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Hermetic Motors

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A 1963 B. Tech (Honours) from IIT Kharagpur and 1996 M.E. From IISc Bangalore, Ravindra has 32 years experience in product development and manufacture of AC & R equipment. He has been trained by A.O. Smith a large USA manufacturer of hermetic motors.

Types of hermetic motors:

Hermetic motors are manufactured in a wide range of sizes from about 1/10 HP (for small refrigerator compressors) to several hundred HP (for centrifugal chillers). The smaller motors up to about 3 HP are usually of single phase design, while larger motors are invariably while larger motors are invariably three phase. Single phase motors are made in the following designs:

- Resistance or capacitor start induction run, in which the motor is started by utilising he startling winding resistance, or an additional capacitor, which is introduced into the motor circuit by means of a startling relay and subsequently taken off the circuit after the motor has run up to speed.
- Permanent split capacitor.

- Capacitor start capacitor run, in which the motor operates essentially as a permanent split capacitor motor, but an additional short time rated, large microfarad capacitor is introduced into the motor circuit by means of a relay to provide a large starting torque.

A solid state device, called a PTC (positive temperature coefficient of resistance) thermistor is also used to provide a hard start in lieu of a starting capacitor, though it provides a lower starting torque than the latter.

Hermetic motors used in hermetic (i.e. fully welded) compressors are invariably 2 pole and operate at 2950 rpm (for 50 Hz supply). They are usually started direct-online Larger motors used in semi-hermetic compressors have 4 or more poles and operate at 1440 rpm or lower speeds. Theses are usually designed for part winding or star-delta starting in order to limit the starting in rush current. In part winding motors, the stator is wound with two star-connected windings which could be either identical to each other or unequal. During starting, one winding is energised first and the second. The part wound motor has a highest starting torque than a star-delta wound motor, but also a higher starting inrush current.

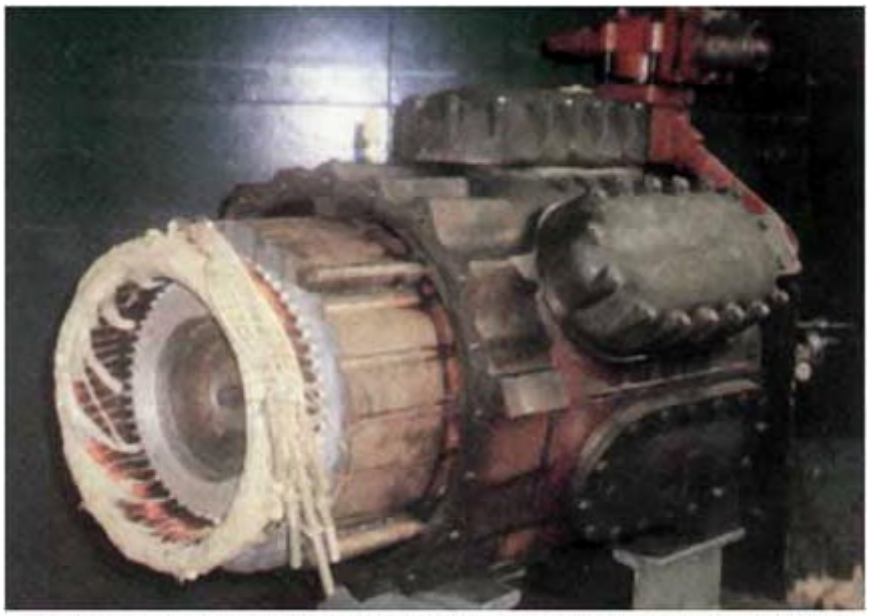

Photo 1 - Stator and rotor assembly mounted on a 75 ton semi-hermetic compressor

Differences between hermetic and standard air-cooled motors:

Though the hermetic motor to apparently similar to any other induction motor, there are some very crucial differences from a standard air-cooled motor in its design, performance and construction:

- **Construction:** A hermetic motor comprises only a wound stator and squirrel cage rotor, without any shaft bearings or motor housing of its own. Because of the space and weight constraint within a hermetic compressor, a hermetic motor is a relatively tight design.
- **Cooling:** Unlike a standard air-cooled motor, the hermetic motor is cooled very effectively by refrigerant (usually, cool suction gas) flowing at high velocities in the air gap, rotor vents and/or passages provided around the back of the stator.
- **High energy density:** Because of the very effective cooling provided by the refrigerant, the hermetic motor has only about 70% active material (stator / rotor core and copper winding / rotor cage) of a standard air-cooled motor of the same output. The magnetic flux and current densities in a hermetic motor are therefore higher than in a standard motor.
- **Loading:** The loading of a hermetic motor, during its operation, fluctuates widely between 50 and 140% of its operating torque at rated load. This requirement, coupled with its need to operate reliably over a wide voltage range, requires that it have a high breakdown torque equal to 225 to 250% of its torque at rated operating conditions. Breakdown torque (for pullout torque) is the maximum load torque which can be applied to an induction motor before it stalls and comes to a halt. The hermetic motor should be so designed that its breakdown torque, at about 85% of its rated voltage, is a little high than its maximum design load. Over-design of the motor may increase discharge gas temperature, apart from reducing the energy efficiency of the compressor.
- **Protection system:** It is essential to provide a properly selected and matched protection system to protect the hermetic motor under various fault conditions such as overloading, locked rotor, single phasing, low voltage high load, high voltage light load and loss of refrigerant charge.
- **Electrical insulation:** The electrical insulation system for hermetic motors must consist of carefully selected materials which are compatible with refrigerant and refrigerant-oil mixtures. Specially formulated and cured hermetic grade winding wire must be used for the stator winding in order to withstand the scrubbing and cleaning action of refrigerants.

Major issues in manufacturing hermetic motors

- **Mechanical dimensions & assembly:** In small hermetic compressors, the stator is usually heat shrunk, while in larger compressors it is bolted in place inside the machined compressor housing. The rotor is also either heat shrunk on the shaft or keyed and bolted in place. Therefore it is important to control the mechanical dimensions particularly the outer diameter and bore dimensions, concentricity and squareness of the stator and rotor as well as the stack length within close tolerances. The winding overhand too must be properly shaped and dimensionally controlled to prevent fouling with the compressor housing.
- **Cleanliness:** The refrigerant and oil present in the refrigeration system are solvents which scrub the stator and rotor and wash any impurities present on them into the system and contaminate it. Any suspended impurities are likely to clog the fine clearances and oil holes in the compressor leading to its failure.
- **Materials:** The laminated stator and rotor cores are made from high permeability, low core loss cold rolled, non-grain oriented silicon steel or decarburized low carbon steel. The insulating coating over the laminations is produced by a steam blueing process instead of conventional varnish coating which might prove incomparable with refrigerant. The winding wire is usually dual coated with a base coat of modified polyester, polystermide or polyester-amide-imide with an overcoat of polyamide-imide. Polyster film, such as Mylar or Melinex is used for the slot insulation. Dacron-Mylar-Dacron and Acrylic resin coated fiberglass sleeving us used as insulation for the lead wire. Polyester yarn (Dacron) is used for end turn lacing and tying on the protective devices. The finished winding is subjected to an over-baked polyurethane or epoxy-base varnish coating which protects the winding and also maintains the integrity of the end turns or winding overhang.

Hermetic motor qualification, testing and quality assurance.

A hermetic motor is subjected to the following qualification tests before it can be cleared for use in a hermetic compressor:

- **Load test on Dynamometer:** The motor is subjected to the following qualification tests before it can be cleared for use in a hermetic compressor.
- **Plug reversal test:** This is an accelerated life test to evaluate the integrity of the construction, materials and insulation system of the hermetic motor. "Plugging" is rapid braking of the motor brought about by suddenly reversing two of the three phases of the supply voltage while it is rotating in any direction. This "plugging"

action subjects the motor winding to severe electromagnetic forces and consequent mechanical stresses.

The test consists of subjecting the hermetic motor to 50,000 or more plugging and reversal cycles in refrigerant-oil mixture in a specially prepared compressor assembly. At the end of the test, the motor must be operable and successfully pass the standard inspection requirements.

- **Performance in compressor:** The motor is assembled in the compressor and subjected to a complete performance text at various load conditions and voltages in a Compressor Calorimeter. The compatibility of the motor protection system and its effectiveness in protecting the hermetic motor under various fault conditions is also validated during this test.

Routine production tests on a hermetic motor are similar to those for a standard air-cooled motor, viz. High Potential (usually, twice the rated voltage + 1000 volts) and Insulation Resistance check, Broken or faulty Rotor Bar check and No Load (or Load) Tests.

Quality Assurance tests by the compressor manufacturer include the Plug Reversal and Compressor Calorimeter tests as described above.

Further, since the hermetic motor is directly assembled into the compressor without any further attention, it must be clean and free of moisture, processing oils and chemicals, rust, uncured varnish, etc. which could contaminate the refrigeration system. The wound stator and rotor are therefore individually subjected to a Cleanliness test, in which the residual impurities, after extraction in a solvent such as xylene or toluol, shall not exceed 3 milligrams per kg of motor weight.

Hermetic motor protection

Small hermetic compressor motors of less than 1 hp are usually protected by an external over-current cum thermal protector which consists of a bimetal switch housed inside a bakelite enclosure (**photo 2**). The protector is mounted on the compressor shell and is connected in series with the motor supply. The bimetal thus senses and responds to both the shell temperature and the motor current and disconnects the motor winding before it can reach dangerous temperatures.

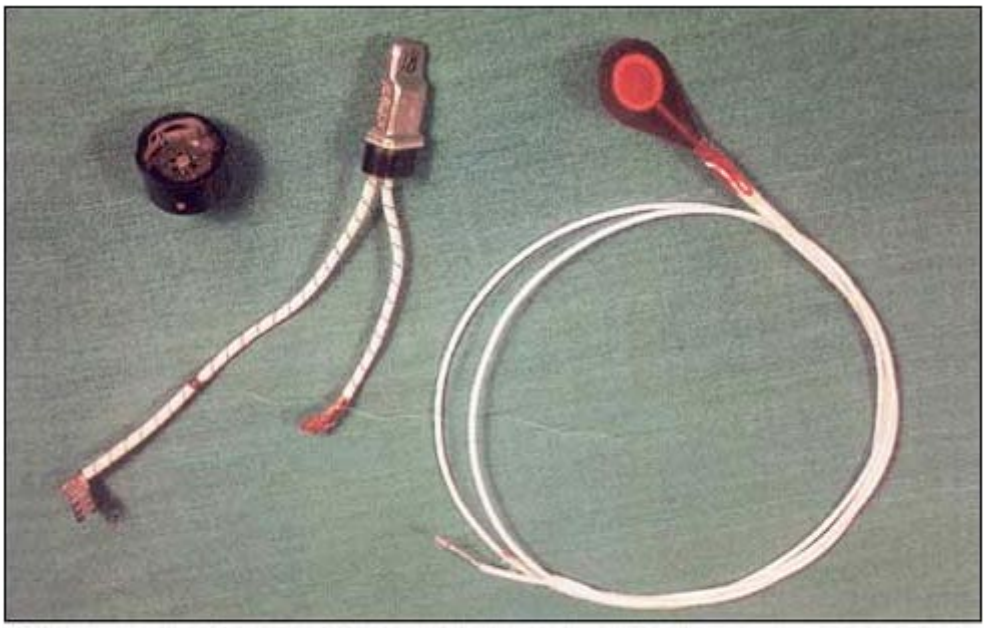

Photo 2 - Extreme left is a "Klixon" external overcurrent cum thermal protector. Centre is a "Klixon" finger shaped, sealed, line-break protector. Extreme right is a "Texas Instruments" PTC themistor.

Hermetic compressor motors above 1 hp are usually protected against overheating (caused by overload, failure to start or excessive operating current) by an internal protector, which is a finger shaped hermetically sealed bimetal device (**photo 2**) embedded in the winding overhang of the hermetic motor and connected in series with it. The internal protector offers better protection than the external protector since it directly senses the motor winding temperature as well as the motor current. It can thus protect the hermetic motor against overheating due to loss of refrigerant charge from the system, which is not possible with the external protector.

Hermetic motors (usually above 20 hp) used in semi-hermetic compressors have PTC thermistors (**photo 2**) embedded in different hot spot areas of the stator winding. These thermistors are connected to an electronic module which senses the quantum increase in resistance in the event of the winding exceeding its safe temperature limit and de-energises the motor contactor.

Hermetic motor burnout

Ignoring or neglecting the use of the specified hermetic grade winding wire, varnish and other materials or the correct processing and other quality assurance requirements of the hermetic motor will result in disaster. The word 'disaster' is not an overstatement, for a hermetic motor burnout can be very expensive and time consuming. The short circuit inside the compressor decomposes the refrigerant into fluorides and chlorides which are extremely corrosive and contaminate the entire refrigeration system.

Therefore, apart from rewinding the hermetic motor, the entire refrigeration system will have to be thoroughly flushed and cleaned of all traces of the contaminants before recuperating it. The compressor oil, filter-drier and capillary tubes have to be replaced. Failure to clean the system thoroughly will result in a repeat burnout caused by corrosives attack on the motor winding insulation by the residual contaminants.

Motor stator before burnout

Motor stator after burnout

Rewinding a hermetic motor requires the same care in processing and use of the approved winding wire and other insulation materials, varnish and the motor protector as in the case of a new motor. In addition, the stator must be thoroughly cleaned of all contamination and products of burnout before it is rewound. Before assembling the motor into the compressor, it should be put through the High Potential, Insulation Resistance checks. If the motor is re-assembled into the compressor in the field, it is advisable to apply a low dc voltage (about 24 volts) to the winding while evacuating the compressor or the refrigeration system. This helps in gently heating the winding and aids the removal of all traces of moisture from it. To conclude, it is important to recognize that the hermetic motor is quite different from a standard air-cooled motor in its design, materials, construction and quality assurance requirements and it manufactured and applied properly, will give years of trouble free operation in a hermetic compressor.