

determined rate will not be found. With increased sensitivity the problem of contamination becomes rather troublesome, so that in many cases the items being tested are brought into a chamber or booth where fresh air is furnished under positive pressure. The use of an audible signal allows the probe operator to concentrate on probing, without having to watch a flame or dial. Equipment maintenance presents a problem, because the sensitivity of the probe must be checked at short intervals. Any exposure to a large amount of refrigerant will cause loss of probe sensitivity. A rough check, such as water submersion testing prior to use of the electronic device is, therefore, frequently employed in order to find large leaks.

Mass Spectrometer. Probably the most sensitive leak detection method in use at this time is the mass spectrometer. The unit to be tested for leakage is evacuated, and then surrounded by a helium and air mixture. The vacuum is then sampled through a mass spectrometer, and any trace of helium indicates a leak or leaks. The sensitivity of the mass spectrometer is extremely high. Leaks of 1×10^{-10} standard cc per sec can be detected by using it. The helium for testing is normally kept inside a chamber or bell completely closed except at the bottom. The unit to be tested is simply raised into the lighter-than-air helium atmosphere.

This method, in addition to being extremely sensitive, has the added advantage of measuring all leaks on all joints simultaneously. A very quick test is therefore possible. However, cost of equipment is high, helium is expensive, the instrument must be carefully maintained, and a method of locating the leaks must be developed.

The amount of helium needed depends on the maximum leak that is considered permissible, the configuration of the system under test, and the time it can be left in the helium atmosphere. The longer a unit is exposed to the helium atmosphere, the lower a concentration is necessary to maintain the required sensitivity. If, due to the shape of the test unit, a leak may occur at a point distant from the point of sampling, care must be taken to provide a good vacuum, and to allow sufficient time for traces of helium to appear on the mass spectrometer.

In general, a helium concentration of more than 10 percent becomes costly. The inherently high diffusion rate will cause it to disperse to the atmosphere, no matter how effectively the bell is designed. As in the case of some other methods discussed in this chapter, the best testing procedure in using the spectrometer is to locate calibrated leaks at extreme points of the test unit, and to adjust exposure time and helium concentration in the most economical manner. One manufacturer of self-contained air conditioners found leaks at a rate of one-tenth of an ounce of refrigerant per year by using a ten percent concentration and submerging the tested part for twenty minutes.

Although the mass spectrometer method is extremely sensitive, the sensitivity that can be used may be limited by the characteristics of the tested system. Since only the *total leak rate* is found with this method, it is impossible to tell whether a leakage rate of, for example, one ounce per year, is due to one fairly large leak, or a number of small leaks. If a sensitivity is desired that will reject units outside of the sensitivity range of tests listed earlier in this chapter, it is necessary to use a helium probe for location of leaks. In this method the part of system to be probed is fully evacuated to clear it of helium, and then while it is connected to the mass spectrometer, a fine jet of helium is sprayed over each joint or suspect area. If a large system is tested, a waiting period is necessary because there is time lag for the helium to pass from the leak point to the mass spectrometer. Isolated areas, such as return bends on one end of a coil, may be hooded and sprayed with helium

to determine whether the leak is in this region, thus saving time.

Special Considerations

In selecting a method of leak detection, it should be noted that there are two general categories, one group furnishing a leak check before refrigerant is introduced into the system, and the other group requiring the use of refrigerant. The methods not utilizing refrigerant have the advantage that heat applied to repair a joint has no harmful effects. If repairs are made on units containing refrigerant, it is usually necessary to remove all gas from the unit before brazing or welding, in order to avoid breakdown of the refrigerant as well as pressure build-up, which will prevent the completion of a sound joint. All leak testing equipment must be calibrated at frequent intervals to assure continued maximum sensitivity.

The calibration of the electronic type leak detector or the mass spectrometer is usually made with equipment furnished by the manufacturer. Mass spectrometers, for example, are usually checked with help of a flask containing helium. The flask has a glass orifice allowing the helium to escape at a known rate, and the operator maintains the desired sensitivity by comparing the noted escape rate with a known standard.

The effectiveness of the system can best be checked with calibrated leaks. If a piece of capillary tubing is flattened and attached to a flask of refrigerant that can be weighed accurately, its leak rate can be determined over a period of time. If this tubing is then built into a test unit, and sent through the normal leak detection cycle, the effectiveness of the detection method can be evaluated. Care must be taken that the test leak does not become closed. To check against closing the leakage rate of the test leak must be determined before and after each test.

From a manufacturing standpoint the use of any leak detection method should be secondary to the prevention of leakage. Improper brazing and welding techniques, lack of cleanliness on parts, use of untested sealing compounds or improper fluxes and brazing materials, and poor workmanship result in leaks in transit or later, whatever the detection method. Careful control and analysis of each joint or leak point will make it possible to concentrate tests on areas where leaks are most liable to occur. If operators must scan hundreds of joints on each unit, the probability of finding all leaks is rather small, whereas concentration on a few suspect areas will reduce field failures considerably.

PERFORMANCE TESTING

Since there are so many types and designs of refrigeration systems today, this section will present specific information on compressor testing only, and otherwise deal with some particularly important aspects of performance testing of other components and complete systems. For additional information on components refer to Chapter 38, Compressors; Chapter 59, Commercial Refrigerators and Dispensing Cabinets; Chapter 60, Household Refrigerators and Food Freezers; Chapter 64, Room Air Conditioners and Dehumidifiers; and Chapter 65, Unitary Air Conditioners.

Compressor Testing

The two prime considerations in compressor testing are power and capacity. Secondary considerations are leak-back rate, low-voltage starting, noise, and vibration.

Testing Without Refrigerant. There are a number of tests designed to measure compressor power and capacity before the unit is exposed to refrigerant. In cases where excessive

power is caused by friction of running gear, *low-voltage tests* have been used successfully to spot defective units very early in assembly. In these tests voltage is increased from a low or zero value to the value that causes the compressor to *break away*, and this value is compared with an established standard. On compressors where valve-plates are accessible, performance tests can be made using an air pump for *leak-back tests*. Air at fixed pressure is put through the unit, to determine the flow rate at which proper valve opening occurs. The air pressure exerted against the closing side of the valve gives an indication of efficiency. This method is effective only when the valves are reasonably tight, and its use is difficult in cases where a valve must be run in before it seats properly.

In a common test using the compressor as an air pump, the air flow through a flow device, such as a flow meter or orifice, is measured. Where the volumetric efficiency of the compressor with refrigerant is known, a fairly simple calculation will give the flow rate that can be expected with air at a given pressure. Since this test makes use of adiabatic compression of the air, the head pressure should be low to prevent overheating of discharge lines and oxidation of oil if the test lasts longer than a few minutes. (The temperature of adiabatic compression is 280 F at 35 psig, but 540 F at 125 psig.) When the compressor is run long enough to stabilize temperatures, both power and flow can be compared with established limits. Temperature readings at discharge, and speed measurements will aid in analyzing defective units. If a considerable amount of air is discharged or trapped, the air used in the test must be dry enough to prevent condensation on the discharge side, as wet air will cause rust or corrosion.

In another test method using the compressor as an air pump, the time is measured in which a volume of air reaches a certain pressure. The pressure used in this test is usually in the neighborhood of 125 psig, so that a reasonable time spread can be obtained. The time needed for measuring the capacity of the compressor must be sufficient for accurate readings, but overheating must be avoided. Power readings can be taken at any point of the cycle that is considered convenient. By shutting off the compressor, the leak-back rate can be measured as an additional check. In any capacity test utilizing air, care should be taken to have the air sufficiently dry and clean to prevent contamination.

The acceptance limits of tests that have been described in the foregoing is best established by taking compressors of known capacity and power and observing their performance during the test. Precautions should be taken to prevent the oil used for lubrication from becoming acid or contaminated if it is to be used for several tests.

Testing with Refrigerant. The most common test method is the so-called *run around cycle*. A number of variations and modifications of this cycle that have been used successfully are described in the literature. Basically this method calls for a condenser large enough to handle the heat of compression, and an expansion device. In principle the gas compressed by the compressor is flash-cooled until its enthalpy is the same as that at the suction conditions, and it is then expanded back to the suction state. This method eliminates the need for an evaporator, and utilizes a condenser about one-fifth the size of that normally used with the compressor. On compressors of small capacity, a piece of tubing which connects discharge to suction and has a hand-valve for expansion, can be used effectively. When used in this simple form, the measure of performance is usually the relationship of suction and discharge pressures to power. When a water-cooled condenser is used, the head pressure is usually known, and the water temperature rise and the flow can be used as capacity indicators. As a further refinement, flow measuring devices can be installed in

the refrigerant lines. This system is charge-sensitive, if predetermined head and suction pressures and temperatures are to be obtained. This is satisfactory when all units have the same capacity and one test point is acceptable, since the charge desired can be determined with very little experimentation. Where a variety of sizes are to be tested, however, or more than one test point is desired, a liquid sump or receiver after the condenser can be used for full-liquid expansion.

In refrigerant testing, the refrigerant should be kept free of contamination and moisture, and the tubing and all other components should be clean and sealed when not in use. In the case of hermetic and semihhermetic systems, a motor burn-out on the test-stand makes it imperative not to use the test-stand until it has been thoroughly flushed, and is absolutely acid free. In all tests, oil migration must be observed carefully, and the oil must be returned to the crankcase.

The length of a compressor performance test depends upon various factors. Stabilization of conditions is a prerequisite if accuracy is to be secured. If oil pump or oil-charging problems are inherent, the compressor should be run long enough to make sure that all defective units are detected. Most manufacturers use test periods from 20 min to one hour. A check of the test system is usually made by running a sample of the production units on a calorimeter under controlled conditions.

Testing of Complete Systems

The performance testing of complete refrigeration systems will be covered only in general detail. From a factory standpoint, a basic decision has to be made as to whether testing of any system is to be done in a controlled ambient temperature, or in an existing shop ambient temperature. In both cases, careful attention must be paid to details, and proper corrections must be made if necessary. Since the problem of measuring air temperature and flow is a rather difficult task, production line tests are usually more reliable when secondary conditions are used as capacity indicators. Measurement of water temperature and flow, power, cycle time, refrigerant pressures, and refrigerant temperatures are reliable capacity indicators.

When testing self-contained air conditioners, for example, a fixed load may be applied to the evaporator, using any air source and either a controlled ambient or shop ambient temperature. As long as the load is relatively constant, its absolute value is not too important. In the case of water-cooled units where water flow can be absolutely controlled, capacity is best measured by the heat rejected from the condenser and the Btu rating found from the weight of water and the temperature differential between inflowing and outflowing water. Suction and discharge pressures can be used to aid in analysis.

Suction and discharge pressures can be used as a direct measure of capacity in units having air-cooled condensers. Again, as long as the load is relatively constant, its absolute value is not important. In other words, air distribution, velocity, or temperature over the coil of the test unit must be kept constant during the test, and the performance of the test unit must then be correlated with the performance of a standard unit. Power measurements are used to supplement suction and discharge pressure readings. As a rule suction and discharge temperatures are useful to determine unsatisfactory operation of the unit, and are particularly important when the evaporator or condenser loads are not reasonably stable. When this is the case, simultaneous readings of suction temperature and pressure throughout an entire cycle will permit the experienced observer to judge the performance of the unit.

The length of the test run depends upon the type of test used, but in general stabilization should be achieved in about ten to fifteen minutes. In units where air flows over the evaporator, a dry-coil test should be made to reach and maintain