1976

An Attempt to Eliminate Reverse Turns from Starting Winding of 2-Pole Hermetic Split-Phase Motor

C. R. Vanjani

Vanjani, C. R., "An Attempt to Eliminate Reverse Turns from Starting Winding of 2-Pole Hermetic Split-Phase Motor" (1976). *International Compressor Engineering Conference.* Paper 239.
https://docs.lib.purdue.edu/icec/239

AN ATTEMPT TO ELIMINATE REVERSE TURNS FROM STARTING WINDING OF 2-POLE HERMETIC SPLIT-PHASE MOTOR

Chandu R. Vanjani, Product Engineer-Hermetic Motors
*Whirlpool Corporation, Evansville, Indiana

DETAILED DESCRIPTION OF PRIOR ART

An alternating current single phase two poles induction motor of the "split-Phase" type consists of main field winding and starting field winding, the two windings being displaced in space quadrature (ninety degrees apart) on the stator core, to get the desired performances under starting and accelerating conditions. In this type of motor the starting field winding remains energized only during starting and accelerating period and is suitably de-energized when a predetermined desired operating condition is attained and thereafter the motor should keep running on main field winding only.

In some split phase motor applications, the starting field winding is de-energized by a centrifugal switch mechanism which is responsive to the speed of the motor. Thus in this case the starting field winding is de-energized when the motor accelerates up to a predetermined speed.

In other split-phase motor applications, particularly in hermetically sealed motor applications, a commercially available current-relay is used very extensively. The current-relay consists of a solenoid coil, a steel armature which slides in the solenoid coil field and a pair of normally open type contacts. The solenoid coil is connected in series with the main field winding and the normally open type contacts are connected in series with the starting field winding, as shown in Fig. 1.

When voltage Vac is applied to the motor, between points 1 and 2, current flows through the main field winding and, since the solenoid coil is in series with this winding, a magnetic field is created by the solenoid coil which lifts the steel armature, thereby closing the relay-contacts. This results in voltage Vac being applied to the starting field winding also. Due to phase displaced currents flowing through the two windings, the motor starts rotating and accelerating. As the motor speed increases from standstill, the current in the main field winding (and solenoid coil) decreases until a predetermined point is reached where the steel armature is too heavy for the decreasing magnetic field, in the solenoid coil, to hold the relay contacts in the closed position. The steel armature then drops out to open the relay contacts, resulting in the de-energization of starting field winding.

The commercially available current-relays are rated for "maximum pick-up" and "minimum drop-out" current limits. Thus a particular rated relay may not pick up if the main field winding current of motor is less than the max. pick-up current and similarly the relay may not drop out if the main field winding current during acceleration does not reach the min. drop-out value.

For a given main field winding that results in desired running performances and that meets the requirements of pick-up of the current relay, the relay drop out should occur around a predetermined speed and torque level.

---

* The background of the work associated with this paper was originated when employed at A.O. Smith Corporation, Electric Motor Division, Tipp City, Ohio

The relay drop out at speeds higher than predetermined value and/or at torque lower than predetermined value is considered a malfunction of relay, which may result in burn out of the starting field winding. The current through the main field winding, during starting and accelerating conditions, is greatly influenced by the reactance of the starting field winding (reactance is proportional to the square of effective forward turns). More specifically, for a given main field winding, larger the reactance of the starting field winding higher the speed and lower the torque at which the relay will drop out. For this reason it is absolutely essential that the effective forward turns of starting field winding be substantially smaller compared to those in main field winding and since starting field winding is formed of wire that is substnatially smaller in diameter, compared to that in the main field winding, it may be subjected to excessive heating rate and high winding temperature rise. While high heating rates are objectionable in general, they are particularly objectionable in those applications where permissible temperature rise of a motor winding should be kept low. One type of such application is motor in hermetically sealed compressor in which external or internal protector used may not be able to respond to excessive heating rate of starting field winding without having nuisance trips under running conditions.

In such applications, using a current-relay, where heating rate in the starting field winding must be kept at a relative low value, the starting field winding consists of some turns wound in the forward direction and some turns wound in the reverse (backwards) direction, the latter being smaller in number (see Fig. 2).

Thus, for a particular number of effective turns, necessary for desired relay operation, (forward turns minus reverse turns) wound with a particular magnet wire size in the starting field winding, the resistance of the starting field winding is increased, resulting in reduction of current through it, and, consequently, reduction in the heating rate of starting field winding.

This general approach of forward and reverse turns in the starting field winding of split-phase motor provides a motor design engineer with a technique of obtaining variable winding resistance (and hence variable winding heating rate) for a given number of effective turns and this method is used, very extensively, throughout the world, at present.

The desirable starting field winding heating rate obtained by the above method could also be achieved by using larger number of all forward turns than those used in the above case (without using reverse turns). But this results in the malfunction of current relay, which does not drop out at desired speed and/or torque level. For example, refer to Fig. 4 which shows the plot of main field winding current and torque versus the speed, during starting and accelerating conditions, of 1/4 HP 120 volts 60 Hz 1 phase 2 poles split phase induction motor, tested at 120 volts applied to both windings. The current-relay used with this motor is rated for maximum pick-up of 12.9 amps and minimum drop out of 10.8 amps. As noted in the figure, the starting field winding in this case, consists of an all forward turn windings displaced in space quadrature from main field winding. It will be noted from Fig. 4 that when main field winding current is 10.8 amps, the motor torque is 7.1 oz.ft. and speed is 3430 rpm, whereas the application requirement of this motor necessitates a minimum torque of 17.5 oz.ft. at speeds around 3200 rpm. The locked rotor starting field winding heating rate of this motor was 26.1^{o}F/Sec. when 120 volts was applied to both windings, till starting field winding temperature reached 300^{o}F.

AN ATTEMPT TO ELIMINATE REVERSE TURNS

Both the reverse turns, used in the starting field winding of the prior art, and a major portion of equal number of forward turns can be omitted from the starting field winding if the starting field winding is shifted in space, in the same direction as the rotation of the motor, as shown in Fig. 3. By shifting, in space, an all forward turns starting field winding out of quadrature with the main field winding and connecting the two windings so that the shift occurs in the direction of rotation of the motor, the mutual leakage reactance, between the main field winding and the starting field winding, is increased. Thus the total leakage reactance (sum of self & mutual leakage reactances) of each winding is increased, resulting in the reduction of currents in both windings, when energized together during starting and accelerating conditions. Thus by shifting an all forward turns starting field winding, by suitable number of slot(s), in the direction of rotation, the current in this winding and hence, its heating rate can be kept to a desirable level. At the same time, the reduction in main field winding current allows the current-relay to drop out at desirable speed and torque levels.

This may be verified by making a motor by using the same main field winding and same effective all forward turns starting field winding used in the previous example, as explained previously by Fig. 4, excepting shifting the starting field winding, in space, by one and a half (1 1/2) stator slots in the same direction as rotation of the motor. Fig. 5 shows the plot of main field winding current and torque versus the speed of this motor. It will be noted, from Fig. 5, that when main field winding current is 10.8 amps., the motor torque is 18.3 oz.ft. and speed is 3210 rpm. The locked rotor starting field winding heating rate of this motor was 17.2°F/Sec. when 120 volts was applied to both windings, till starting field winding temperature reached 300°F. It may further be noted that in the particular motor example used above, the application of motor calls for the starting field winding heating rate to be limited to 18.5°F/Sec. maximum.

The starting field winding heating rate of motor of Fig. 4 may be reduced to acceptable level of 18.5°F/Sec. by increasing the number of all forward turns starting field winding in quadrature with main field winding, but this would further worsen the accelerating performance of this motor and the current relay may never drop out even at nominal voltage of motor (at voltages higher than nominal, the relay drop out problem worsens further).

Thus it may be possible to eliminate all reverse turns as well as a major portion of equal number of forward turns, from the starting field winding, and still avoid the malfunction of commercially available current-relay, while keeping the starting field winding heating rate at a relatively low value and this is achieved by shifting an all forward turns starting field winding out of quadrature with the main field winding and connecting the windings so that the shift occurs in the direction of rotation of the motor.

The following are the advantages of arranging starting field winding as described above:

1. Substantial savings in the cost of magnet wire used in starting winding.
2. Saving of winding machine time due to deletion of substantial number of turns.
3. Saving in the set-up time for winding machine.
4. No necessity of special winding machine with reverse turns capability.
5. Less bulk of wires in the end-coils which are required to be maintained within specified dimensions.

THE LIMITATIONS

So far, so good. But there is also a dark side of the shield. The shifted starting field winding has adverse effect on relay function under low voltage; especially when the windings are hot. Fig. 6 shows plots of main field winding currents at 98V when its temperature is 200°F. If the relay has drop out of 10.8 amps, it will drop out at 2480 rpm. But if that relay has a pick of less than 11.4 amps then the relay will pick up again, as evidenced by horizontal line at 2480 rpm. Shortly after pick the main field winding current will be less than 10.8 amps so the relay will drop out again and thereafter the main current may be enough to cause pick up again, thus resulting in "relay-chattering." This relay-chattering may continue until "main only" current is less than pick up current of the relay.

From Fig. 6 it is evident that larger the differential between pick up and drop out currents of a particular relay, the lesser the relay-chattering. It is also evident from this figure that in this example if this differential is greater than or equal to 1.0 amps there will be no chattering under test conditions of Fig. 6. On the other hand this larger differential narrows the voltage range of satisfactory relay operation.

CONCLUSIONS

Some modern current relays have as small a differential as 0.10 amps and such relays will not function properly with shifted starting field winding. About 1.0 amp differential and careful design of shifted starting winding may result in a successful application.

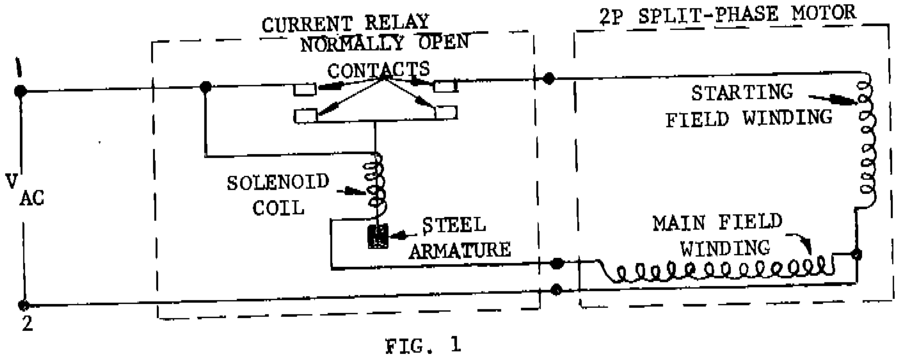


FIG. 1

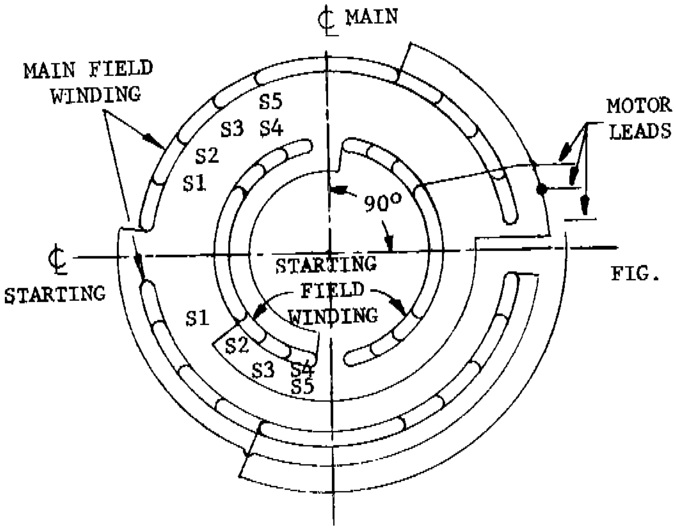


FIG. 2

1. ROTATION: COUNTER CLOCKWISE LEAD END (SHOWN)
2. STARTING FIELD WINDING IN SPACE QUADRATURE WITH MAIN FIELD WINDING
3. S1, S2, S3, S4 ARE FORWARD AND S5 ARE REVERSE TURNS IN STARTING FIELD WINDING, WOUND CONTINUOUSLY IN A POLE, S4 > S5

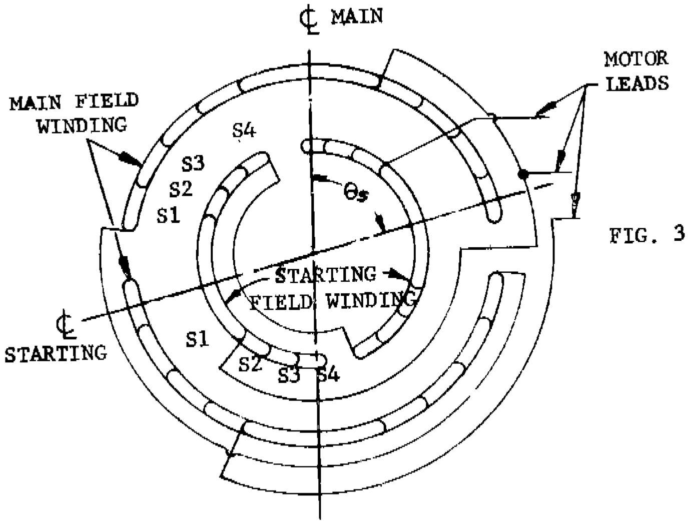


FIG. 3

1. ROTATION: COUNTER CLOCKWISE LEAD END (SHOWN)
2. STARTING FIELD WINDING SHIFTED ONE STATOR-SLOT, IN SPACE, IN THE DIRECTION OF ROTATION. THIS SHIFT MAY BE OTHER THAN ONE SLOT, AS DICTATED BY DESIGN CONSIDERATIONS, SO THAT $\theta_s < 90°$

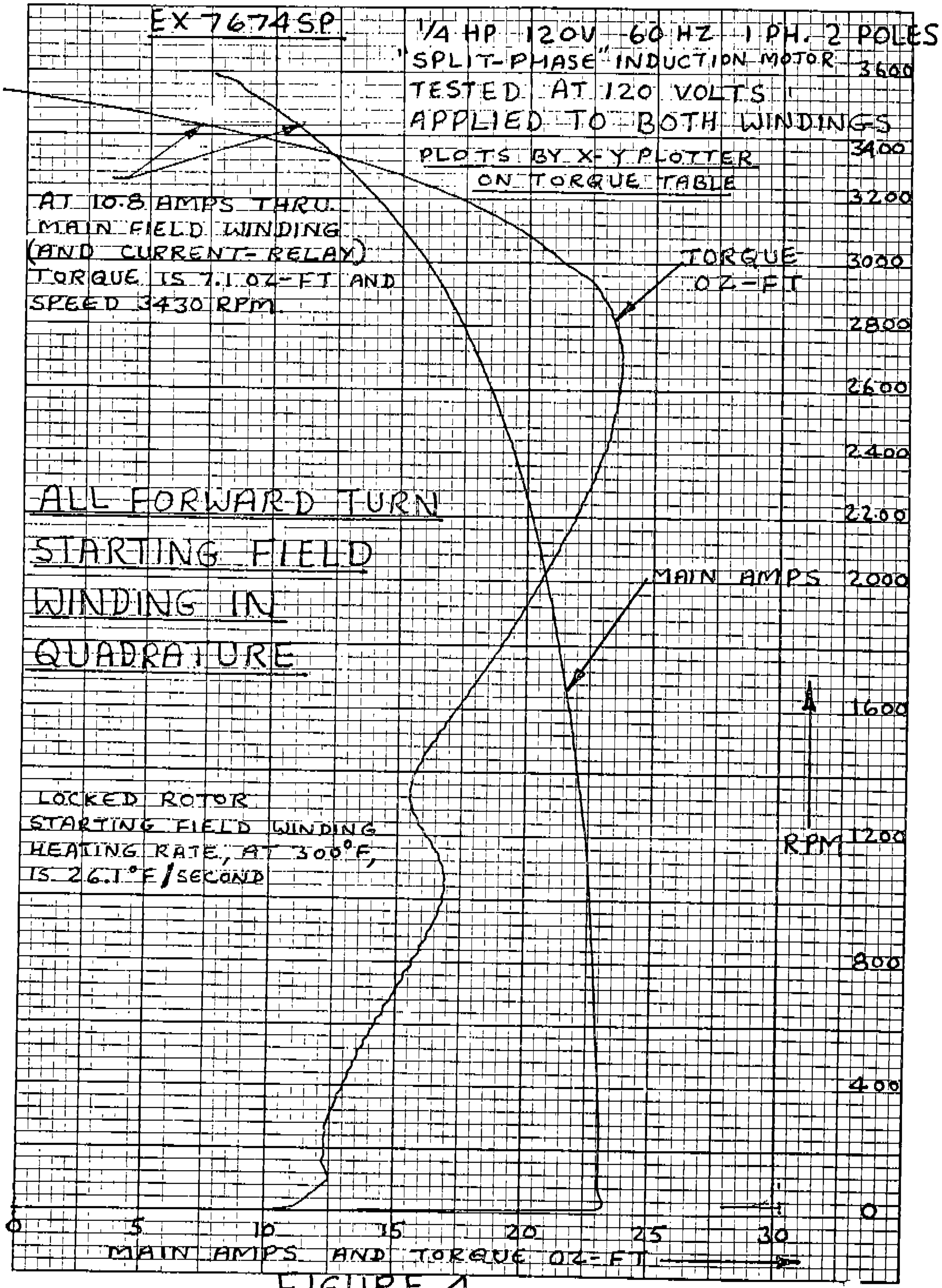
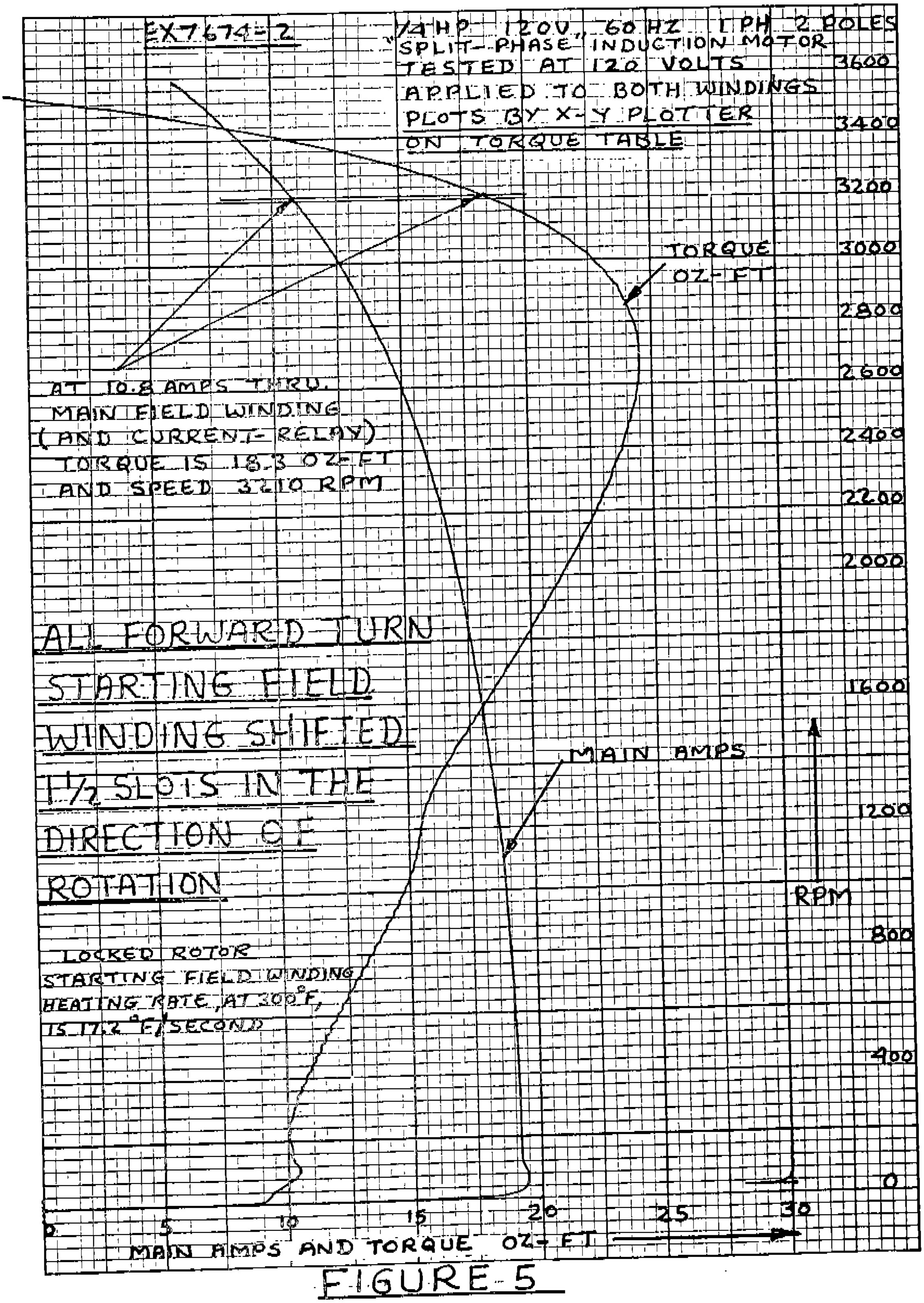

EX 7674SP
1/4 HP 120V 60 HZ 1 PH. 2 POLES
"SPLIT-PHASE" INDUCTION MOTOR
TESTED AT 120 VOLTS
APPLIED TO BOTH WINDINGS
PLOTS BY X-Y PLOTTER
ON TORQUE TABLE
AT 10.8 AMPS THRU.
MAIN FIELD WINDING
(AND CURRENT-RELAY)
TORQUE IS 7.1 OZ-FT AND
SPEED 3430 RPM.
ALL FORWARD TURN
STARTING FIELD
WINDING IN
QUADRATURE
LOCKED ROTOR
STARTING FIELD WINDING
HEATING RATE, AT 300°F,
IS 26.1°F/SECOND
TORQUE
OZ-FT
MAIN AMPS
RPM
3600
3400
3200
3000
2800
2600
2400
2200
2000
1600
1200
800
400
0
0
5
10
15
20
25
30
MAIN AMPS AND TORQUE OZ-FT

FIGURE 4

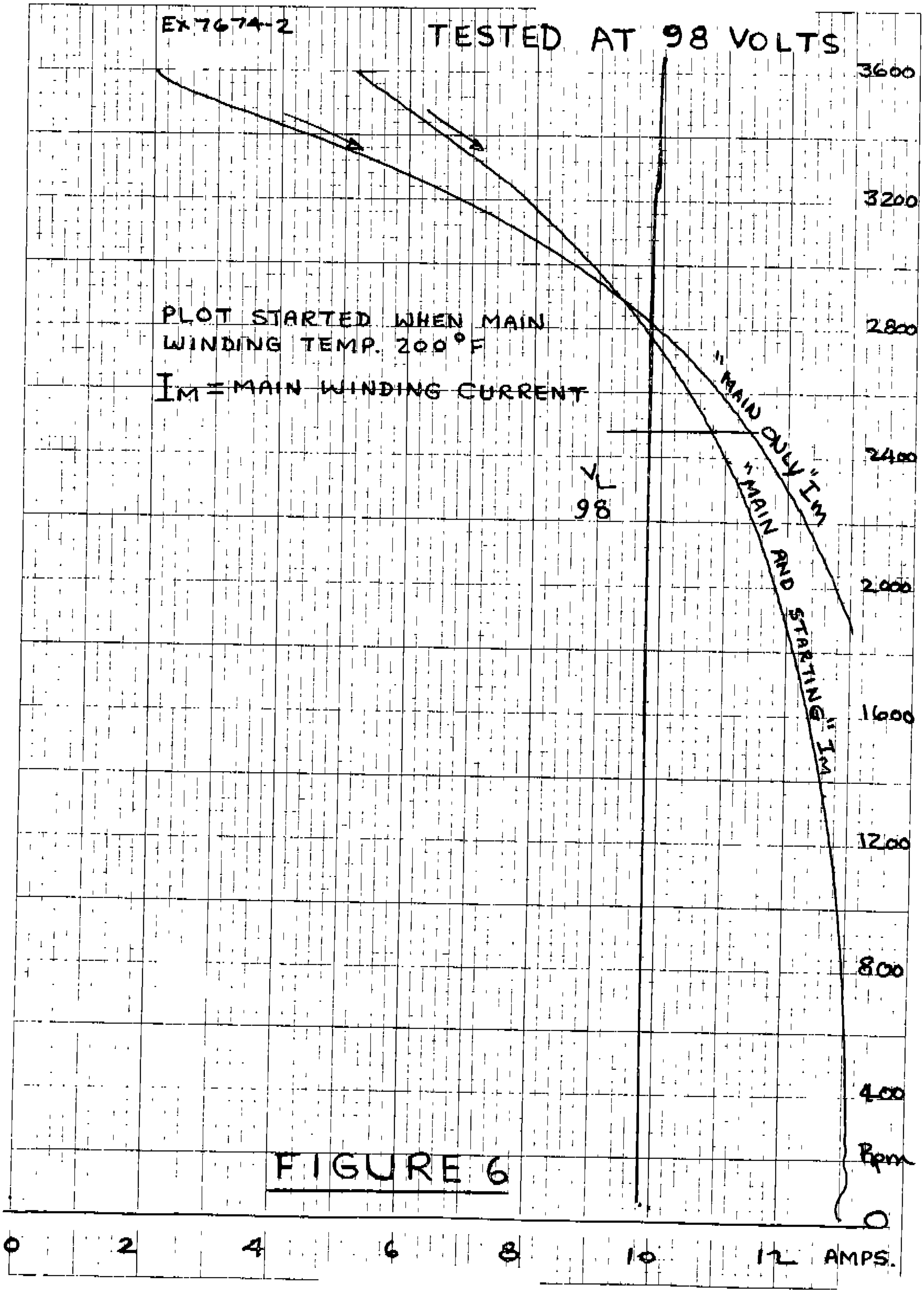


AT 10.8 AMPS THRU.
MAIN FIELD WINDING
(AND CURRENT-RELAY)
TORQUE IS 18.3 OZ-FT
AND SPEED 3210 RPM

ALL FORWARD TURN
STARTING FIELD
WINDING SHIFTED
1½ SLOTS IN THE
DIRECTION OF
ROTATION

LOCKED ROTOR
STARTING FIELD WINDING
HEATING RATE, AT 300°F,
IS 17.2 °F/SECOND

FIGURE 5



PLOT STARTED WHEN MAIN WINDING TEMP. 200°F

I_M = MAIN WINDING CURRENT

FIGURE 6