (acids, etc.) present in the failed unit.
4. While the system is open, check the metering device
   a. Check for restrictions on TEV units
   b. Check the liquid inlet screen on the TEV
   c. Check the TEV and bulb for security and condition
5. Change the liquid-line filter-drier, or install one if none is present
   Caution: Do not oversize.
6. Consider installing isolation valve(s) in the system
7. Install a suction-line filter-drier (where needed)
8. Set the replacement compressor in place (do not attach the gas lines)
9. Check the motor resistance readings
10. Connect the compressor electrically (ensure that the terminal box and cover are in place and secure)
11. Close the electric circuit and operate the compressor for a short period of time (15 to 20 seconds)
12. Using nitrogen, check all pressure switches for proper settings
13. Connect the compressor gas lines (sweat or bolt up)
14. Following EPA guidelines for proper gas mixtures, check the system for leaks (no pure gas)
15. Evacuate the system to the proper level
   a. HCFCs to 1,000 microns (holding)
   b. HFCs or PFCs to 500 microns
   Caution: Do not operate the compressor during this procedure.
16. Charge the system according to the manufacturer’s recommendations (never allow liquid in the low side)
17. Check the operational cycle (always keep a log of relevant operational data)
18. If a suction-line filter-drier has been installed, make arrangements for a return call within 48 hours to
   a. Check for pressure drop across filter-drier
   b. Check lubricant for presence of acid

B. With service valves in system

   Observe the same procedure as listed above, with the following additions noted:

   1. Isolate the receiver if possible (if a receiver is installed)
   2. Check the solenoid valve(s) or other system devices (CPR, EPR, etc.) for condition, and replace as necessary
   3. Check the lubricant level in the compressor during operation (remove excess lubricant as necessary)
   4. After about three hours, check the pressure drop across the filter-driers (see Table 1)

VI. REPLACING LARGER COMPRESSORS WITH SERVICE VALVES

A. Mechanical failures

   After determining that a compressor has failed—whether the cause is mechanical or electrical—the first step is always to open all electric circuits. Then recheck all of the circuits a second time to ensure that voltage is not present. If it is a mechanical failure, proceed as follows:

   1. Isolate the compressor with service valves
   2. Recover the refrigerant in the compressor body according to EPA specifications
   3. Remove and replace the compressor following proper procedures
   4. Before connecting the compressor to the refrigerant lines, check the following devices for proper operation and settings
      a. Low-pressure switch
      b. Oil pressure switch
      c. High-pressure switch
      d. Motor resistance(s)
   5. Evacuate the replacement compressor to the proper levels for the refrigerant being used
      a. HCFCs to 1,000 microns (holding)
      b. HFCs to 500 microns (holding
         Note: Never use the system compressor for this function. Remember, the high-side valve is closed.

   6. While evacuating the replacement compressor, inspect the failed compressor (semi-hermetic compressors) in order to determine the cause of the initial failure and identify actions that may be necessary for preventing a recurrent failure
      Note: Should the vacuum rise above 2,500 microns, it is an excellent indication that a leak is present. Find and correct it before going on to Step 7.

   7. Open the service valves, and restart the replacement compressor

   8. Add refrigerant as needed to bring the system to normal operating conditions

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<th>Temporary installation</th>
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Table 1. Maximum recommended pressure drop for suction-line filter-driers, psi
9. Observe the level of lubricant in the crankcase during the initial run period and remove any excess.

10. After the replacement compressor has run for a period of time and stabilized, check the pressure drop across the filter-driers (it normally should not exceed 2 psi for filter-driers in the liquid line, or 3 psi for suction-line filter-driers in air conditioning systems using R-22).

11. Take corrective actions as necessary if the pressure drops are excessive.

B. Electrical failures

If you are dealing with an electrical failure, all of the steps in the mechanical section need to be followed. In addition, the following items need to be addressed:

1. Recover the refrigerant from the system in order to
   a. Examine TEV screens (clean or replace)
   b. Replace the liquid-line filter-drier (or install one if none is present)
   c. Clean solenoid valves, if present
   d. Replace suction-line filter-drier, if present

2. Evacuate the system to the required levels, per the refrigerant to be used
   a. HCFCs to 1,000 microns (holding)
   b. HFCs to 500 microns (holding)
   *Note: Never use the system compressor for this function. If you are unable to hold these levels and the vacuum rises above 2,500 microns, it is an excellent indication that a leak is present. Take the necessary actions to find and correct it before going on to Step 3.

3. Charge the system with refrigerant (either new, recycled, or reclaimed), then start the system and put it into operation.

4. Observe the level of lubricant in the sight glass, and remove excess as necessary.

5. After the compressor has operated for a period of one to three hours, check the driers for pressure drop and take corrective actions as necessary.

6. Make adjustments as necessary to correct any conditions noted in the examination of the failed compressor, such as:
   a. Suction superheat
   b. Unloader sequence steps
   c. Low-pressure cut-out settings
   d. Oil failure switch settings
   e. Temperature control settings
   f. Freeze stat settings
   g. Condenser fan cut-in/cut-out settings.
   h. Restart controller settings (delays)

7. Make a log of how the unit operates, so that you have a reference to return to later on if the need arises.

NOTES

Note #1

Service technicians should become very familiar with such vendor bulletins as Sporlan Catalog 201 and Alco Catalog 28, which give tonnage values for driers used with present-day refrigerants. Because it is important for driers to be sized correctly (neither oversized nor undersized), all manufacturers’ recommendations should be adhered to. When suction-line filter-driers are to be installed, carefully observe the instructions per the vendor’s bulletins, or potential damage to the replacement compressor can result.

Many technicians install a suction-line filter-drier (as well as a liquid-line filter-drier) and, once it has been installed, forget that it’s there. They never think about returning to see if it is experiencing excessive pressure drop, or if the cores need to be removed and ordinary filters installed (as is the case with some larger units). This is especially true in today’s workplace, because refrigerants must be recovered in order to accomplish such change-outs. For this reason, technicians should give some thought to installing a bypass loop around the liquid-line filter-drier, as shown in Figure 1. This arrangement allows the technician to check the pressure drop (and, if necessary, bypass the refrigerant flow around the drier), recover the refrigerant from the drier(s) to be

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[Diagram of Bypass Loop]
changed, evacuate the replacement drier, and restore the system to operation—all in a comparatively short time, and at a reduced cost to the customer. Such a course of action adds to the potential service of the replacement compressor, no matter what caused it to fail in the first place.

Note #2

Table 1 on page 4 lists the maximum recommended pressure drop for suction-line filter-driers.

Note #3

To review the full range of EPA regulations would take several pages, so suffice it to say that the competent technician must be fully aware of those regulations. Different gases require different levels of evacuation, depending on the quantity and type of refrigerant being recovered. If in doubt, obtain a copy of U.S. 40 CFR Part 82, Subpart F, or the RSES Refrigerant Usage Certification handbook. The possibility of further changes in the EPA regulations implementing Section 608 of the Clean Air Act make it imperative for the technician to stay abreast of developments in this area.

Note #4

Before installing a replacement compressor, be sure to check the motor terminals for proper resistance (never in a vacuum).

**APPENDIX: MOTOR BURNOUT ELECTRICAL CHECK**

Many motor failures can be traced directly to the malfunction of electrical components. Low voltage often contributes to component malfunction, and ultimately to compressor failure. If low voltage is a known problem, the technician should give consideration to the installation of “buck/boost” transformers to alleviate the condition.

It is imperative that a thorough electrical check of each component, plus a series check of all controls wired in place, be made prior to the start-up of a replacement compressor. The following electrical items can contribute to a compressor failure, and should be checked whenever a replacement is being installed:

- Wiring (look for charred wire and insulation)
- Supply voltage, phase balance
- Relays
- Start and run capacitors (measure values)
- External overload devices
- Remote protective devices (fuses and circuit breakers)
- Contactors
- Thermostats

**Wiring**

*Caution:* Make sure that all power sources are turned off. Many systems use multiple power sources. Wear protective equipment and exercise extreme caution when working around these potential hot spots.

Check all wiring, looking for burned insulation, loose connections, etc. Check the type and size of all fuses, making certain that they conform to the manufacturer’s recommendations and are in compliance with local codes. Do the same with circuit breakers. Look for signs of corrosion and for any mechanical damage. Take corrective action where needed.

**Supply voltage and phase voltage balance**

To be sure that the voltage being supplied is within the accepted tolerance stamped on the unit’s nameplate, always check the supply voltage while the unit is under load. A ±10% deviation from the nameplate value is usually acceptable, but many 208/230-V motors will present problems if the voltage being supplied is more than 5% below the nameplate value (that is, the lower voltage on multi-voltage motors).

In three-phase installations, it is very important to check phase voltage for proper balance. Make this check at the “T” side of the contactors, with the compressor operating under load. The deviation between phases should not exceed 2%. More than this will seriously affect the compressor motor, and should be corrected. *Note:* Look at a building’s lighting circuit as a potential source of this type of unbalance.

**Relays**

Relays can malfunction due to welded contacts, an open coil, or an armature welded to the coil. Since in most cases it is difficult to determine if the relay is
acceptable, and since the cost is minor, it is always a prudent idea to replace the relays when replacing the compressor, especially in cases where there has been a motor failure.

**Start and run capacitors**

Capacitors should be tested in accordance with the recommendations of the test equipment manufacturer. Confirm that the capacitance reading obtained is in agreement with the capacitor’s stated values. In the event that suitable test equipment is not available, these parts should be replaced.

**External overloads and remote devices**

In most cases, it is impossible to determine the calibration or condition of these components. Because they may have been responsible for or affected by the original motor failure, they should be replaced.

Remote devices, such as oil pressure failure switches, high- and low-pressure switches, and defrost timers, should be closely checked for proper operation. Should there be any doubt, replace the component. In “part wind start” applications, the delay device used for step starting should be checked very thoroughly, and the time increment noted. Again, if you are doubtful about this part, replace it.

**Contactors**

Contactors should be checked for cleanliness, and for clean mechanical operation. Points should be observed for pitting and burns. The armature and the holding coil should be clean and free of oxidation. If there is any doubt about the contactor or its components, it should be replaced—or, in the case of larger units, rebuilt with replacement parts for that particular device. If a motor failure has occurred, contactor replacement is strongly recommended.

**Thermostats**

Thermostats can be the source of many problems, and should be checked any time a compressor is being replaced. Note the location of the thermostat, and how it might be affected by drafts (in the case of air conditioning) or vibration (in many refrigeration applications). A system that lacks a time-delay relay in the control circuit may be susceptible to rapid cycling of the compressor if the thermostat is subject to contact chatter.

**Safe filling capacity of refrigerant cylinders**

The service technician needs to be very aware of the condition of the equipment being used and the procedures being followed in the course of recovering refrigerant from any system. Among the items that require constant attention are:

- Be familiar with recovery cylinder markings (yellow tops, gray bottoms)
- Correctly identify the refrigerant being transferred into the recovery cylinder
- Be familiar with recovery standards for the equipment being used (remember that equipment manufacture dates can change the recovery requirements)
- Be aware of the test dates of the recovery cylinders being used (5-year retest)
- Be familiar with the operation of the equipment being used
- Document the procedures used and the quantity of refrigerant recovered, as well as what was done with the product after recovery
- Use proper safety equipment (safety glasses, gloves) when performing this operation
- Do not overfill recovery cylinders (the nominal rule now used is 80% of capacity)
  
  *Do not vent!*

**AFTERWORD**

Approximately 80 to 85% of the compressors returned to the manufacturer or remanufacturer are returned because they have failed motors. However, only about 5% of those units are true “motor failures.” That is, only a small number of compressors actually fail because of a defective motor. Which means that a far larger percentage of burned-out motors are the result of some other problem(s) in the system. (As a service technician, you should also know that from 2 to 10% of the compressors being returned have no problems whatsoever, and are correct in all respects.)

Many compressor manufacturers and remanufacturers now require all electric start/run components to be changed in cases where a motor failure has
occurred. You must provide proof that you have done so, or the warranty will not be honored if the replacement is returned.

Technicians should also take note of the advances that have been made in tools and instruments in recent years. The infrared thermometer has proven to be an excellent tool for taking superheat readings, and is a time saver as well. This tool is almost mandatory when you are working on a new system, as is a digital multimeter (preferably a true RMS model). Most technicians today have nitrogen available. This product can be used to set pressure switches while a compressor is out of the system. Again, it can be a real time saver—and, in the case of a high-pressure switch, perhaps a life saver.

Finally, always be aware that help on almost any matter is available through your local RSES chapter, or through RSES International Headquarters.