TABLE 9: LOAD TEST OF PARALLELED GENERATORS

Terminal Volts	Gen. #1 Amps	Gen. #2 Amps	Load Amps

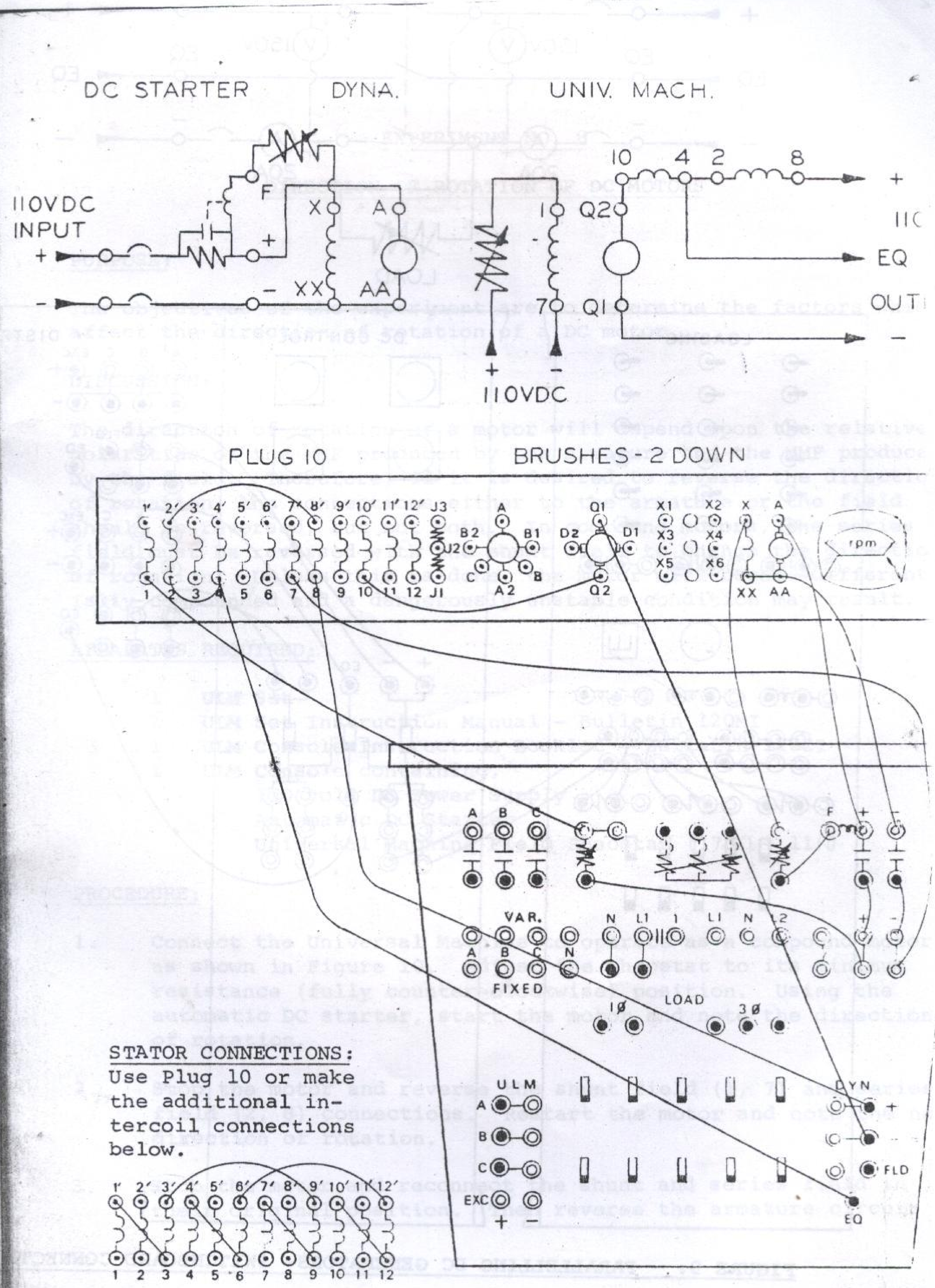


FIGURE 8: PARALLELLING DC GENERATORS- MACHINE CONNECTIONS

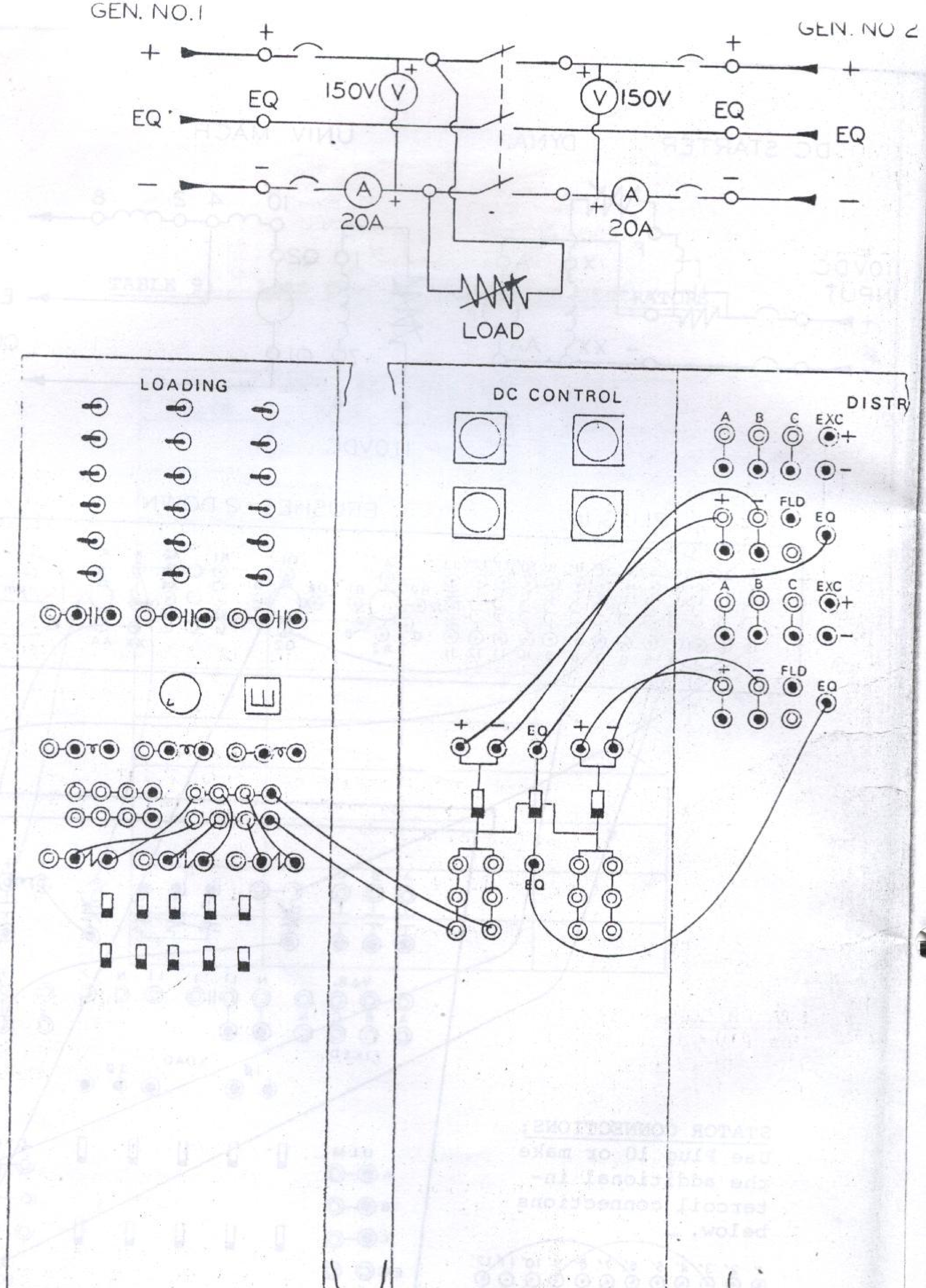


FIGURE 9: PARALLELLING DC GENERATORS- SWITCHBOARD CONNECTIONS

2

EXPERIMENT NO. 8

DIRECTION OF ROTATION OF DC MOTORS

PURPOSE:

The objectives of the experiment are to determine the factors whic affect the direction of rotation of a DC motor.

DISCUSSION:

The direction of rotation of a motor will depend upon the relative polarities of the MMF produced by the armature and the MMF produce by the field. Therefore, if it is desired to reverse the directio of rotation, the connections either to the armature or the field should be reversed, but not both. In compound motors, the series field must be reversed with the shunt field to change the directio of rotation. Unless this is done, the motor will become different ially compounded and a dangerously unstable condition may result.

APPARATUS REQUIRED:

1 ULM Set
1 ULM Set Instruction Manual - Bulletin 120MI
1 ULM Console Instruction Booklet - Bulletin 120CI
1 ULM Console containing,
110 volt DC Power Supply
Automatic DC Starter
Universal Machine Field Rheostat (173Ω + 11Ω)

PROCEDURE:

1. Connect the Universal Machine to operate as a compound motor as shown in Figure 10. Adjust the rheostat to its minimum resistance (fully counter-clockwise) position. Using the automatic DC starter, start the motor and note the direction of rotation.

2. Stop the motor and reverse the shunt field (1, 7) and series field (2, 8) connections. Restart the motor and note the ne direction of rotation.

3. Stop the motor and reconnect the shunt and series field in their original position. Then reverse the armature circuit

connections. The compensating field (4, 10) is part of the armature circuit and should be reversed with the armature. Start the motor and note the direction of rotation.

REPORT:

Draw the connection diagrams used in Steps 1, 2, and 3 and indicate the direction of rotation.

QUESTIONS:

1. If the polarity of the DC input to a shunt motor were reversed, would the motor run in the reverse direction? Why?

2. Draw wiring diagrams of a shunt motor with (A) a reversing field switch and (B) a reversing armature switch. Which do you think is the best method?

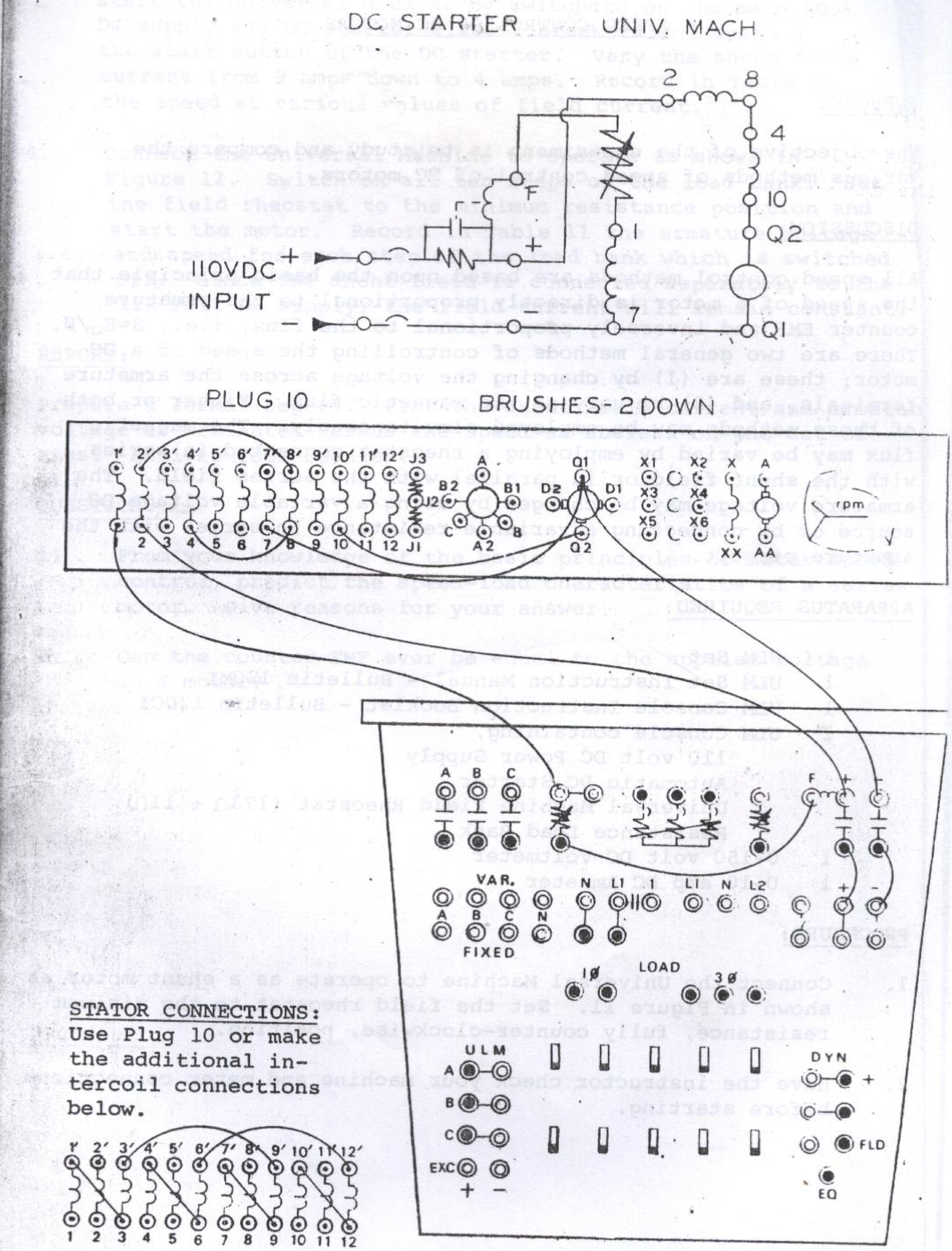


FIGURE 10: COMPOUND MOTOR- DIRECTION OF ROTATION

EXPERIMENT NO. 9

SPEED CONTROL OF DC MOTORS

PURPOSE:

The objective of the experiment is to study and compare the various methods of speed control of DC motors.

DISCUSSION:

All speed control methods are based upon the basic principle that the speed of a motor is directly proportional to the armature counter EMF and inversely proportional to the flux, i.e., $S=E_C/\emptyset$. There are two general methods of controlling the speed of a DC motor; these are (1) by changing the voltage across the armature terminals, and (2) by varying the magnetic flux. Either or both of these methods may be employed simultaneously. The magnetic flux may be varied by employing a rheostat connected in series with the shunt field or in parallel with the series field. The armature voltage may be changed by using a variable voltage DC source or by connecting a variable resistance in series with the armature circuit.

APPARATUS REQUIRED:

1 ULM Set
1 ULM Set Instruction Manual - Bulletin 120MI
1 ULM Console Instruction Booklet - Bulletin 120CI
1 ULM Console containing,
    110 volt DC Power Supply
    Automatic DC Starter
    Universal Machine Field Rheostat ($173\Omega + 11\Omega$)
    Resistance Load Bank
1 0-150 volt DC Voltmeter
1 0-10 amp DC Ammeter

PROCEDURE:

1. Connect the Universal Machine to operate as a shunt motor as shown in Figure 11. Set the field rheostat to the minimum resistance, fully counter-clockwise, position.

2. Have the instructor check your machine and meter connections before starting.

3. Start the Universal Machine by switching on the main AC, DC supply and DC starter circuit breakers and pushing the start button of the DC starter. Vary the shunt field current from 9 amps down to 4 amps. Record in Table 10 the speed at various values of field current.

4. Connect the Universal Machine to operate as shown in Figure 12. Switch on all ten steps of the load bank. Set the field rheostat to the minimum resistance position and start the motor. Record in Table 11 the armature voltage and speed for each step of the load bank which is switched off. Since the shunt field is connected separately to the 110 volt DC supply, the field current will remain constant.

REPORT:

Prepare a formal report. Plot the shunt field current and armature voltage as ordinates versus the speed as abcissa on one set of axes. Analyze your results.

QUESTIONS:

1. From your knowledge of the basic principles of motor speed control, predict the speed-load characteristics of a series motor. Give reasons for your answer.

2. Can the counter EMF ever be equal to the applied voltage in a motor?

TABLE 10: VARYING FLUX

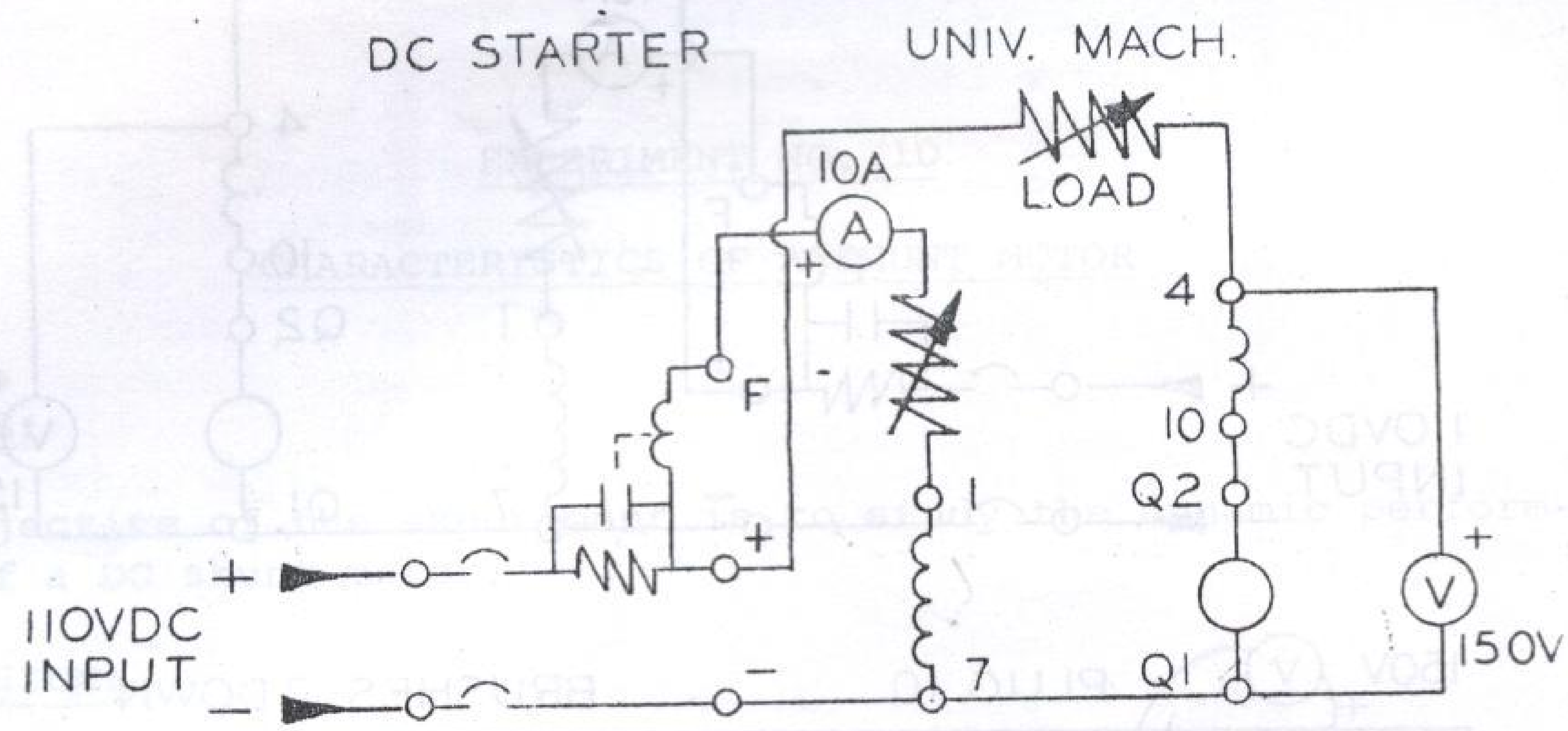
Fld Amps	RPM

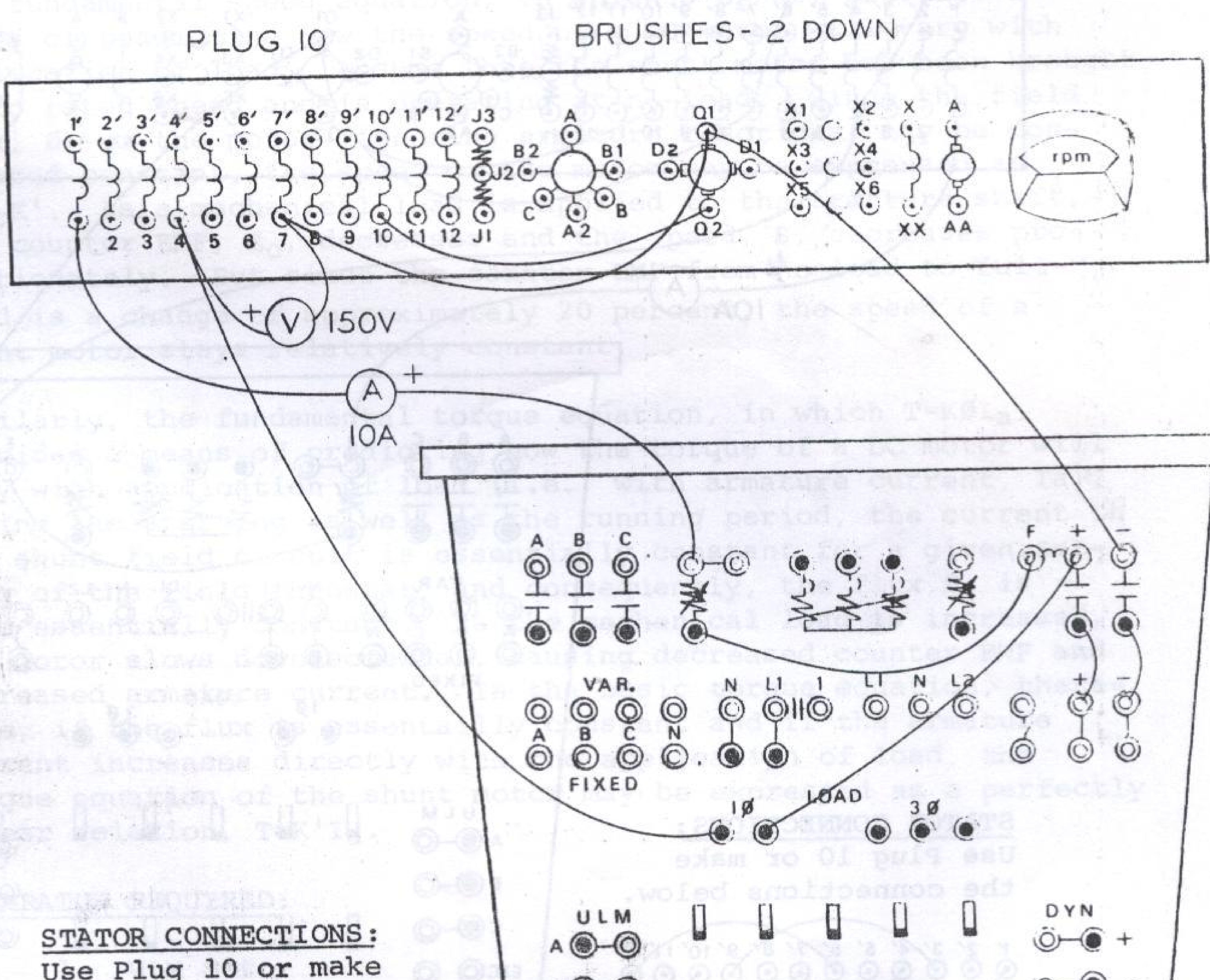
E_{Arm} = ________ Volts

TABLE 11: VARYING VOLT

Arm Volts	RPM

I_{Fld} = ________ Amps





STATOR CONNECTIONS:
Use Plug 10 or make
the connections below.

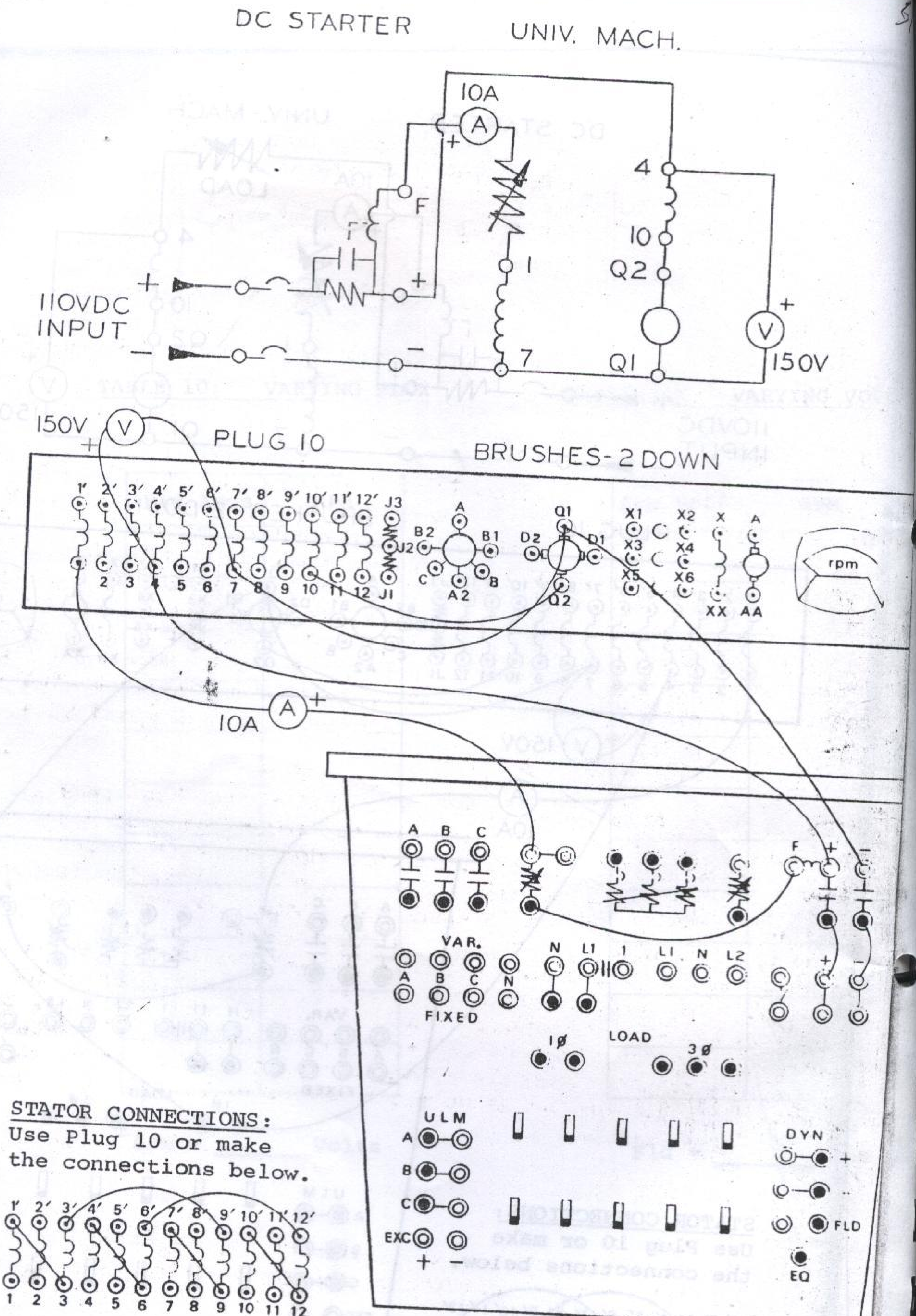


FIGURE 11: SHUNT MOTOR FIELD SPEED CONTROL

EXPERIMENT NO. 10

CHARACTERISTICS OF A SHUNT MOTOR

PURPOSE:

The objective of the experiment is to study the dynamic performance of a DC shunt motor.

DISCUSSION:

The fundamental speed equation, in which $S=E_C/K\emptyset$, provides a means of predicting how the speed of a DC motor will vary with application of load. Assume that the shunt motor has been brought up to rated speed and is operating at no-load. Since the field flux, Ø, of the motor (ignoring armature reactions) may be considered constant, the speed of the motor may be expressed as $S=E_CK'$. As a mechanical load is applied to the armature shaft, the counter EMF, E_c, decreases and the speed, S, decreases proportionately. But since the counter EMF from no-load to full-load is a change of approximately 20 percent, the speed of a shunt motor stays relatively constant.

Similarly, the fundamental torque equation, in which $T=K\emptyset I_a$, provides a means of predicting how the torque of a DC motor will vary with application of load (i.e., with armature current, Ia). During the starting as well as the running period, the current in the shunt field circuit is essentially constant for a given setting of the field rheostat, and consequently, the flux, Ø, is also essentially constant. As the mechanical load is increased, the motor slows down somewhat, causing decreased counter EMF and increased armature current. In the basic torque equation, therefore, if the flux is essentailly constant and if the armature current increases directly with the application of load, the torque equation of the shunt motor may be expressed as a perfectly linear relation, $T=K'I_a$.

APPARATUS REQUIRED:

1 ULM Set
1 ULM Set Instruction Manual - Bulletin 120MI
1 ULM Console Instruction Booklet - Bulletin 120CI

1 ULM Console containing,
   110 volt DC Power Supply
   Automatic DC Starter
   Dynamometer Field Rheostat (250Ω)
   Universal Machine Field Rheostat (173Ω + 11Ω)
   Resistive Load Bank
1 0-150 volt DC Voltmeter
1 0-15 amp DC Ammeter
1 0-10 amp DC Ammeter

PROCEDURE:

1. Connect the Universal Machine to operate as a DC shunt motor as shown in Figure 13. Adjust its rheostat to the minimum resistance (fully counter-clockwise) position.

2. Connect the Dynamometer to operate as a separately-excited shunt generator. Adjust its rheostat to the maximum resistance (fully clockwise) position.

3. Have the instructor check your machine and meter connections before starting the machine.

4. Start the shunt motor by switching on the main AC, DC supply and DC starter circuit breakers and pushing the start button of the DC starter. Adjust the shunt field current to 6 amps Adjust the Dynamometer Field Rheostat to its minimum resistance position.

5. Record in Table 12, the armature amps and volts, field amps, and speed of the Universal Machine, and torque of the Dynamometer for each of the ten load steps. The output torque can be read directly from the Dynamometer's spring scale.

6. Adjust the Universal Machine Field Rheostat to its minimum resistance position and repeat Step 5. Record your new data in Table 13.

REPORT:

Prepare a formal report. From the data in Tables 12 and 13, plot the motor's speed, voltage, and amps as ordinates versus the outpu torque as abcissa for the two different values of shunt field current. Which curve demonstrated the fundamental speed equation? Discuss the difference in performance of the motor for the two values of shunt field current.

QUESTIONS:

1. Does weakening the shunt field current, at any one load setting to maintain a constant speed, increase or decrease armature current? Why?

2. What would occur if the field circuit of a loaded shunt motor were suddenly opened?

TABLE 12: RATED FIELD CURRENT

Torque											
Volts											
Armature Amps											
Field Amps											
RPM											

TABLE 13: FULL SHUNT FIELD CURRENT

Torque											
Volts											
Armature Amps											
Field Amps											
RPM											

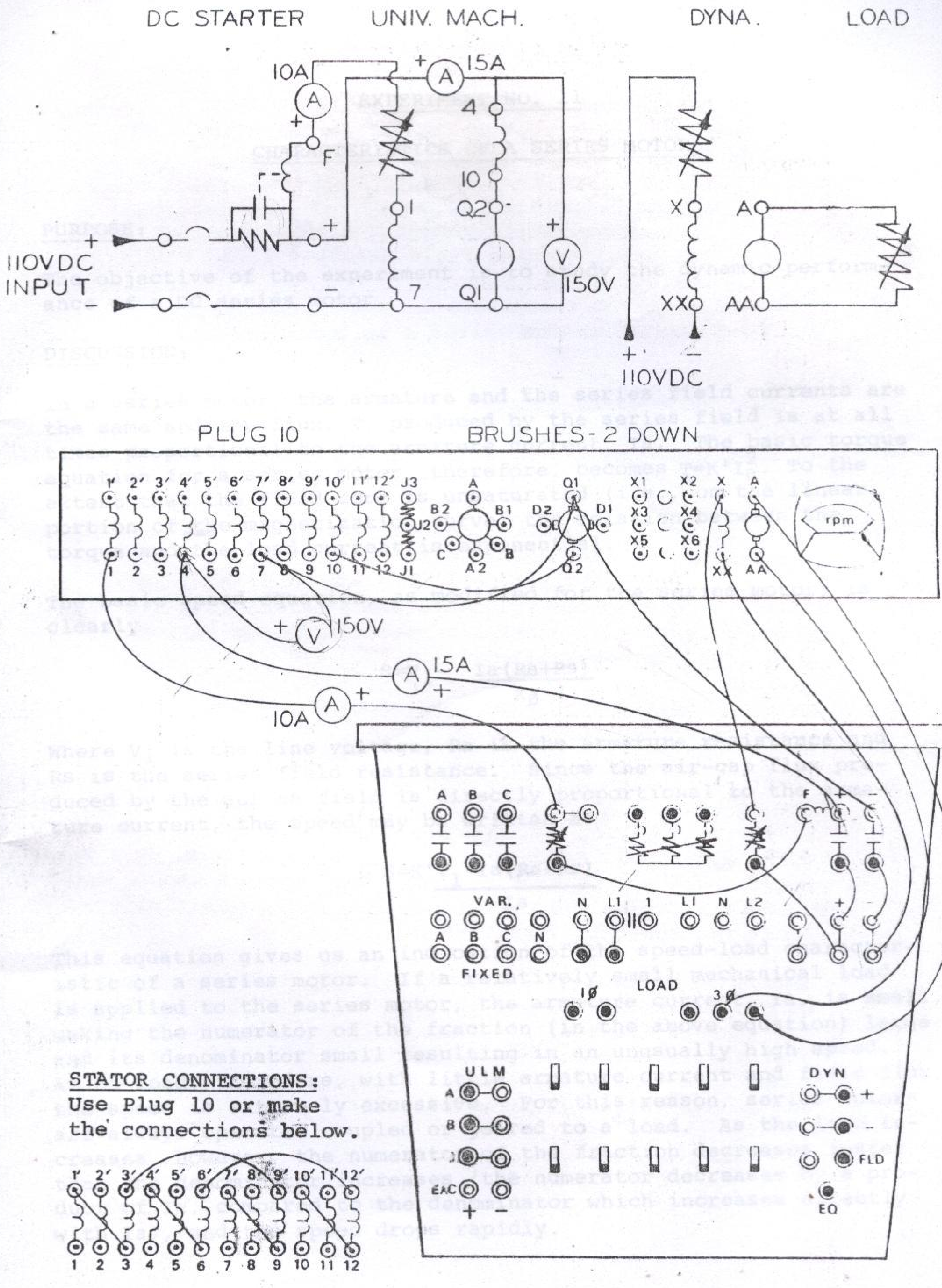


FIGURE 13: SHUNT MOTOR CHARACTERISTICS

EXPERIMENT NO. 11

CHARACTERISTICS OF A SERIES MOTOR

PURPOSE:

The objective of the experiment is to study the dynamic performance of a DC series motor.

DISCUSSION:

In a series motor, the armature and the series field currents are the same and the flux, Ø, produced by the series field is at all times proportional to the armature current, Ia. The basic torque equation for a series motor, therefore, becomes $T=K'I_a^2$. To the extent that the field core is unsaturated (i.e., on the linear portion of the magnetization curve) the relation between the torque and the load current is exponential.

The basic speed equation, as modified for the series motor, is clearly

$$S=V_1-\frac{Ia(Ra+Rs)}{K\varnothing}$$

Where V_1 is the line voltage, Ra is the armature resistance and Rs is the series field resistance. Since the air-gap flux produced by the series field is directly proportional to the armature current, the speed may be written as

$$S=\frac{K'V_1-Ia(Ra+Rs)}{Ia}$$

This equation gives us an indication of the speed-load characteristic of a series motor. If a relatively small mechanical load is applied to the series motor, the armature current, Ia, is small, making the numerator of the fraction (in the above equation) large and its denominator small resulting in an unusually high speed. At no-load, therefore, with little armature current and field flux, the speed is extremely excessive. For this reason, series motors are always operated coupled or geared to a load. As the load increases, however, the numerator of the fraction decreases faster than the denominator increases (the numerator decreases by a product of Ia, compared to the denominator which increases directly with Ia), and the speed drops rapidly.

APPARATUS REQUIRED:

1 ULM Set
1 ULM Set Instruction Manual - Bulletin 120MI
1 ULM Console Instruction Booklet - Bulletin 120CI
1 ULM Console containing,
  110 volt DC Power Supply
  Automatic DC Starter
  Dynamometer Field Rheostat (250Ω)
  Universal Machine Field Rheostat (173Ω + 11Ω)
  Resistive Load Bank
2 0-150 volt DC Voltmeters
1 0-15 amp DC Ammeters

PROCEDURE:

1. Connect the Universal Machine to operate as a DC series motor as shown in Figure 14. Note that the Universal Machine Field Rheostat (in its maximum resistance, full clockwise) is connected to the F jack of the DC starter. This energizes the field failure circuit so that the starter may be used with a series motor (having no shunt field).

2. Connect the Dynamometer to operate as a separately-excited shunt generator. Adjust its rheostat to the maximum resistance (fully clockwise) position.

3. Have the instructor check your machine and meter connections before starting the machine.

4. Start the series motor by switching on the main AC, DC supply and DC starter circuit breakers and pushing the start button of the DC starter. Adjust the Dynamometer Field Rheostat to yield a 110 volt output. The ULM, when operated as a series motor, need not be started under load because the Dynamometer (when its field is excited) provides enough initial load to limit the speed to a safe value.

5. Record in Table 14, the armature amps, volts, and speed of the Universal Machine and the torque of the Dynamometer, for each of the ten load steps. It will be necessary to adjust the Dynamometer Field Rheostat after each load step is added to maintain the 110 volt output. The output torque can be read directly from the scale.

REPORT:

Prepare a formal report. Using the data in Table 14, plot the motor's speed, voltage and current as ordinates versus the output torque as abcissa. Discuss the relationship of the curves to the fundamental speed and torque equations.

QUESTIONS:

1. Why is the speed of a series motor increased with decreased load?

2. Why should a series motor always carry some load?

3. Does the commutation become better or worse with increases in load?

4. What are some applications best suited for DC series motors?

5. What would be the effect on the performance of the machine if a diverting resistance were placed in parallel with the series field?

TABLE 14: SERIES MOTOR LOAD TEST

Torque											
Volts											
Amps											
RPM											