SERVICING OPEN TYPE COMPRESSORS

Most open type compressors can be readily serviced in the field. Often repairs can be made on the job, but in some cases it is preferable to take the compressor into a shop for servicing. The following covers some of the more common servicing operations.

REPLACING VALVES

Leaking valves are one of the most common causes of failure or poor compressor performance. Methods of checking the suction and discharge valves were covered previously in Part I.

The first step in replacing the valves is to pump down the compressor to approximately 2 to 5 psig suction pressure. This can be done by operating the compressor and slowly closing the suction s.o.v. and intermittently operating the compressor until the suction gauge reads just above atmosphere. The line switch should then be opened and the discharge s.o.v. then closed. The high pressure gas in the cylinder head can be allowed to bleed off by loosening the discharge s.o.v. gauge plug or any high pressure connection on the cylinder head or body. The cylinder head cap screws can then be removed and the valve plate and cylinder head taken off.

One should inspect the valve plate, inside of the cylinder head, cylinder walls and piston heads when the compressor is thus opened. If any copper plating, corrosion, or carbonization of the oil is observed, it indicates the presence of moisture or acid in the system. Unless steps are taken to correct the situation, more severe trouble will soon be experienced.

If the corrosion, oil carbonization, etc. is not too severe, changing the valve plate, cleaning the cylinder head, replacing the oil and installing a new drier will probably remedy the situation. If there is evidence of severe acid reaction, however, the compressor should be completely dismantled and cleaned, the entire refrigerant charge should be purged, a new drier installed and the system thoroughly evacuated before being recharged and placed in operation.

If a large system charge is involved and contamination is not too severe, instead of purging the charge a system cleaner (suction line filter dryer and replacement liquid line dryer) can be employed to remove the acid and moisture from the system.

In replacing the valve plate only, the gasket surfaces of the cylinder head and top of the body should be scraped to remove all bits of the old gaskets. Do not let any particles of gasket or any foreign matter fall into the cylinders or crankcase. The new valve plate and valve reeds should be washed in solvent and blown off with compressed air, if available.

New gaskets should be installed after being lightly coated with refrigerant oil. The edges of the reeds should be felt to determine whether they have any burrs. (Some reeds are stamped and not deburred, in which case the reed must be installed with burred edge away from the valve plate or valve seat).

If the serviceman has to cut out a gasket, the gasket material must be as thick as that originally furnished. (If a valve plate gasket is too thin, there is danger of a piston hitting the valve plate or a suction reed.)

After replacing the reeds, gaskets, valve plate and cylinder head, tighten all cylinder head bolts finger-tight. Then with a socket wrench or box wrench go around tightening each capscrew a little at a time until all capscrews are snug and tightened evenly.
Figure 1 illustrates a good order in which to tighten the cylinder head capscrews. The proper amount of torque to be applied is approximately as follows:

<table>
<thead>
<tr>
<th>Size</th>
<th>Capscrews</th>
<th>Torque</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4&quot;</td>
<td></td>
<td>100 in. lbs.</td>
</tr>
<tr>
<td>5/16&quot;</td>
<td></td>
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</tr>
<tr>
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<td></td>
<td>400 in. lbs.</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td></td>
<td>500 in. lbs.</td>
</tr>
</tbody>
</table>

The next step is to open the discharge s.o.v. gauge port and purge some refrigerant through the crankcase and cylinder head or, preferably, evacuate the compressor with a good vacuum pump, break the vacuum with refrigerant vapor and with the gauge plug replaced, the valve can then be opened and the compressor operated.

When the air has cleared, all joints of the compressor should be leak tested.

**REPLACING SEALS**

Of the troubles that do occur with open-type compressors, a seal leak is one of the most serious. If the system is operating on a positive low-side pressure, a seal leak results in loss of refrigerant and oil. In extreme cases, so much oil might be lost as to cause complete scoring or seizing of the compressor. If the normal low side pressure is a vacuum, a seal leak is all the more disastrous, as air and moisture is
then drawn into the system, resulting in contamination of the entire system. This requires considerable
time, expense, and effort to correct.

When leak tested and found to be leaking refrigerant, the seal assembly should be replaced. There are
many designs of seals, although the one illustrated in Figure 2 is perhaps the most common. This type of
seal assembly consists of a stationary bellows with an internal spring. The force of the spring maintaining
a strong contact between the nose of the seal and the shaft shoulder produces an effective seal.

![Type of Inside Stationary Seal](image)

**FIGURE 2**

To replace a seal, it is usually advisable to remove the compressor and do the work on a bench or in a
shop.

To remove the compressor, open the line switch and close the suction and discharge shut-off valves.
Then loosen the gauge plugs and let the gas in the compressor escape. Remove the capscrews by which
the shut-off valves are attached to the compressor body. Then loosen the valves from the body, allowing
the valves to remain on the suction and discharge lines. Loosen the compressor hold-down bolts,
disconnect the control lines and remove the compressor and flywheel from the condensing unit.
Remove the flywheel from the shaft, using a wheel puller. The seal assembly can then be removed.

The replacement seal parts should be washed in solvent and dried before installation. All parts must be handled carefully. The seal nose or ring will be ruined if these finely machined surfaces are scratched or marred in any way. The seal faces should be wiped clean on a chamois.

With the seal design shown in Figure 2, it is important that the shaft be clean and entirely free of corrosion and sharp edges. If the shaft is corroded or marred, it can be polished using a fine emery cloth. After thoroughly washing the shaft in solvent and blowing it off, apply a light coating of refrigerant oil to the shaft and inside of the rubberlike friction ring.

The replacement seal assembly should be installed by reversing the dismantling procedure. All gasket surfaces should be scraped and new gaskets should be used. Refrigerant oil should be applied to the seal faces, shaft and gaskets.

The capscrews should be tightened uniformly, and no more torque applied than the following:

<table>
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</tr>
<tr>
<td>1/2&quot;</td>
<td>Capscrews</td>
<td>500 in. lbs.</td>
</tr>
</tbody>
</table>

The compressor should be recharged with the proper amount of refrigerant oil of the type and exact viscosity recommended by the compressor manufacturer.

The flywheel can then be attached and the compressor reinstalled in the condensing unit. The compressor should then be evacuated and the vacuum broken with refrigerant vapor, the valves opened and the compressor operated. As soon as the air is clear of refrigerant, the seal and all gasketed joints should be leak tested.

OVERHAULING OPEN TYPE COMPRESSORS

Due to the many different designs, different tolerances and limits of alignment, variation in clearances of the various makes and models of open type compressors, the instructions on overhauling must be very general. If a compressor is noisy or inefficient (other than due to defective valves), it is usually necessary to completely disassemble the compressor and inspect it thoroughly, if a good repair job is desired.

The compressor can be removed by the same procedure as outlined above for repairing the seal. The compressor should then be dismantled by first removing the cylinder head, valve plate, and bottom plate. Using a center punch, the pistons and rods should be marked so they can be reassembled in their same relative location. The seal assembly, shaft, and piston-pin-rod assemblies should then be removed. All parts should be cleaned in solvent and inspected for wear and defects.

Worn connecting rods are frequently the cause of a noisy compressor. The fit of the rods to the shaft or eccentrics should be tested. If excessive play seems to exist, the rods should be replaced. If the shaft journals or eccentrics are scored or, on checking with a micrometer, found to be out-of-round, they should be replaced.

If more than a slight amount of play is observed between the piston pins and rods, oversize piston pins should be installed or the rods and pins replaced. If the pins are locked to the rods or the normal bearing
being between the piston pins and pistons, or piston bushings, excessive play at this point will require
installation of oversize piston pins, or new pistons and pins.

If the pistons incorporate piston rings, new rings should be installed. If the pistons are of the ringless type,
then fit should be closely checked. If over .001" clearance exists between the diameter of the piston
(ringless type) and average diameter of the bore, new pistons should be installed. (With ringless pistons
the desired clearance is usually .0004" for small size bores of 1-1/4" or less, and increasing to .0007" for
the largest sizes of ringless pistons.) If the new piston is too tight a fit, the cylinder can be lapped with the
old piston, or honed until the proper fit is obtained.

In an emergency a loose ringless piston can sometimes be made to operate satisfactorily by cutting
grooves and installing rings on it.

Badly worn or scored cylinder walls or main bearings require a major repair operation, and in a properly
equipped shop. If oversize pistons can be obtained, the cylinders can be bored and lapped oversize to fit
the new pistons. If oversize pistons cannot be obtained, and the cylinders are badly scored, the cylinders
can sometimes be bored 1/8" or more oversize, and sleeves installed. Obviously, when it comes to boring
cylinders, installing sleeves, etc., proper and accurate equipment for doing these operations is necessary.
The same holds true if replacing main bearing bushings. In most cases, proper alignment will not result if
the worn bushings are merely pressed out and new bushings pressed in and reamed to fit the shaft. For
quiet operation and long life the main bearing bores must be at an absolute right angle to the cylinder
bores. Even a slight misalignment will result in excessive wear and noise in a very short time.

To replace main bearings, therefore, in most cases requires installation of new bushings, and then boring
these to proper size, with the center of the bore at the exact specified dimension from the top of the
cylinder and with the center-line of the main bearing bores exactly 90° from the center-line of the
cylinders.

Thus, replacing main bearing bushings is not usually a job easily done in the field, although it can be
done in a well equipped machine shop.

If new piston rings are to be installed, they should first be fitted to the cylinder bores. The ends of each
ring should be filed to provide a clearance of 2-1/2 to 3 thousandths inch per inch of piston diameter. The
clearance at the joint of each ring should be checked with a feeler gauge.

In fitting wrist pins, if they are too tight, they can be lapped with #400 carborundum paper in a speed
lathe. If the wrist pins are locked to the rod or piston, they should be carefully located to assure even
clearance at the ends, then locked securely. If wrist pins are not locked to either rod or piston, brass
buttons should be inserted in each end after the wrist pin is centered in the piston.

All bearings, journals, thrust faces, pistons, and cylinder walls should be carefully inspected for wear,
scoring, corrosion, copper plating, and scratches. Any defects should be removed by grinding, lapping,
honing, or replacement of the part.

In reassembling a compressor, care should be exercised to avoid getting dirt inside the body or in any
internal parts. Bearings, journals, seal components, valve reeds, cylinder walls, and piston rings should
be lightly coated with refrigerant oil. New gaskets should be used and coated with refrigerant oil. As the
capscrews are tightened, they should be turned only a few degrees alternately. The torque exerted
should not exceed that listed in the previous paragraph covering replacement of seals.
After the compressor has been completely reassembled, all joints should be leak tested before the compressor is dehydrated and charged with oil. This can be done by connecting a charging line to the gauge port of the suction s.o.v. and charging the compressor with R-12 or R-22 to a gauge pressure of 50 to 150 psig. All joints should then be carefully checked with a leak detector, or the entire compressor immersed in a tank of water. With a good leak detector and this pressure inside the compressor, any leak of consequence should be thus located.

If pressure is built up by adding dry nitrogen or any other gas to the refrigerant, a pressure regulating valve and a pressure relief valve set at 175 psig maximum should be connected in the charging line.

CAUTION: When no leaks are observed, recover the refrigerant and evacuate the compressor to a deep vacuum. If an oven is available, heat the entire compressor assembly to 250°F while it is being evacuated. This drying procedure should be performed without a charge of refrigerant oil in the crankcase. A minimum of four hours is recommended. Evacuate to not over 500 microns Hg psia. If an oven is not available, triple evacuation is recommended evacuating to a deep vacuum, then breaking the vacuum with R-12 vapor, repeating this procedure until the third evacuation, when an absolute pressure of not over 500 microns Hg should be attained.

After breaking the vacuum and charging to a positive pressure, new dehydrated oil of the type and viscosity recommended by the compressor manufacturer should be introduced to the crankcase. If no information is available as to the recommended oil, use a good quality, dewaxed, 150 viscosity refrigerant oil. Then charge with refrigerant vapor to a pressure of 10 to 15 psig, unless it is to be immediately installed in a system. (If charged just to atmospheric pressure while the compressor is hot, the internal pressure will be at a partial vacuum when the compressor cools to room temperature).

SERVICING HERMETIC COMPRESSORS

Some hermetic compressors (welded type) cannot generally be serviced in the field. If anything goes wrong with one of them, it has to be returned to the factory or to a well equipped compressor repair shop.

However, field serviceable hermetic compressors (also called "accessible" hermetics or "semi-hermetics") which are bolted together with gasketed joints can often be serviced or even overhauled, just like conventional open type compressors.

CAUTION: Always open the line switch before closing the discharge s.o.v., opening the compressor, or touching any wiring or electrical terminals.

CHECKING VALVES

Just like open type compressors, hermetic compressors incorporate suction and discharge valves. A discharge valve leak can be found quite easily by installing a suction pressure gauge and closing the suction s.o.v. immediately after the compressor is stopped. A crankcase pressure rise of over 3 psig per minute indicates excessive leaking of high pressure gas into the low-side and corrective measures should be taken. If the system incorporates an oil separator, the valve in the oil return line should be closed, or the line removed from the compressor, to make sure the trouble is not a leaking float valve in the oil separator.
If no oil separator is used or no leakage of the float valve evidenced, then the leakage must be that of the discharge valves or a leaking valve plate or cylinder head gasket. In either case, the cylinder head and valve plate must be removed and the valve plate and gaskets inspected.

One cylinder of a multiple cylinder compressor might pump well while another cylinder is not pumping at all. Therefore, even though a hermetic compressor will pump a satisfactory vacuum with the suction s.o.v. closed, inefficient operation might still be occurring, due to this vacuum being attained by only one cylinder.

Except in an emergency, hermetic type compressors should not be operated with the suction s.o.v. closed. Under deep vacuum, the atmosphere to which the motor windings, leads, and terminals are exposed has greatly reduced dielectric strength. As a consequence, an arc between the winding or one of the leads and the compressor body might occur, breaking down the insulation and necessitating replacement of the motor. 18 inches Hg vacuum is the recommended maximum.

So, since a good vacuum indicated in the gauge is inconclusive and endangers the motor winding, it is recommended that where suction valve leakage is suspected, the valve plate and suction reeds be removed for careful inspection. One should observe the valve seats under a magnifying glass, looking for any mar on the seat, foreign particles, corrosion, etc. The suction reeds should be carefully inspected to see if they are seating all around the suction ports. They should also be checked carefully for deflection which can sometimes be felt by drawing each reed between one’s fingers, and sometimes can best be checked by visually observing reflected light from the surface of the reed.

If deflection of the suction reeds is found to have occurred, liquid or oil slugging is indicated. The cause of the slugging must be ascertained and corrected, or nothing will be accomplished by replacing the suction reeds.

To replace the valve plate and suction reeds, scrape all gasket surfaces of the body and cylinder head, being careful to avoid having any bits of gasket fall into the cylinder, crankcase, or suction chamber. Install the suction reeds, valve plate gasket, valve plate, cylinder head gasket and cylinder head in the order named, coating the gaskets and valve reeds with refrigerant oil.

Tighten cylinder head capscrews finger tight; then, using a box wrench or socket wrench, turn capscrews alternately 1/4 turn at a time until they are tightened to the following torque:

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<td>1/2&quot;</td>
<td>Capscrews</td>
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</tr>
</tbody>
</table>

Figure 1 illustrates a good order in which to tighten the cylinder head capscrews. If not tightened evenly, distortion of the cylinder body and seizing of a piston could occur. If tightened too tightly, there is a possibility of breaking the capscrew or stripping the threads.
If a torque wrench is available, use it to measure the in. lbs. torque. If no torque wrench is available, one will have to estimate the torque. (100 in. lbs. means a force of 10 lbs. exerted on the end of a 10 in. wrench; 400 in. lbs. torque equals a 40 lbs. force on the end of a 10 in. wrench, etc.)

After installing all the capscrews, the cylinder head should be purged with refrigerant vapor and, when the air has cleared, the gasketed joints should be carefully leak tested with an internal pressure of 50 to 150 psig. When no leaks are indicated, the compressor valves can be opened and the compressor operated.

**WARNING:**
If pressure is built up by adding dry nitrogen or any other gas to the refrigerant, a pressure regulating valve and a pressure relief valve set at a maximum of 175 psig should be connected in the charging line.

**CHECKING ELECTRICAL SYSTEM**

The electrical phase of refrigeration system is sometimes more cause of trouble than mechanical difficulties. And it is generally the refrigeration serviceman who is called in whenever a refrigeration system does not operate satisfactorily, regardless of whether the trouble is mechanical or lies in the electrical system. Therefore, it is becoming increasingly necessary for the refrigeration serviceman to have an understanding of the electric components and the function of each. One can best diagnose electrical troubles if he knows what the relay is supposed to do and how it operates, why starting capacitors are used and what a running capacitor is supposed to accomplish, etc. It is not beyond the ability of the average refrigeration serviceman to understand all these points if he but spends a little time studying. In fact, it is the only way he can readily diagnose troubles, avoid making unnecessary replacements, and do an efficient job of servicing equipment in this present era where a majority of the equipment in the field and most of the systems currently manufactured incorporate hermetic type motor-compressors.
Referring to Figure 6, you will see the electrical hook-up of a simple system as used in most household refrigerators, home freezers, beverage coolers, etc. The motor stator consists of two windings, a running winding and a starting winding. The running winding itself will not start the compressor. It takes a starting winding to supplement the running winding to bring the compressor up to speed. When the compressor gets nearly up to a normal operating RPM, the relay automatically takes the starting winding out of the circuit and allows the compressor to run on the running winding only. Referring to Figure 6, you will note the motor has three terminals, designated as "R", one end of the running winding, "C" standing for "common", meaning this terminal is connected to both the running and starting windings, and "S", which is the starting terminal. The line is connected to the running winding through the control and with one side of the line passing through the holding coil of the current relay. When refrigeration is called for and the control contacts close, the line is applied instantaneously to the running winding. As the rotor is in a stationary position for an instant, a heavy current is drawn, which passes through the magnetic coil of the relay and exerts a magnetic attraction on an armature, to which one of the contacts is attached. Opposing this magnetic force, which tends to close the contacts, is a light spring which tends to hold the contacts open. Thus, when the motor is trying to start and drawing a heavy current, the magnetic attraction is high and overcomes the pull of the spring, or in some types of relays, gravity, closing the contacts. The closing of the contacts closes the circuit of the starting winding, thus putting the starting winding across the line, just as the running winding is. As the motor accelerates, the current or amperage is reduced, and consequently, the magnetic force of the coil decreases. The current relay is designed so that when the rotor gets up to nearly full speed the spring, or the force of gravity, overcomes the reduced force of the magnetic coil and the contacts are parted, opening the circuit between the starting winding and the line.
So, with a current relay the contacts are normally open during the off cycle and are closed only for an instant when the compressor tries to start and while it is accelerating to nearly full speed.

The motor illustrated in Figure 6 is termed a split phase motor. This is a low starting torque motor and is a type normally used in capillary tube systems of 1/2hp or less. With a capillary tube system, the high side pressure comes down nearly to the low-side pressure during the off cycle. Therefore, low starting torque requirement results, permitting the use of a split phase motor. The starting winding is somewhat out of phase with respect to the running winding, thus providing some starting torque. However, this type of motor normally does not have sufficient torque to permit its being used with an expansion valve system, or even with a capillary tube system if the pressures do not sufficiently come to a balance during the off cycle and before the control again calls for refrigeration.

CURRENT RELAY AND CAPACITOR

Figure 7A illustrates a similar system incorporating a current relay also. But in this case you will note a starting capacitor is incorporated. The motor is thus a capacitor-start induction-run motor. The motor has to be designed to be used with a starting capacitor. In other words, one cannot merely take a split phase motor and add a starting capacitor to the circuit in order to make a capacitor-start motor. The capacitor-start motor has relatively high starting torque and is the type of motor normally used in systems incorporating expansion valves, high side floats, low side floats, and such refrigerant feed devices which normally do not permit the high side pressure to come down to a balance with the low side pressure.
during the off cycle. Thus, the compressor has to start with a pressure differential across the piston and a high starting torque motor is required. With this type of motor, the starting capacitor induces a current in the starting winding, which is approximately 90° out of phase with that of the running winding.

The starting capacitor is an electrolytic type capacitor and is designed to stay in the circuit for only a few seconds. The starting capacitor has a certain capacity, which is measured in microfarads, or "mfd." For any given motor, there is a certain capacitance that will provide maximum starting torque.

![Figure 7B](image)

**Figure 7B**

*Effect of Capacitance on Locked Rotor Torque*

Figure 7B illustrates how the locked rotor torque of a 1/5 hp, 110 volt, 60-cycle motor is affected by changes in starting capacitance (mfd). Note that maximum locked rotor torque occurs with a starting capacitor sized at 120 mfd. With higher or lower capacitance, less starting torque is developed. Therefore, when replacing capacitors it is important to always replace the capacitor with one of the proper mfd capacitance. All capacitors also have a voltage rating. It is important that a replacement capacitor be rated for a voltage no less than that specified by the motor manufacturer. A capacitor with a higher voltage rating can be used, however.
POTENTIAL RELAY AND STARTING CAPACITOR

Referring to Figure 8, you will see another electrical system. But in this case a potential relay is incorporated rather than a current relay. As explained previously, the current relay operates on current or amperage. A potential relay, as this name implies, operates on potential or voltage. It will be noted that the holding coil of the potential relay is connected in parallel with the starting winding. With this type of relay the contacts are normally closed, which means closed during the off cycle. When the control contacts close, calling for refrigeration, the starting winding is thus already connected to the line through the relay contacts and starting capacitor. It will be noted that the relay magnetic coil, being in parallel with the starting winding, will have imposed upon it the same voltage, or potential, as that of the starting winding. This voltage is low as the rotor starts to revolve. But as the motor starts to pick up speed, a voltage is induced in the starting winding. This voltage increases with the speed of the motor or compressor until a point is reached where the magnetic force of the relay holding coil overcomes the force of the spring and the contacts part. The motor is then left running on the running winding only. So with a potential relay the contacts are normally closed, but open the instant the motor gets up nearly to full speed. The contacts are held open by the relay holding coil as long as the motor continues to run.

With regard to the induced voltage mentioned above, this might be simply and briefly explained by considering the rotor and starting winding a generator. Thus, as the speed of the rotor is increased, the generated voltage becomes greater. This generated voltage could be considered the terminal voltage of the starting winding. Thus the magnetic coil of this type relay, being connected across the starting winding terminals, is operated by the voltage or potential of the motor starting winding. From this it gets its name. Whereas the magnetic coil of the current relay carries the full motor current of the running winding, the magnetic coil of the potential relay carries a very small current being in parallel with the starting winding and having relatively high resistance.

The starting winding terminal voltage at which the relay is designed to operate or at which the contacts of the relay will open is normally well above the line voltage. In fact, it might be over 50% greater than the
line voltage. When the relay contacts open, however, they will remain open until the terminal voltage of
the starting winding goes down to approximately one-half the line voltage before the magnetic attraction
of the holding coil is overcome by the force of the spring. The reason for this is that the gap between the
armature and the holding coil is much less when the contacts are open. Therefore, it takes much less
voltage for the coil to hold the contacts open after they are once parted.

An electrical system incorporating a potential relay start capacitor combination presents a relay problem
which was not recognized when such systems were first introduced. When the potential relay contacts
part, the start capacitor remains charged and if the control, overload or any other device opens the line
circuit soon after the compressor starts, the relay contacts immediately close, discharging the start
capacitor across the contacts of the relay. This results in burned relay contacts and short life of a potential
relay.

To avoid this happening, it is now common practice to incorporate a "bleed resistor" (see Figure 9),
connected across the terminals of a start capacitor in a system employing a potential relay. The bleed
resistor is usually 15000 to 18000 ohms rated 2 watts. Its function is to de-energize the start capacitor
within a few seconds after the potential relay contacts open, rather than depend on the internal resistance
of the capacitor to bleed its charge, which may take several minutes.

![Figure 9 — Start Capacitor with Bleed Resistor](image-url)
HOT WIRE RELAY AND STARTING CAPACITOR

Figure 10 illustrates a third type of relay, which is known as "hot wire relay." A hot wire relay normally incorporates an overload device also. This type of relay actually works somewhat like a time switch. As the motor is trying to start and drawing a heavy current, the running winding current passes through a piece of straight, stiff wire, indicated on this drawing as "hot wire." As current is conducted through this wire, as happens immediately when the control contacts close, the wire heats up very quickly and becomes elongated, due to thermal expansion. Through a pivot, this movement is transmitted to a movable arm, which revolves clockwise, as shown.

The starting contact is connected to this arm through two springs in such a way that the contacts snap open with very little movement of the arm or very little expansion of the hot wire. Thus, a hot wire relay is primarily a time switch, opening the starting winding circuit within a very few seconds after the line circuit is closed. Within this short time, however, the starting winding assists the running winding in getting the rotor up to speed, so that the running winding alone can handle the load.

In case of excessive load on the motor, if the running winding cannot maintain normal running speed and the motor stalls, the resulting increased current will cause further expansion of the "hot wire" and further movement of the arm until the second set of contacts are opened by similar snap action.

These are the overload contacts, and when they open, the entire circuit is opened. During the normal off cycle, or when the control stops the motor, the starting contacts will again close as soon as the hot wire element cools down a matter of seconds. They are thus in position for the next start. If the overload contacts open, the hot wire element immediately begins to cool, and these contacts will reset in a short...
time, giving the motor another attempt to start and continue running. The hot wire relay has been superseded by the current- and potential-type relays.

It may be seen that the relay, regardless of type, merely serves as an automatic switch to complete the circuit between the starting winding and the line for sufficient time to get the motor up to speed.

**POTENTIAL RELAY — CAPACITOR START — CAPACITOR RUN**

![Diagram of Capacitor Start - Capacitor Run Motor](image)

Figure 11 illustrates a system incorporating a capacitor-start, capacitor-run motor. This type of motor employs a running as well as a starting capacitor but, again, the motor must be designed as a capacitor-start, capacitor-run motor. The hook-up shown is exactly the same as illustrated by Figure 8, except that a running capacitor is connected in parallel with the starting capacitor without going through the relay contacts. In other words, the running capacitor is connected in parallel with the starting capacitor, without going through the relay contacts. In this hook-up, the running capacitor is connected from the end of the running winding to the end of the starting winding. Note that the running capacitor is left in the circuit at all times. The running capacitor serves to make this a two phase motor running on a single phase line. It serves to put the current and voltage in phase with one another and to improve the power factor. As a result, for a given horsepower and given load, a capacitor-run motor will draw considerably less current, or amperage, than an induction-run motor.

For this reason capacitor-run motors, or those incorporating running capacitors, are becoming increasingly popular, especially in room air conditioners. As an example, a one-hp capacitor-run motor has approximately the same amperage rating as a 3/4 hp induction run motor of the same voltage and frequency.
A running capacitor differs from a starting capacitor. Running capacitors are of the oil type and are built to stand their rated voltage indefinitely, whereas a starting capacitor will stand its rated voltage for only a few seconds, as stated previously. For the same mfd and voltage ratings, a running capacitor or oil-type capacitor has much larger dimensions than an electrolytic capacitor.

**PERMANENT SPLIT CAPACITOR (ALSO CALLED: CAPACITOR RUN)**

Figure 12 illustrates a system using a permanent split capacitor (PSC) motor, which is also (and correctly) called a capacitor-run motor. Note that this type hookup does not use a relay, but has the start winding in the circuit continuously. To prevent the start winding from overheating, and to provide some starting torque, a run capacitor is inserted in series with the start winding. The PSC motor is widely used in air conditioning type hermetic compressors because of its efficiency and low cost. PSC motors have low starting torque, and must be used with refrigeration systems in which the high and low side pressures nearly equalize during the off cycle. Most PSC motors are designed to be converted to capacitor start-run by addition of a "starting kit", consisting of a potential type relay and starting capacitor. The conversion is wired exactly as the "Potential Relay-Capacitor Start-Capacitor Run" previously discussed. Starting kits are classified as two types, "Supplementary Starting", also called "Low Starting Torque" kits, will give enough starting torque to overcome partially unequalized pressures or low voltage problems. "High Starting Torque" kits incorporate a higher mfd rating on the start capacitor and are used when a standard thermostatic expansion valve is used in a refrigeration system where high and low side pressures do not equalize. Sometimes both type kits are available for the same compressor, but there are cases where only the supplementary starting kit is available. It is best to follow the compressor manufacturer's recommendation in applying starting kits, since use of the wrong components may result in a relay coil burnout, contact chatter or hangup, and start winding burnout.
PERMANENT SPLIT CAPACITOR WITH SOLID STATE START

A recent development is use of positive temperature coefficient resistors (PTCR) for supplementary (low torque) starting of permanent split capacitor motors. The PTCR is constructed entirely of solid-state material and acts as a resistor in series with the start winding. The PTCR is used in place of the start capacitor and relay normally used for supplementary starting. Like the start capacitor-relay, it is wired in parallel with the run capacitor. When the compressor starts, the PTCR is at "low resistance" and the motor starts as a split phase motor. The high current flow causes the PTCR to heat up, and the solid state material will suddenly increase its resistance when a given temperature is reached. The temperature setting of the material is selected so that adequate starting torque has been provided without overheating the start winding. At high resistance, current flow virtually ceases through the PTCR, and the PTCR continues to stay out of the circuit until the compressor shuts off. "Reset time", the time required for the PTCR to cool off and its resistance to return to a lower level is usually about two minutes. The reset time is lessened by any additional cooling, such as mounting on a heat sink, or air-flow over the device.

One size PTCR can be applied to several different size compressors, and the manufacturer's recommendations should be followed in selecting a size.

The advantages of PTCR start assist are lower cost, less bulk, and most importantly, elimination of moving parts. PTCR's are fail safe in that they open the circuit if they burn out, thus protecting the start winding. The disadvantage is that they do not provide as much starting torque as a start capacitor-relay does.

MOTOR PROTECTION

All refrigeration motors must be equipped with some sort of overload protection. Excessive loads can be imposed on a motor by a variety of causes, and some means of protecting a motor against the possibility of burning out must be provided.

In the explanation of the "hot wire" relay it was mentioned how this relay incorporates a current overload protection. Where potential relays or current relays are used, however, "inherent" overload protectors are widely used. An inherent protector is one which operates either from over-temperature or over-current, or a combination of the two. Thus it is compensating in that when a motor is cold, it allows a much heavier current than it will permit when the motor is hot.

Inherent motor protection systems are designed to protect the motor against over-temperature and/or overcurrent. Some consist of a single device sensitive to current and stator temperature; some incorporate separate devices for current and temperature; some depend on a single highly sensitive temperature operated device. The latter must have minimum lag and operate within a few seconds to provide locked rotor protection.

The most reliable motor protector is the "line break" type, which opens the line circuit directly when the motor becomes overloaded or overheated. Thus, protection is not dependent upon the contactor opening the line circuit, which occurs with pilot circuit protective devices. The inherent line break type of protection is popular with modern hermetic units in the range of fractional to 5 or 7-1/2 hp. Such systems are not presently available for the larger size motors. So it becomes necessary to use the pilot type system. In this case, overcurrent and/or over-temperature opens the holding coil, or pilot circuit, of the contactor which, in turn, causes the contactor to open and break the line circuit.
Figure 14
Wiring Diagram - Two Terminal Inherent Type Overload- Single Phase

Figure 14 illustrates an inherent overload and its location in the circuit of a single phase system. Being in series with the "common" motor terminal, it carries both the starting and running winding currents. It will be noted that the bimetal element which carries two sets of contacts is exposed to two sources of heat: the heat generated by a heater coil above the bimetal disc and heat being transmitted from the motor winding through the motor housing. Thus, it is the effect of these two sources of heat that operates this type of overload protector.
Figure 15 illustrates another type of inherent protector for single phase motors. This is a three terminal type and is used to provide extra fast operation in case the motor cannot get off the starting winding or if it stalls. The heater element is connected between the line and starting circuit, thus generating heat only when the relay contacts are in the closed position. The bimetal disc will be heated up rapidly and the circuit will be opened in a very few seconds if the motor fails to get off the starting winding. In the normal running condition the bimetal disc operates from the temperature of the motor winding by the heat conducted through the motor housing. The three terminal type of inherent protector is primarily used in connection with suction cooled motor-compressors.

It will be noted that the fan motors are connected across the line on the supply side of the motor protector and on the load side of the control. Thus, the fan motors cycle with the compressor on normal control operation, but in the event the motor protector trips, the fan motors will continue to run, thus cooling off the motor and getting it back on the line as quickly as possible.

In the past there have been other types of motor protection. In some cases a current relay or potential relay incorporates an over current device similar to that of the hot wire relay. On older equipment, some single phase hermetic type compressors did not have inherent overloads, but depended upon heater coils in magnetic line starters for overcurrent protection.
A modern variation of the external protection is the automatic reset internal line break protector which incorporates a current sensing, temperature responsive thermostat on or close to the motor windings. The thermostat opens the "common" connection of the compressor in the event of excessive current flow (Figure 16).

![Diagram of wiring diagram](image-url)

**Figure 16**
Wiring Diagram - Two Terminal Inherent Type Overload Single Phase
Some recent variations use a thermostat which senses both start and run winding current, shown in Figure 17.

![Diagram of overload and control circuit](image)

**Figure 17**

Inherent Single Phase Overload sensing both Start and Run windings individually

Many single phase hermetic compressors above 1-1/2 hp use internal line break protectors.

Internal line break protectors usually cannot be field serviced, and one should be careful when condemning a compressor as having "open windings". Be sure to allow the compressor to cool down to be sure the protector isn't just open, giving the illusion of a bad compressor.

**Magnetic Starters for Three-Phase**

By comparison, a three-phase system is relatively simple in that we have only the motor winding, contactor or magnetic starter, control, and motor protector.
Figure 18 illustrates a typical wiring diagram for a three-phase motor/compressor employing a magnetic starter, with heater elements for overcurrent protection.

The magnetic starters and heater coils used in connection with hermetic type compressors are usually of the "quick-trip" type. They are designed to trip very quickly in the event of a locked rotor, when the motor does not readily get up to full speed, if the line should go single phase or when the current rises rapidly for any reason. By thus providing quick action in taking the motor off the line in such emergencies, this type starter provided much more accurate control and protection against over-current at the normal running condition, as compared to standard starters.

In the selection of heater coils, the recommendations of the motor-compressor manufacturer should be strictly adhered to. The manufacturer selects and specifies the largest size heater element that can safely be used. Oversizing of heating coils is a common cause of motor burnouts. Usually when the magnetic starter is tripped by a heater coil, the starter is doing just what it is designed to do—to protect the motor from overheating or burnout. The starter should not be reset until the motor has had a few minutes to cool off. Then the reason for the tripping should be ascertained. Low or high line voltage, unbalanced voltages, excessive discharge pressure, higher suction pressure than that for which the compressor was designed to operate (misapplication), lubrication failure, sludge, copper plating of internal surfaces, etc., can all cause increased amperage and consequent tripping of the starter. Obviously, the proper remedy is to correct the actual condition, not to arbitrarily oversize heater coils and perhaps lose all motor protection.

Occasionally starters or heater coils are defective or not properly calibrated. So the only way for a service man to know whether or not the starter is tripping prematurely is to have available an accurate ammeter
and test the actual current at which the starter trips. (In most cases heater coils are selected to trip at approximately 25% above the nameplate amperage rating, although in some cases it could be as low as 15%, and in some instances as high as 40%).

INHERENT THREE PHASE CURRENT PROTECTION

Some three phase compressors have been manufactured which incorporate inherent type protection also.

Figure 19
Wiring Diagram - Three Phase Motor with External Inherent Overload and Contactor

Figure 19 illustrates what we might term "external" inherent overloads. In this case two of the three supply lines pass through inherent protectors. A contactor is used in conjunction, the holding coil of the contactor being energized from the two inherent protectors. Thus, in the event either protector trips, the contactor breaks all three legs to the motor instantaneously.
Figure 20 illustrates another new development in three phase inherent protection. A single protector is herein incorporated and connected at the "Wye" of the three phases. An over-current in any one phase, overheating of the motor winding, or a combination of the two, breaks the contacts of the inherent protector and immediately stops the motor.

One of the great advantages of these two systems is that they are of the automatic reset type, but do not let the motor come back on the line until the winding has cooled down to a safe operating temperature. Another advantage is that the protector and the motor are exposed to the same ambient temperature. In some instances magnetic starters are mounted remotely from the motor-compressors and may be at a higher or lower ambient temperature relative to that of the compressors. Thus, they sometimes trip prematurely and in other cases do not give adequate protection. Heater coils are designed and selected for protection based on a starter ambient temperature of 104°F. Thus, if the starter is mounted in a location where the temperature is much higher than this, or where exposed to solar heat, premature tripping will result, as might be expected. Where magnetic line starters are used, therefore, it is desirable to have them operating at the same ambient as that of the motor-compressor. Starters should always be shaded or mounted so they are not in the direct rays of sunlight.
SOLID STATE THREE PHASE MOTOR PROTECTION

The most recent development in motor protection involves use of an electronic circuit to signal the compressor contactor to open in the event of dangerous motor temperatures.

Figure 21 shows a typical circuit. A sensor (actually very fine wire of high resistance) is buried in each of the compressor motor's phases. Should the temperature of any one winding approach the danger point, the solid state module (see Figure 22) is signaled by the change in resistance of the hot sensor. The electronic circuit in the module opens the control circuit, causing the compressor contactor to open. When the winding has cooled to a safe temperature, the module automatically resets. This protection system does not sense motor current at all, but relies on temperature alone. The advantage of a temperature sensitive protector is that it senses any overheating of the motor, regardless of whether it is caused by high current or other causes (such as high suction gas temperature, high or low voltage, etc.). Since it is a pilot duty system, the solid state protection is rendered useless should the contactor stick or weld. As with any pilot duty protector that relies on the contactor, adequate sizing of the contactor is necessary to prevent overstressing and subsequent failure. When hundreds or thousands of dollars are at stake, the contactor is not the place to cut costs.
Although the sensors themselves are inaccessible, one or more can be bypassed with a suitable resistor, if made necessary by opening of one or two sensors. Obviously the compressor protection is lessened, but this may be preferable to replacing a compressor that is out of the manufacturer's warranty. Should this procedure become necessary, consult the compressor manufacturer for proper procedure and selection of resistor (ohms and wattage).

When checking the sensors, an ohmmeter of less than 6 volts must be used, otherwise damage will result. Under no circumstances should line voltage (for continuity check) be applied to the sensors or the sensor leads of the module.

Due to its high cost, solid state protection is used only on larger three phase motors. There are some solid state protectors that incorporate sensors in series, rather than in parallel. If a solid state module becomes inoperative, the module must be replaced, as it is not field-repairable.

CONTACTORS

Whereas open type compressors are usually driven by motors protected by magnetic line starters, and as early model hermetic motor-compressors were also, most modern hermetic compressors incorporate inherent protection and with them contactors are used rather than magnetic line starters.

A contactor is a very important component of the electrical system, especially in units having pilot circuit operated motor protectors. The contactor not only controls the normal operation and cycling of the compressor with pilot operated protectors the life of the motor is dependent on the contactor. Thus, a sticking contactor, welded contacts etc. can void the motor protection action when the latter is not of the line break type.

In event of a motor burnout it is imperative that the contactor be carefully inspected for damage or malfunction and replaced if there is any indication of the contactor having caused the motor burnout or suffered damage as a result of the motor failure. Some contactors produced in the past would stick closed when overheated, resulting in motor burnouts which, in turn caused the circuit breaker to trip. But by the time the service engineer arrived on the job the contactor had cooled down sufficiently to become free.
CHECKING THE MOTOR-COMPRESSOR

In a single phase system the major parts are the motor, relay, starting capacitor (when used) and running capacitor (when used). It is very difficult to check a relay without a rather elaborate setup. However, one can manually apply a starting capacitor by simply touching the leads to the running and starting terminals as the line switch is closed. Thus, one is doing manually just what the relay does automatically. In the case of a split phase motor, a jumper can be used to momentarily connect the running and starting terminals as the relay does.

If a motor will not start or will not get off the starting winding with the relay connected, but starts and continues to run normally when the starting capacitor or a jumper (with split phase motors) is manually applied momentarily, as outlined above, and draws normal current in doing so, it is likely the relay is the cause of the trouble.

A relay can also be visually checked for a burned out holding coil, which is very conspicuous, badly oxidized contacts, or contacts that do not operate, due to some binding action, a broken lead to the coil, etc.

Figure 23-A shows a test cord which can be used for many checking operations. It is simply a service cord with a lamp receptacle in one side of the line. It can be used for both continuity and ground checks. With the cord cap plugged into a line, the test points can be touched to any circuit supposed to be closed and the lamp should light. As illustrated in Figure 23-B, as long as there is no open circuit in a motor winding, the lamp should light as the test probes are touched to the motor terminals. If the lamp does not light, an open circuit is indicated. In Figure 23-C, we show this same test cord being used to check for grounds. The motor winding is supposed to be insulated from the frame and laminations, so when the test points are applied as shown, the lamp should not light. If it does, a grounded winding is indicated. Testing the motor windings for open circuits and grounds may not be conclusive, however. Some of the coils may be shorted, one to the other, and still pass the continuity and ground checks.
When using the test CORD shown in Figure 23-C, make sure that the side of the line incorporating the test lamp is plugged into the "hot" side of the line, and the corresponding probe is then touched to the motor terminal. As you can see, if the other probe is touched to the terminal and the hot side of the line going to the lamp is touched to the motor frame, the lamp will light regardless of whether or not the motor is actually grounded. As a matter of fact, the lamp will light whether or not the other probe is touched to the motor frame, assuming the frame of the motor is actually attached by a ground wire to a water pipe or ground of some sort.
Figure 24 illustrates a simple device which will often show up a shorted stator winding. Anyone can make this inexpensive device from two flashlight batteries, a flashlight bulb and receptacle. This can be used for continuity tests and will show up to some degree variation in resistance. The starting winding of a motor always has more resistance than the running winding. So when the test points are touched to the terminals of the starting winding, the light will not be as bright as when the points are touched to the terminals of the running winding. In some cases, when connected to the starting winding, the filament barely glows. But on the running winding the bulb usually lights up to nearly full intensity. If the bulb lights to equal intensity on both windings, it indicates a defect—usually a shorted starting winding. If the bulb is brighter on the starting winding than on the running winding, it indicates either the stator leads are reversed or the running winding has a partially open circuit or loose connection. The actual intensity is not so much an indication as the relative intensity. As shown in Figure 24-B, on the starting winding the light will always be dimmer than when on the running winding, as in Figure 24-C. On low torque motors the starting winding may cause the filament of the bulb to barely glow.
Figure 25 illustrates a much more accurate method of checking the windings for resistance and grounds, by means of an accurate ohmmeter. To use an ohmmeter, first disconnect all wires from the motor terminals. To check the running winding, touch the ohmmeter leads to the common and running terminals, as shown in Figure 25-A. For the starting winding, as shown in Figure 25-B, the resistance should be substantially higher than that of the running winding.

One cannot, of course, determine whether the resistance readings are correct without having the manufacturer's specification, which is seldom the case. However, one can go by the ratio of starting winding resistance to running winding resistance, which should be approximately as follows: For low torque motors, such as low torque capacitor-start induction-run or split phase type, the starting winding resistance is approximately eight times that of the running winding. For high torque motors, such as capacitor-start induction-run or capacitor-start capacitor-run, the starting winding resistance will usually be three or four times that of the running winding resistance. Another check which can be made with an ohmmeter and which is quite revealing, even though one does not know exactly what the resistance of the windings should be, is that of checking the resistance between the "running" and "starting" terminals to see if it equals exactly the sum of the resistances of the starting and running windings. In other words, if the resistance between the R and S terminals is less than the sum of the resistances of the starting and running windings, a short between the running and starting windings is indicated.

For three phase motors the resistance between any two terminals should be exactly the same as the resistance between any other two terminals.

The running winding resistance is generally the same for both high torque and low torque motors of a given horsepower, voltage, etc. However, the starting winding resistance is much higher in a low torque motor as compared to a high torque motor.

In the foregoing we have shown how a defective relay can be detected very often and how the motor windings can be checked.
CAPACITORS

The other major components of the electrical system are the capacitors.

Although the subject of this section of the manual is that of servicing compressors, one cannot avoid relays, capacitors, overloads, starters, contactor controls and such accessories in any discussion pertaining to trouble diagnosis of hermetic motor-compressors. The capacitors of a hermetic type system have a very great effect on the operation of the motor, and very often motor-compressors are replaced in the field when they are not defective at all. In many instances the starting capacitor is defective, which does not permit the motor to start. In such cases all one has to do is replace the starting capacitor and not the entire compressor assembly. The same holds true of a running capacitor which, if defective, can cause a compressor to draw an excessive current and perhaps cycle on the overload. With this in mind, the following are suggestions on how to check starting and running capacitors.

The spark test, that of touching the leads of a capacitor to a line, then removing the leads from the line and touching them together to see if a spark occurs, is not a conclusive test. All this shows is that the capacitor does not have an open circuit or, if a fuse is blown in doing this operation, that the capacitor is shorted. Also such a test might even cause breakdown of a start capacitor. Therefore, the spark test should be avoided.

It is a simple matter, however, if one has at hand an accurate ammeter and voltmeter, to determine the exact mfd capacitance of either a starting capacitor or running capacitor. By connecting a capacitor to a line having a voltage not greater than the voltage rating of the capacitor, one can check the amperage drawn and the exact voltage, as illustrated in Figure 26.
By applying the actual readings for amperage and voltage to the capacitance formula,

$$C = 2650 \times \frac{\text{Amperes}}{\text{Volts}}$$

one can quickly determine whether the capacitor actually has its rated mfd capacitance. In making this check, a fuse should be incorporated between the capacitor and the line, just in case the capacitor should be shorted.

**WARNING:** When checking starting capacitors, you should leave the capacitor connected to the line for only a few seconds. Starting capacitors will blow up if left connected to the line more than a very short time. Also, when checking any capacitor, you should wear protective goggles or have the capacitor shielded in some way, in case it should blow up in your face.

**CAUTION:** After the capacitor is so tested, a good capacitor will remain in a charged condition. To avoid being shocked by accidentally touching the leads, discharge the capacitor through a bleed resistor.

A capacitor failure should always be investigated to determine the actual cause of the failure rather than merely assume the capacitor itself was defective. Some causes of capacitor failure are:

a. **Excess Voltage.** One cannot assume the capacitor voltage rating should be the same as the line voltage. A 115V motor may need only a 115V-rated start capacitor or it may require one rated as high as 220V. A run capacitor for a 230V motor may have to have a rating of 370 or 440V. Capacitors should not be subjected to voltages over 110% of their stamped rating.

b. **Short Cycling.** Short cycling on overload, low pressure controls, over-temperature controls, high pressure cut-outs and any automatic reset device can cause overheating and failure of a starting capacitor. Start capacitors can normally be operated 60 times per hour of 1 second duration, 30 starts per hour of 2 second duration and 20 starts per hr of 3 second duration. If, after replacing a start capacitor, short cycling is observed, the cause of the short cycling should be determined and corrected or the capacitor will fail again.

c. **Excessive Temperature.** Overheating of a capacitor can cause failure. This applies particularly to run capacitors. If installed in an enclosure ventilation is quite necessary (perforations in the enclosure, louvers, wire mesh etc.). To protect against personal injury, some type of enclosure for run capacitors (in case they should blow up) is usually a code requirement.

d. **Capacitor Deterioration.** A start capacitor may operate in a system for many years. But when not in operation, such as when stored in a stock room etc., its life is limited. A start capacitor which has been on a shelf for many years may suffer internal corrosion and when put in operation be found defective or fail very shortly.

The subject of capacitors, capacitor selection and replacements is a very broad subject and all factors cannot be covered in this section. However, the foregoing covers some of the main points to be considered when capacitor failures occur.
When repeat failures are experienced, it is well to check the compressor or motor manufacturer’s specifications and recommendations relative to capacitor mfd and voltage. Occasionally some service engineer previously replaced a capacitor with one of improper mfd or voltage rating. To replace that one with one of the same rating may simply result in repeat failure.

When replacing a run capacitor it is important to connect the “identified terminal” to the “R” terminal of the compressor. (See Figure 27.)

When so connected if the run capacitor becomes internally shorted to the case and thus grounded, the result is merely a heavy current through one side of the line directly to ground and the fuse blows without the motor suffering damage. But if the run capacitor is connected with the identified terminal attached to the “S” terminal, and the run capacitor becomes internally grounded, a heavy current is imposed on the start winding and a burnout may occur even with the overload open (with a 230 v. motor even with the overload contacts open there can be 115 v. to ground through the run and start windings, which the start winding cannot withstand for long. (See Figure 28.)
Therefore, it is vital that the identified terminal of the run capacitor always be connected to the "R" terminal of the motor to avoid possible burnout of the motor should the run capacitor become internally grounded.

**EMERGENCY OPERATION**

If a capacitor is found to be defective, the equipment can still be kept running at times in an emergency. In the event a starting capacitor is found defective and one does not have an exact replacement, it is possible oftentimes to combine two or more capacitors to provide the same resultant mfd as that of a single capacitor. As illustrated in Figure 26, when two capacitors are connected in parallel, the resultant mfd is the sum of the capacitance of the two or more individual capacitors. When capacitors are connected in parallel, each capacitor must have a voltage rating equivalent to the voltage rating of the single capacitor which is being replaced.

Also illustrated in Figure 26, when two capacitors are connected in series, the resultant mfd equals the product of the capacitance of the two capacitors divided by the sum of the capacitance of the two capacitors. When the two capacitors are of the same mfd, each substitute capacitor could have a voltage rating of one-half the voltage rating of the single capacitor being replaced. It will be noted from the formula for a series hook-up the resultant capacitance of two equal capacitors is one-half the capacitance of one of them. Thus, two 115 volt capacitors can be used as a substitute for a single 230 volt capacitor, providing each of the 115 volt capacitors has an mfd rating double that of the 230 volt capacitor being
replaced. Likewise, for a 330 volt capacitor, three 110 volt capacitors could be connected in series as a substitute. In this case each of the three capacitors must have a capacitance three times that of the single one for which the combination is substituted.

For three or more capacitors connected in series, the resultant capacitance "C" can be calculated by the following formula:

\[
\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}, \text{ etc.}
\]

In an emergency a capacitor-run motor can sometimes be operated without a running capacitor by reducing the load. An open circuited running capacitor will generally result in an increased amperage of 30 to 35%. This allows a quick test of a running capacitor in that one can check the running current and then disconnect the running capacitor. If no increase in amperage occurs, it indicates a defective running capacitor. If an increase in current of approximately 30% occurs when the running capacitor is disconnected, it indicates the running capacitor is functioning properly.

If a running capacitor is found to be defective and a substitute is not readily available, one can sometimes continue to obtain refrigeration, at least to a limited extent, by throttling the suction shut-off valve, thus reducing the suction pressure. The recommended procedure is to apply an ammeter and gradually close the suction shut-off valve, or throttle it, until the amperage gets down to not over 25% over the nameplate rating of the motor. With the suction shut-off valve throttled thusly, a reduction in capacity will result, but considerably more refrigeration will thus be obtained than would occur with the compressor cycling on the overload.

As outlined previously, a system can be operated manually without the relay. If a relay is found to be defective and an exact replacement is not readily available, one can continue operation by manually applying the starting capacitor to the "R" and "S" terminals for an instant as the line switch is closed. In this way one is manually closing the starting circuit long enough to get the motor up to speed, then removing the starting capacitor from the circuit. It is then necessary to block the control or insert a jumper between the control terminals to prevent cycling on the control. This procedure often avoids the necessity of unloading the product from a low temperature case or cooler. The unit can be kept running overnight or over a weekend in an emergency until a replacement relay can be procured. If the motor is a capacitor-run type, the running capacitors could be connected directly to the proper motor terminals.

CHECKING VOLTAGES

For proper trouble diagnoses an accurate voltmeter and an accurate ammeter are essential—as necessary as a set of gauges and leak detector for a refrigeration serviceman to do a proper job. Motors are rated by full load amperes, or approximately 80% of the maximum amperage for which a motor is designed. Motors are also rated at some specified voltage. Most refrigeration motors are good for continuous operation at a current draw of 25% over the nameplate rating of the motor. If a motor overload is tripping or the motor cycling on an overload, it might be due to an over current or a weak overload tripping prematurely. The only way to make sure is by the use of an ammeter, finding out what the current actually is, and then comparing it with the nameplate rating of the motor. (In the case of air cooled units, if the ammeter's reading includes the fan motors, their current must be subtracted from the total to get the correct current of the motor-compressor only. The same thing holds true of any other motors, solenoid valves, electric heaters, etc.)
Many failures are due to low voltage and, in some cases, high voltage. Most motors are good for operation 10% above or below their stamped rating. One exception is 208/230 volt single-phase hermetic compressors which are usually good for 10% above 230 v. to 5% below 208 v. Most of the low voltage trouble comes at the starting period when maximum current is being drawn. A sag in line voltage at the motor terminals often occurs during this period when the motor is drawing its heavy current and trying to accelerate. If the motor is tripping the overload as it tries to start, one of the first things to check is the line voltage at the motor terminals. As shown in Figure 29 below, a voltmeter should be connected directly across the running winding terminals, and the voltage checked as the motor is trying to start. During this short period the voltage at the motor terminals must be maintained at no less than 90% of the rated voltage of the motor (103.5 volts for 115 volt motors and 207 for 230 volt motors). Very often the voltage at the receptacle or at the service entrance to the building may be very satisfactory but, due to inadequate wiring, long extension cords, poor contacts or connections, etc., a voltage drop within the building will occur. Also, the voltage at the motor terminals may be within limits when the motor finally gets up to speed, but if it is too low when the motor is trying to start, something should be done to bring it up. The only remedy for low voltage is to do what is necessary to increase the voltage to within 10% of the motor rating. Alteration of the relay, changing starting capacitors, etc. will not prove satisfactory and may result in serious failure of the entire system.

High line voltage can also be the cause of trouble especially when the motor is lightly loaded, such as in the case of very low temperature applications. The time to check for high voltage is when the motor is up to speed and operating on the running winding only when drawing minimum current.
In replacing electrical components one should always insist upon exact replacements. It must be remembered that the electrical components of hermetic type condensing units are designed to operate as a system. Modification of any one component may impose excessive stress on some other component. For example, a wrongly sized starting capacitor may cause improper relay operation. The relay may take the starting capacitor out of the circuit before the compressor has developed sufficient speed for the running winding alone to carry the compressor. Replacing a running capacitor with one of the wrong mfd capacitance rating may result in the motor drawing excessive current or might cause the relay holding coil to burn out in a very short time.

Another important thing to check in the event of trouble is the wiring. One should check the wiring against the diagram in the service manual or the wiring diagram supplied with the motor. Also, one should make sure that all connections in the junction box and the terminals of the relay are tight and no stray wires are causing shorts or grounds.

In some cases of miswiring a motor burnout may occur due to the protector being eliminated from the circuit. In other cases the start winding and run winding might be reversed, resulting in insufficient current to operate the motor protector but rapid overheating of the start winding. This applies particularly to PSC motors. To positively check for miswiring of PSC motors (used, considerably in residential air conditioners), before starting up a unit after compressor replacement check the resistance (ohms) across the line connections of the condensing unit. (See Figure 30.) As mentioned previously, the resistance of the starting winding is much greater than that of the run winding. So by applying an ohmmeter to the line terminals (manually closing the contactor and with line switch open) a check can be made to insure proper wiring of the compressor.
Referring to Figure 30, the resistance indicated on the ohmmeter which is connected to the line terminals should read a value no greater than the actual resistance of the run winding (resistance between compressor terminals "R" and "C"). If a greater resistance is indicated miswiring of the compressor is generally the cause and the wiring must be corrected before applying the line to the unit.

**ELECTRICAL TROUBLE CHART**

The following is a resume of some of the common causes of trouble and possible remedies.

**HERMETIC CONDENSING UNIT SERVICE CHART**

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Cause</th>
<th>Remedy</th>
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<tbody>
<tr>
<td><strong>A. Compressor will not start-no hum.</strong></td>
<td>1. Open line circuit.</td>
<td>1. Check wiring, fuses, receptacle.</td>
</tr>
<tr>
<td></td>
<td>2. Overload kicked out.</td>
<td>2. Wait for reset; check current.</td>
</tr>
<tr>
<td></td>
<td>3. Control contacts open.</td>
<td>3. Check control, check pressures.</td>
</tr>
<tr>
<td></td>
<td>4. Open circuit in stators.</td>
<td>4. Replace stator or motor compressor.</td>
</tr>
<tr>
<td><strong>B. Compressor will not start-</strong></td>
<td>1. Improperly wired.</td>
<td>1. Check wiring against diagram.</td>
</tr>
<tr>
<td><strong>hums intermittently (cycling on overload).</strong></td>
<td>2. Low line voltage.</td>
<td>2. Check main line voltage determine location of voltage drop.</td>
</tr>
<tr>
<td></td>
<td>3. Open starting capacitor.</td>
<td>3. Replace starting capacitor.</td>
</tr>
<tr>
<td></td>
<td>4. Relay contacts not closing.</td>
<td>4. Check by operating manually. Replace relay if defective.</td>
</tr>
<tr>
<td></td>
<td>5. Open circuit in starting winding.</td>
<td>5. Check stator leads. If leads okay, replace stator or motor compressor.</td>
</tr>
<tr>
<td></td>
<td>8. Tight compressor.</td>
<td>8. Check oil level-correct binding.</td>
</tr>
<tr>
<td></td>
<td>10. Compressor seized.</td>
<td>10. Determine and correct cause of seizure (tight bearing of piston, broken suction reed etc.)</td>
</tr>
<tr>
<td><strong>C. Compressor starts, motor will not get off</strong></td>
<td>1. Low line voltage.</td>
<td>1. Bring up voltage</td>
</tr>
<tr>
<td><strong>starting winding.</strong></td>
<td>2. Improperly wired.</td>
<td>2. Check wiring against diagram.</td>
</tr>
</tbody>
</table>
### Compressor Design, Application and General Service Part 2;
**Servicing Open and Hermetic Types**

*By: John L. Zant CM*

*By: Bernard A. Nagenhast*

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Running capacitor shorted or grounded.</td>
<td>4. Check by disconnecting running capacitor.</td>
</tr>
<tr>
<td>5. Starting and running windings shorted.</td>
<td>5. Check resistances. Replace stator if defective.</td>
</tr>
<tr>
<td>7. High discharge pressure.</td>
<td>7. Check discharge shut-off valve. Check pressure.</td>
</tr>
<tr>
<td>8. Tight compressor.</td>
<td>8. Check oil level. Check binding.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1. Low line voltage.</th>
<th>1. Bring up voltage.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Additional current passing through overload.</td>
<td>2. Check for added fan motors, pumps, etc., connected to wrong side of overload.</td>
</tr>
<tr>
<td>3. Suction pressure high.</td>
<td>3. Check compressor for proper application.</td>
</tr>
<tr>
<td>4. Discharge pressure high.</td>
<td>4. Check ventilation, restrictions.</td>
</tr>
<tr>
<td>5. Overload weak.</td>
<td>5. Check current–replace overload if defective.</td>
</tr>
<tr>
<td>7. Stator partially shorted or grounded.</td>
<td>7. Check resistances, check for ground. Replace stator or compressor if defective.</td>
</tr>
</tbody>
</table>

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**D. Compressor starts and and runs but cycles on overload.**
### COMPRESSOR DESIGN, APPLICATION AND GENERAL SERVICE PART 2;
SERVICING OPEN AND HERMETIC TYPES

By: John L. Zant CM
By: Bernard A. Nagenhast

<table>
<thead>
<tr>
<th>Problem</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Compressor tight.</td>
<td>9. Check oil level. Check for binding.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Short cycling.</td>
<td>1. Replace starting capacitor with series arrangement or reduce number of starts per hour.</td>
</tr>
<tr>
<td>2. Prolonged operation on starting winding.</td>
<td>2. Reduce starting load (install suction regulating valve), increase voltage if low.</td>
</tr>
<tr>
<td>3. Relay contacts sticking.</td>
<td>3. Clean contacts or replace relay.</td>
</tr>
<tr>
<td>4. Improper capacitor.</td>
<td>4. Check parts list for proper capacitor rating—mfd and voltage.</td>
</tr>
<tr>
<td><strong>E. Starting capacitors burn out.</strong></td>
<td></td>
</tr>
<tr>
<td>1. Excessive line voltage.</td>
<td>1. Reduce line voltage to not over 10% over rating of motor.</td>
</tr>
<tr>
<td>2. High line voltage and light load.</td>
<td>2. Reduce voltage if over 10% excessive. Check voltage imposed on capacitor and select one equivalent to this in voltage rating.</td>
</tr>
<tr>
<td><strong>F. Running capacitors burn out.</strong></td>
<td></td>
</tr>
<tr>
<td>1. Low line voltage.</td>
<td>1. Increase voltage to not less than 10% under compressor motor rating.</td>
</tr>
<tr>
<td>2. Excessive line voltage.</td>
<td>2. Reduce voltage to maximum of 10% over motor rating.</td>
</tr>
<tr>
<td>3. Incorrect running capacitor.</td>
<td>3. Replace running capacitor with correct mfd. (see compressor manufacturer's specs.)</td>
</tr>
</tbody>
</table>
### OVERHAULING SEMI-HERMETIC TYPE COMPRESSORS

If the hermetic compressor is of the field serviceable type, it can often be satisfactorily overhauled in the average refrigeration serviceman's shop. If the compressor is of the welded case type, facilities would have to be available for grinding or cutting the weld between the upper and lower halves of the housing. Also, facilities would be required for rewelding the two halves upon completion of the overhaul, without burning any internal parts or allowing oxidation of the metal on the inside surface of the housing.

In dismantling the compressor, one should be very observing, as very often the exact cause of the failure can best be determined by carefully inspecting each part of the compressor as it is being disassembled. For example, copper plating and carbonized oil deposits are an indication of moisture or acid in the system. Broken or badly distorted suction or discharge reeds (see Figure 31), and broken wrist pins or bent or broken connecting rods (see Figure 32), are a pretty sure indication of liquid refrigerant or oil slugging.

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<table>
<thead>
<tr>
<th>4. Short cycling.</th>
<th>4. Reduce number starts per hour.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Incorrect mounting.</td>
<td>5. Mount relay in correct position.</td>
</tr>
<tr>
<td>7. Incorrect relay.</td>
<td>7. Use relay properly selected for motor characteristics. (See compressor manufacturer's specs.)</td>
</tr>
</tbody>
</table>
Therefore, unless the cause of this trouble is eliminated, the replacement compressor might similarly fail in a short time.

To disassemble the motor-compressor, first drain the oil from the crankcase. If the oil is discolored, avoid getting it on your skin as it may contain hydrochloric or hydrofluoric acid, which is extremely injurious. If a sample of the oil is to be chemically analyzed (which is often revealing, relative to the original cause of the failure), a few ounces of the oil should be immediately sealed in a clean, dry glass container.

The cylinder head and valve plate, motor housing or cover plate, rear bearing housing cover and bottom plates should then be removed. Next, the motor rotor should be removed, using a brass bar or a hammer handle will do to block the shaft while the shaft nut or rotor locking device is loosened and removed. The rotor can then be slipped off the shaft and the key removed from the shaft. The piston and rod assemblies should then be marked for number of bore and direction of rotation. If the connecting rods are of the automotive type, the caps should be removed and the piston-rod assemblies removed by withdrawing through the cylinder bores, or taken out through the crankcase if possible. With some compressors this cannot be done until the shaft is removed, however. With eccentric type rods, the eccentric shaft must be withdrawn through the eccentric rods. In multiple cylinder compressors, the second eccentric has to be pulled through the first rod, etc. To do so, the rod has to be properly lined up with the eccentric and the shaft sometimes turned slightly to get both aligned and clear all obstructions. Considerable care should be exercised in this operation to avoid bending a rod, marring an eccentric, or otherwise damaging a part. When everything is correctly aligned, the shaft can be removed very easily. If any binding occurs, do not use force, but check to see exactly what is causing the obstruction or binding.

With the shaft, rods, pistons, etc. removed, the compressor is pretty well disassembled. With some compressors it may be necessary or desirable to remove an oil pump, oil intake tube or screen, suction strainer, oil check valves, or any such parts either before or after the shaft is removed.

If the stator is to be removed, the leads should be marked or tagged with the respective terminal designation as they are removed from the terminals. The stator can then be removed from the body. The stator is sometimes a slip fit in the body and held in place by clamps, in which case it can be removed quite easily. In other cases it is a press fit in relationship to the body. In the latter case, newer compressors require that the outer casting be quickly heated up to 150 - 200°F and the stator dropped.
out. Some older compressors have holes in the stator laminations, which in some cases are tapped or equipped with a tapped bushing at the bottom of the stator. Machine bolts can then be threaded into these holes through a bar placed across the face of the body (Figure 33), and the stator thus withdrawn. If the stator does not incorporate tapped bushings, the holes will have to be tapped, which should be done to a considerable depth. If the stator is an extremely tight pressed fit in the body, the withdrawal can be facilitated by quickly heating the body to a temperature of 150 to 200°F and/or applying dry ice to the inside surface of the stator.

![Diagram of Stator Puller in Place](image)

**CLEANING AND INSPECTING THE PARTS**

The next step is to clean the inside of the body and all parts very thoroughly. All dirt, sludge, carbonized oil, corrosion and gums must be removed. as well as all gasket material. If the stator winding has badly burned, special solvents and equipment may be needed to remove all residue. Live steam containing a degreasing agent is effective in many cases. With some residues methyl alcohol or trichloroethylene may be more effective.

⚠️ **Do not use carbon tetrachloride. There are many solvents as good, or better, which are much less dangerous to use. It is dangerous to breathe the fumes of carbon tetrachloride or allow it to contact the skin.**

CAUTION:
When all parts are thoroughly cleaned, they should be carefully inspected. The journals of the shaft and eccentrics should be visually inspected for scoring, cracks, nicks or marks of any kind. All oil ports and drilled holes should be checked for restrictions. All journals and eccentrics or crank pins should be checked with an accurate micrometer for wear, taper, and out-of-roundness. In general, it pays to replace such parts showing the least wear, scoring, out-of-roundness, etc. In some cases, especially in an emergency, parts can be saved by stoning, grinding or lapping, if one wants to take the time and has the necessary equipment available.

The connecting rods or eccentric rods should also be inspected for scoring, wear, and out-of-roundness, and replaced if any such defects are observed. In an emergency, however, a piston pin bore can sometimes be rebored or reamed oversize—necessitating the piston bore also to be reamed and oversize piston pins being obtained. The connecting rods or eccentric rods should also be checked for alignment of the piston pin bores with respect to the eccentric or crankpin bores. A connecting rod alignment jig is usually required to accomplish this, however. The rods can usually be straightened if they are found to be only slightly deflected. If a rod is rebushed, it is essential the exactly specified dimension for the distance between the piston pin and crankpin bore be maintained, the two bores be in perfect alignment and proper clearances between the rod and crankpin and rod and piston pin be assured.

The cylinder bores should be checked carefully for any sign of scoring, taper, and out-of-roundness. Slight scoring can sometimes be eliminated by lightly honing the cylinder. With ringless pistons, however, an enlargement of the cylinder of only one half thousandth of an inch will reduce the efficiency of the compressor. In an emergency, however, the cylinder can be lightly honed and the piston equipped with a piston ring. If excessively scored, and proper equipment is available, the cylinder can sometimes be bored 1/8" or more oversize and a sleeve pressed into place, the sleeve then bored and honed to fit the piston. The boring of the sleeve, however, is a critical operation in that the cylinder bore must be in perfect alignment with the centerline of the shaft main bearings.

The main bearings of any compressor are not easily replaced, unless the shop is very well equipped with precision machines and accurate gauges. This applies to both open type compressors and hermetics. With hermetic compressors, misalignment might be evidenced more readily as the rotor will drag on the stator, or an uneven air gap between rotor and stator will result if the main bearings are out of alignment. However, with open type compressors any misalignment between the main bearings and cylinder bores will cause binding of the rods and pistons, and the repaired compressor will be extremely short-lived.

If facilities are available, new main bearing bushings with bores a few thousandths of an inch less than the shaft journals can be pressed into place. It will then be necessary to locate from the stator bore of the motor housing in boring the main bearing bushings. This is the only way a uniform air gap between the rotor and stator can be assured. To simply press out the worn bushings, press in new bushings and ream them to fit the shaft will seldom result in satisfactory alignment. There are some exceptions, where the main bearings consist of removable inserts and the compressor is designed for field replacement of such inserts.

The pistons should be inspected next for scoring, wear, taper, and out-of-roundness. Slight scoring might possibly be corrected by lightly stoning or lapping the surface with #400 carborundum paper. However, pistons also might better be replaced if any wear is detected, except in an emergency. In the latter case, they could be lapped in a speed lathe and equipped with new piston rings, rebored or reamed for oversize piston pins, etc., providing the machine shop is equipped for such work. In this case, also, the alignment
of the piston pin bore with the piston wall surface is critical, and perfect 90° alignment is a necessity to avoid binding or excessive friction.

If the valve plate, after disassembly, is found to have wear, nicks, or evidence of etching of the seats, a replacement valve plate assembly should be used in the reassembly of the compressor. Merely lapping the valve seats is unsatisfactory as it lowers the surface of the seat with respect to the rest of the valve plate surface, and the reeds will not seat properly, leakage resulting. With proper facilities, however, if the seats are not too deeply damaged, the entire valve plate surface can be ground, and the seats then very lightly lapped. New reeds, springs, and safety wire or locking devices should be used in the reassembly of the valve plate.

The motor rotor seldom has to be replaced, but it should be inspected for defects. If a replacement must be obtained, all identification on the compressor nameplate should be noted, as well as the manufacturer, part number, etc. of the stator.

(Even though they may be designed for the same compressor, same hp, voltage, frequency and phase, one make of rotor cannot be used with some other make of stator.)

The stator should be replaced if any burned insulation is observed or evidenced by odor; resistance checks indicate a ground or short circuit or the coils mechanically damaged in any way. Many established compressor repair shops find it most economical to rewind or replace the stator in every overhauled compressor which has been in operation over one year. Stators can be rewound in certain repair shops, although complete facilities for doing so, knowledge and skill of the operator are essential. Many motor repair shops are capable of rewinding a stator from an open type motor but unable to do a satisfactory job on a stator from a hermetic compressor. Obviously, extreme cleanliness is a requisite for the latter, while a little dirt between the laminations or in the coils of the open type motor might not cause any trouble.

The oil pump, if incorporated, should be checked for operation before being reinstalled. If it will not pump or does not provide the specified pressure after being cleaned and reassembled, it should be replaced.

**REASSEMBLING THE COMPRESSOR**

Make sure the inside of the body and all the parts going into the reassembly are absolutely clean and dry.

The first operation is that of inserting the stator. If it is a press fit, warm the body to 150° to 200°F to facilitate this operation. If the stator incorporates oil ports, it is important to insert the stator in the right position. (Horizontal type motor compressors frequently have an oil port at the bottom of the stator. It is necessary that this port be at the bottom and exactly centered to assure proper lubrication.) If the stator is a slip fit to the body, it should be properly positioned and the clamps then installed. If the stator is supposed to be a press fit, but is not tight in the body with the stator and body at same temperature, it will have to be clamped or strips of shim stock placed every 90° around the stator as it is pressed into the body. (If stator is not tight in body, it may revolve during the starting condition, breaking the leads.)

The three stator winding leads should then be attached to the proper motor terminal studs, twisting the three leads to take up the slack and keeping them clear of the rotor, shaft, and any revolving mechanism. If the motor is three phase, it makes no difference to which terminal a lead is attached. But if single phase, it is necessary to connect the leads to the proper terminals. If the leads are not marked, the following method can be used to determine the “Start”, “Common”, and “Run” terminals:

Using an accurate ohmmeter, check the resistance (ohms) between all leads, marking the leads #1, #2, and #3. The maximum resistance will be between "R" and "S". The minimum resistance will be between "R" and "C". For example, if after tagging the leads 1, 2, and 3, the following resistances are ascertained:
Between #1 and #2 . . . 1.5 ohms (min.)

Between #1 and #3 . . . 4.5 ohms

Between #2 and #3 . . . 6.0 ohms (max.)

Then #1 and #2 are thus known to be the running winding, one of them being "R" and the other "C". Also, #1 and #3 are thus determined to be the starting winding, one of them being "C" and the other "S". Since #1 lead is then known to be a lead of both the running and starting windings, it must therefore be the "common" or "C" lead. Since the minimum resistance was found to be between #1 and #2, and #1 was just proved to be "C", it follows that #2 must be "R", leaving #3 lead which would have to be "S".

The pistons, piston pins, and rods should be reassembled, making sure the rods are mated with the same pistons as before. The piston pins should be accurately centered before being secured. If of the "free floating" type, a new brass button should be inserted at each end of each piston pin.

If piston rings are to be incorporated, new rings should be installed and fitted to the cylinders. The ends of the rings should be filed squarely to provide a clearance of 2-1/2 to 3 thousandths inch per inch cylinder diameter. This clearance should be checked with a feeler gauge.

The piston-pin-rod assemblies and the shaft can then be installed, reversing the disassembly procedure and applying a light coating of refrigerant oil to all bearings, etc. Be sure each piston is reinstalled in the same cylinder bore from which it was originally removed. Be sure each rod is installed to revolve in the same direction of rotation as originally.

If the assembly is of the eccentric type, exercise care in inserting the shaft, lining up each rod and revolving the shaft slightly as it is positioned. DO NOT USE FORCE. If any binding occurs, determine the cause of misalignment or the exact obstruction. To force the shaft might bend a rod. The housing cover or rear bearing cover should then be installed, lubricating the bearing with refrigerant oil and lightly coating the new gasket with refrigerant oil.

The motor rotor can then be installed, slipping it along the shaft without using the key. After the rotor is in position, revolve it until the keyway in the rotor lines up with the keyway in the shaft; then insert the key. With the shaft blocked, tighten the nut or locking device to the end of the shaft and rotor.

Then insert a feeler gauge between the rotor and stator to make sure that uniform air gap prevails. When the gap is approximately the same all the way around, tighten the lock nut securely, hitting the handle of the wrench with a hammer. If the locking system is the use of a serrated washer, a new washer should be used. If it consists of a plate which fits over the nut and attaches to the rotor, do not loosen the lock nut to align the holes of the plate with those of the rotor tighten the nut a few more degrees.

If the assembly incorporates an oil flinger, make sure the motor leads are tied to clear the flinger as it revolves.

The shaft should next be revolved manually to make sure the tops of the pistons will not hit the suction reeds or valve plate as they reach the top of the stroke. If one does, it will be necessary to remove the piston-rod assembly and grind the top of the piston to provide sufficient clearance.

It is then advisable to connect a line of proper voltage to the "R" and "C" terminals (if single phase compressor) and touch the leads of the proper starting capacitor (or run capacitor if PSC motor) to the "R" and "S" terminals as the line switch is closed. This is just to check the operation while the body is open do not run the compressor for more than a few seconds.
The motor cover plate, bottom plate, and bearing cover plate can then be reinstalled, using new gaskets and coating them with refrigerant oil. The capscrews should be tightened alternately and uniformly to approximately the following torque:

<table>
<thead>
<tr>
<th>Size</th>
<th>Capscrews</th>
<th>Torque</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4&quot;</td>
<td></td>
<td>100 in. lbs.</td>
</tr>
<tr>
<td>5/16&quot;</td>
<td></td>
<td>275 in. lbs.</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td></td>
<td>400 in. lbs.</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td></td>
<td>500 in. lbs.</td>
</tr>
</tbody>
</table>

In reassembling and reinstalling the oil pump, if used, make sure the gaskets are correctly positioned, i.e., so that the gasket oil port holes line up exactly with the ports of the oil pump and body or housing cover.

The suction reeds, valve plate and cylinder head can then be reinstalled as outlined previously under the heading "Replacing the Valve Plate". The shutoff valves can then be mounted and the motor-compressor leak-tested and dehydrated. If an oven is available, a better dehydrating job can be done by heating the motor-compressor to 250°F, while the compressor is evacuated. This procedure should be done without oil in the crankcase. The compressor should be evacuated for a minimum of four hours after it is heated to 250°F. A vacuum pump capable of evacuating to not over 500 microns Hg absolute pressure should be used. If the compressor is not heated while being evacuated, triple evacuation is recommended.

Before disconnecting the vacuum pump, the vacuum should be broken with refrigerant vapor, and the motor-compressor charged to a positive pressure. Oil should then be charged into the crankcase to the recommended oil level. Only new, dry refrigerant oil of the compressor manufacturer's specified viscosity and type should be used. If the manufacturer's recommendation is unknown and cannot be determined, use #150 viscosity, dewaxed oil with dielectric strength of 25,000 volts.

With all the widely different designs of hermetic motor-compressors that have been produced, it is rather impossible to include in this manual detailed instructions pertaining to each and every make and model. The foregoing, therefore, has to be rather general, with a lot left to the good judgment and ingenuity of the repair man.

But with the proper tools and facilities, the exercise of care and use of good judgment, any mechanic who can successfully overhaul an open type compressor should be able to overhaul a field serviceable hermetic motor-compressor. But with the proper tools and facilities, the exercise of care and use of good judgment, any mechanic who can successfully overhaul an open type compressor should be able to overhaul a field serviceable hermetic motor-compressor.
OIL SAFETY SWITCHES

On compressors incorporating a force feed oil pump an oil safety switch is highly recommended. And in many cases the full compressor warranty does not apply if the oil safety switch is not used. This component serves several useful purposes:

a. It takes the compressor off the line if the crankcase oil supply runs low.

b. It stops the compressor if the oil pump fails to prime within a given time period, becomes inoperative or for any reason insufficient oil pressure occurs.

c. If excessive oil foaming occurs frequently due to liquid refrigerant spillback through the suction line low oil pressure results. Thus an oil safety switch often protects the compressor against liquid washout and slugging. Similarly, in cases of severe liquid migration to the compressor crankcase during a prolonged off cycle, excessive foaming and loss of oil may occur on startup. Thus, an oil safety switch may avoid damage to the compressor from migration.

The oil safety switch is designed to provide a given time lag to give the oil pump a limited time to prime and develop sufficient oil pressure for adequate lubrication. The time lag is usually from 1.5 to several minutes. The compressor manufacturer's recommendations or specifications should be followed in the selection and installation of an oil safety switch.

CONCLUSIONS

A good service engineer should always be observing and attempt to diagnose any malfunction or compressor failure. Unless the exact cause of failure is determined and corrected, repeat failures will likely occur.

A hermetic compressor burnout may occur as a result of some electrical fault or failure of an electrical component or it could be the result of some mechanical failure. For example, lack of lubrication can cause excessive wear of the main bearings, causing the shaft to drop down to where the rotor drags on the stator. The result is a motor burnout. But it is not actually an electrical failure. The fault was lack of lubrication and unless this cause is corrected, repeat compressor failure will likely result.

In some instances the compressor may seize and a motor burnout occur, even though the motor protection system is designed to prevent motor damage. This may indicate both a mechanical failure and an overload failure. But you can be assured the seizure occurred before the motor burnout. A bearing does not seize, a piston does not bind or a suction reed does not break after the burnout.

Therefore, it is wise to check these items when a burnout does occur. With a semi-hermetic compressor it takes but a few minutes to determine whether or not the compressor is seized, suction reed broken and fallen into the cylinder, rotor dragging on the stator etc. Unless such causes (liquid slugging, lack of lubrication, overheating of the compressor etc.) are corrected the replacement compressor may likewise soon fail. The important fact is that a motor burnout is not necessarily an electrical failure, not necessarily a defective motor.