1972

Application Considerations of Line-Break, Internal Protectors

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APPLICATION CONSIDERATIONS OF LINE-BREAK, INTERNAL PROTECTORS

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INTRODUCTION

Through the past fifteen odd years, the electrical protection of small integral horsepower motor compressors has evolved through several generations of devices and schemes into the present state. At the start of that period, most compressor protection was of the dome-mounted, line-break variety or used remote, current sensing overloads combined into a motor starter. These devices, along with pressure switches, provided a measure of protection considered adequate for that day.

The air source heat pump, which fifteen years ago was struggling to obtain commercial acceptance, imposed a whole new list of requirements on the motor compressor. On a cooling system, the compressor motor was required to operate from approximately 70% to 140% full load, while the heat pump required approximately 35% to 140% of full load. Protection at the lighter load became a problem due to reduced cooling gas flow through the motor, and in single-phase equipment higher phase winding current at light load compounded the problem. This was further aggravated by over voltage conditions causing increased motor losses or system faults which, at times, drove motor temperatures past the danger point.

The hermetically sealed pilot duty thermostats emerged as the preferred means of protection for the heat pump. Development did not stop at this point, for the thermostat led to motor designs which would remain within tolerable temperature limits over the required operating range. The thermostat and motor development was not enough. Locked rotor protection was supplemented by pilot duty current-sensing external devices. Here, at last, was a protection system which aided in providing compressor reliability adequate for the heat pump. The technology gained on the heat pump carried over to the cooling-only equipment, thus raising the reliability in that area also.

The next area of protection with wide commercial acceptance was a line of small line-break protectors designed to be installed in or near the motor windings in single-phase motors. These devices, sometimes with an auxiliary series heater, were and are operating successfully in many applications and installations.

This paper will be concerned with the application of the more recently developed protectors for polyphase compressors which are physically small enough to be used inside a compressor with capacities up through approximately 150 locked rotor amperes and the more reliable cylindrical-shaped protectors for single-phase compressors. This discussion is limited to experience with hermetically sealed reciprocating motor compressors in the integral horsepower sizes with internal spring mounting and a low side case.

DESIGN CONSIDERATIONS

The basic criteria for the protection system design which had been used since the internal thermostat introduction was used with some principles from the early internal line-break development. These criteria are:

1. The protector must allow compressor operation over the entire desired operating range which may be imposed by the system to which it is applied with consideration of voltage and frequencies desired.

2. The protector must limit motor temperatures to safe limits under the various system faults or recognized temporary overstress conditions imposed by the system.

3. The protector must limit system pressures when other provisions such as pressure switches are not provided.

4. The protector must have sufficient cycle life to maintain the above protection through the

useful life of the product.

5. First cost of the compressor and the system with a strong consideration of warranty or complaint cost must also be evaluated.

While most of the above appear to center around the protector, the motor design is of great importance. In most cases, a motor design adjustment will be necessary to complete an application.

MOUNTING MEANS

One of the earliest considerations of application of the new family of hermetically sealed line-break protectors is the mounting means. At first glance, the protectors involved seem large for the space which might be allowed for mounting. Some early tests ended in temporary disaster when, for the single-phase devices, a cavity was formed between the main and phase winding which would practically cover the protector with magnet wire. Here, during locked rotor cycling, the high magnetic flux density directed the arc produced between the contacts inside the case against the side of the case. Very few cycles were required to burn a hole in the case, allowing refrigerant leakage into the case. The products then produced by electrical arcing in refrigerant lead to practically immediate, devastating failure of the motor. A review of the more severe locations of high magnetic flux was in order at this point. The final mounting for the polyphase protector was to tie the protector into a cup, formed of soft heat conducting metal mounted on the upper end turns of the motor by welding the cup to a heat conducting fin made such that part is between the outside and middle phases and part between the middle phase and the inside phase of a concentric wound, wye connected motor. The protector is connected into the junction of the wye and its operation stops the current flow.

The single-phase protector was located in a rolled heat conducting fin whose extension is inserted between the main and phase windings. Here the connection will depend on whether or not a supplementary phase winding heater is provided in the protector. Photographs of both single and polyphase arrangements are included in this paper.

With these mountings, the most desired results obtained are as follows:

1. The protector can be located in an area of low magnetic flux density.

2. The protector has good thermal coupling with all phases of the motor.

3. Exposure to suction gas flow is obtained allowing maximum cooling of the protector during heavy load conditions.

4. A solid, reliable mounting is obtained.

5. The protector is located above the motor in the most desirable location for fault protection.

CHOICE OF INTERNAL COMPONENTS

The choice of internal components must now be considered. The bimetallic disc resistance and/or heater resistance is chosen as high as possible to insure rapid operation during fault conditions. Figure 1 illustrates the desirable winding temperature results during a stalled rotor condition. The dotted line represents a poor application with resistance too low or disc opening temperature too high. Motor burnout can result in such an application if the stall occurs during a very cold start or at an extreme undervoltage. Figure 2 is included to illustrate a comparison with a motor protected by an internal thermostat and external, current sensing protectors. This disc opening temperature is chosen as low as possible to protect the windings from overheating during times of high voltage and/or low gas flow. Low gas flow can be the result of cold outdoor operation of a heat pump or the loss of refrigerant charge from the system.

In the single-phase compressor, the addition of a supplementary start winding heater can be used to a great advantage. The greatest value is that protection can be obtained on a capacitor-start, capacitor-run (CSR) application when the starting capacitors inadvertently remain in the circuit, causing very high phase winding currents with a resulting high rate of rise in winding temperature. When the additional start winding heater is not used, some supplementary means of protection must be applied; such as, an external start winding protector whose only function would be to protect for this potential problem. In many cases, the single-phase compressor uses a capacitor in series with the phase winding which allows a small current through the winding during the off cycle. Should the capacitor fail shorted during the off cycle, the winding will become overheated very quickly. In most applications, the start winding heater will cause the protector to open, thus protecting the winding. A further control of operating range can be obtained by the choice of heater resistance. As voltage is increased or load is decreased, the phase winding current increases. Heater choice is extremely important for protection of the phase winding from overheating at very low loads, or during a loss of system charge. Without the heater, it would be difficult for the protector to sense the winding temperature unless it were buried in the winding. We have already determined this to be undesirable because of arc travel, so as the current increases and/or cooling due to gas flow decreases, the heat within the protector increases causing the protector to operate.

Without the heater, a lower bimetal opening temperature would be required.

Choice of heater resistance can limit operating range and protect the mechanical parts of the compressor from the high torque available at overvoltage. This feature makes protection for loss of condenser fan without a high pressure switch, with or without an internal pressure relief valve more practicable. A pressure relief valve, whether located inside the compressor shell or connected externally, will operate during a system fault when a predetermined differential pressure is reached, usually about 500 psi. Hot gas is bypassed into the low side which will heat the protector which is already seeing high current due to the high load causing the protector to trip.

Figure 3 is included to illustrate the operating range of a motor compressor with an internal thermostat. The compressor will not run continuously above the lines shown. Figure 4 shows a disc only or with a series heater. This will also illustrate a heater in intimate contact with a disc which does not carry current. Figure 5 shows the range controlled by a single-phase protector with an auxiliary start winding heater. The dotted line in Figure 5 indicates the effect of increasing the heater resistance.

In polyphase systems, protection from double current in one phase caused by a single-phased primary in a wye-delta or delta-wye distribution system is easily handled by a properly applied protector.

The following is a summary of conditions for which protection can be obtained:

1. High load - caused by dirty condenser, hot outdoor conditions, system overcharge, etc.

2. Low load - or loss of refrigerant charge.

3. Low voltage.

4. High voltage.

5. Failed outdoor fan - may require bypass valve.

6. Normal refusal to start in a permanent split capacitor application - this can be due to pressure differential.

7. Capacitor failure.

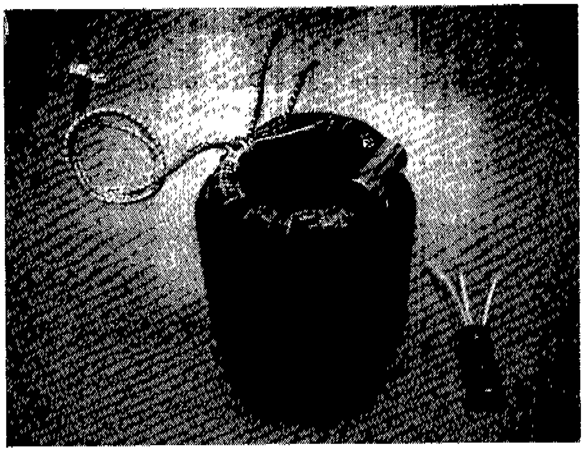
8. Other power supply faults - wire off, single phased secondary or primary, etc.

9. Mechanical failure of compressor.

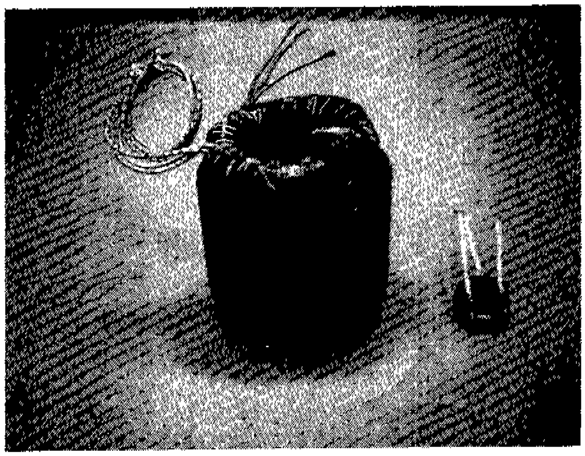
Due to the increased functional capabilities of motor protectors and the resultant elimination of other limit controls, we have become much more dependent on the reliability, durability and accuracy of the motor protector. Extensive life tests must be run both in the development phase and as quality audits to determine that reliability is adequate for the application.

SUMMARY

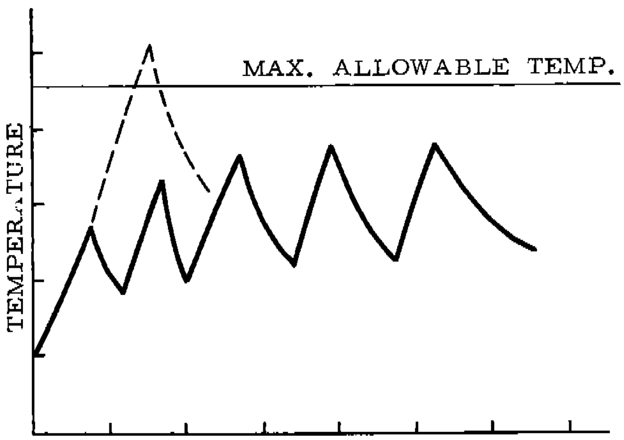
The latest family of line-break, internal protectors represents an opportunity for the compressor manufacturer. Lower cost protection for not only the hermetic motor, but the compressor and system as well, can be obtained with an increase in reliability if care is taken in application. The complexity of the system demands sophistication in its design, but the consideration of the motor protector as a system protector has many benefits.



SINGLE PHASE STATOR WITH PROTECTOR

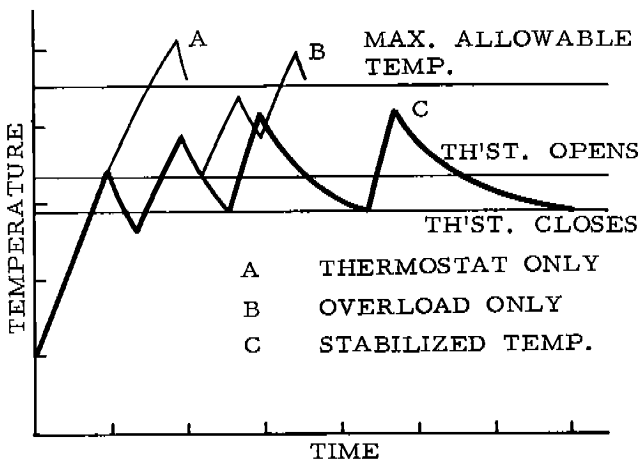


POLYPHASE STATOR WITH PROTECTOR



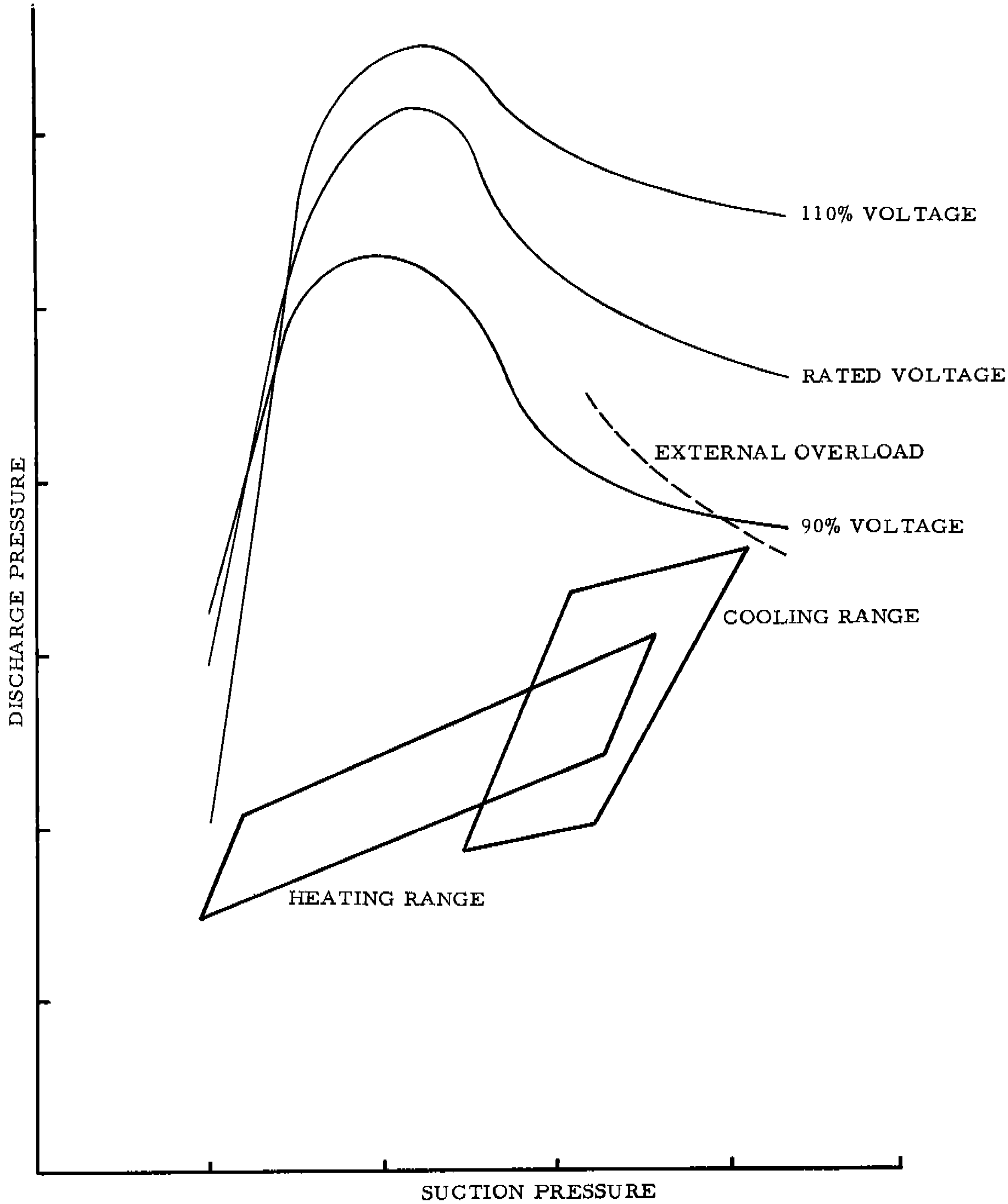
LOCKED ROTOR TEMPERATURE
INTERNAL PROTECTOR

Figure 1



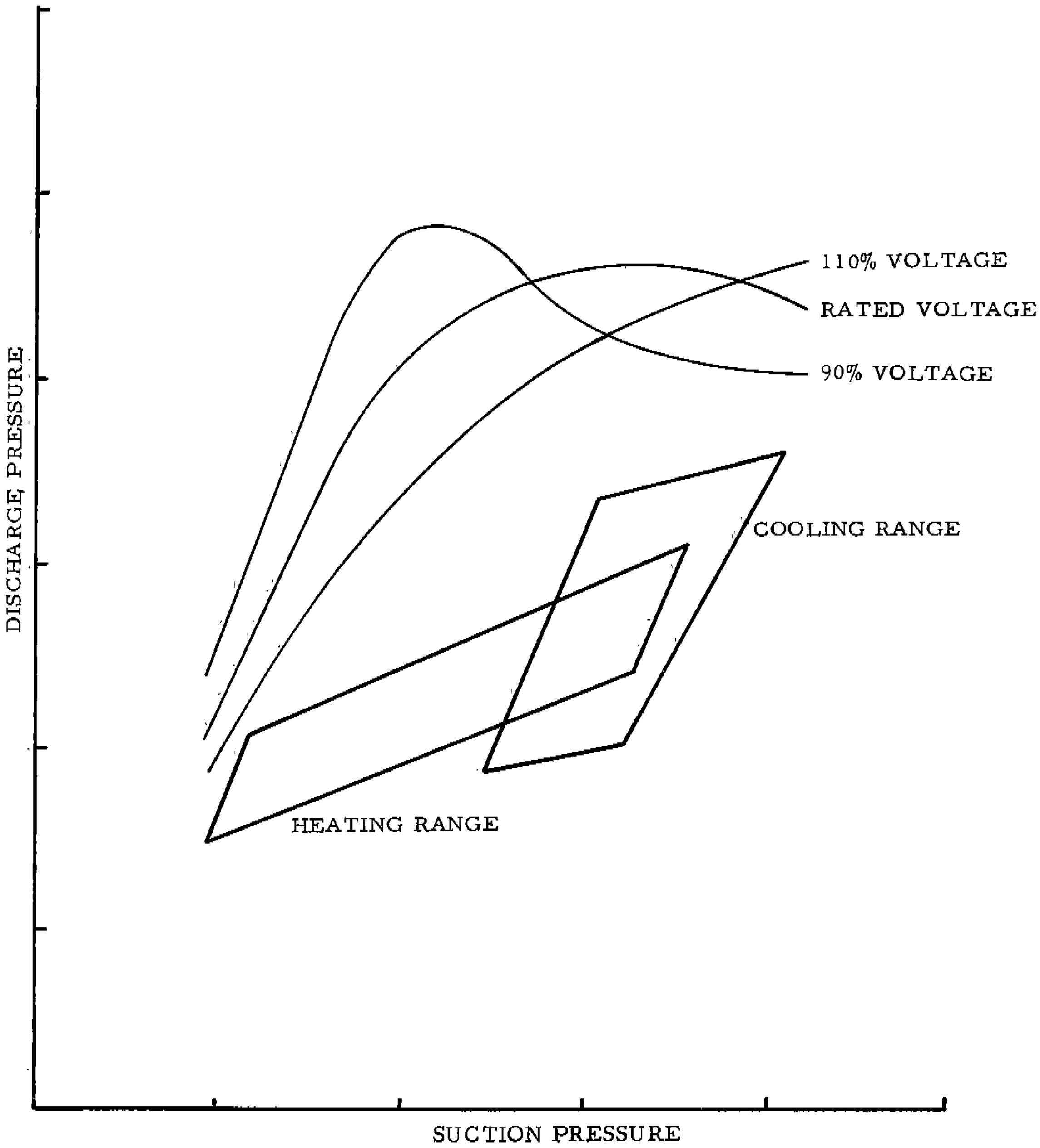
LOCKED ROTOR TEMPERATURE
THERMOSTAT AND EXTERNAL OVERLOAD

Figure 2



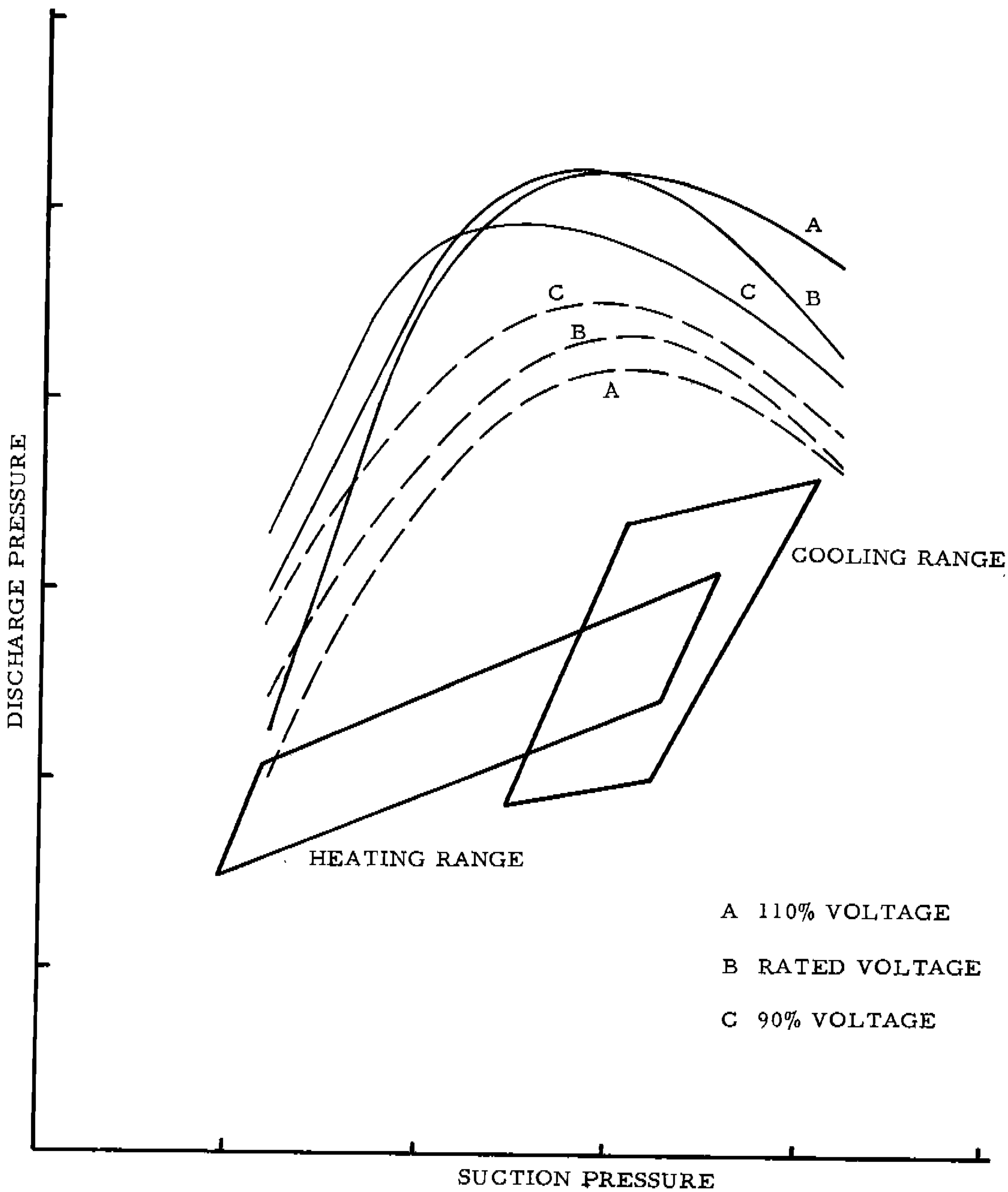
OPERATING RANGE - PILOT DUTY THERMOSTAT

Figure 3



OPERATING RANGE - INTERNAL, LINE BREAK PROTECTOR WITH DISC ONLY
SINGLE PHASE OR POLYPHASE

Figure 4



OPERATING RANGE - SINGLE PHASE PROTECTOR WITH START WINDING HEATER

Figure 5