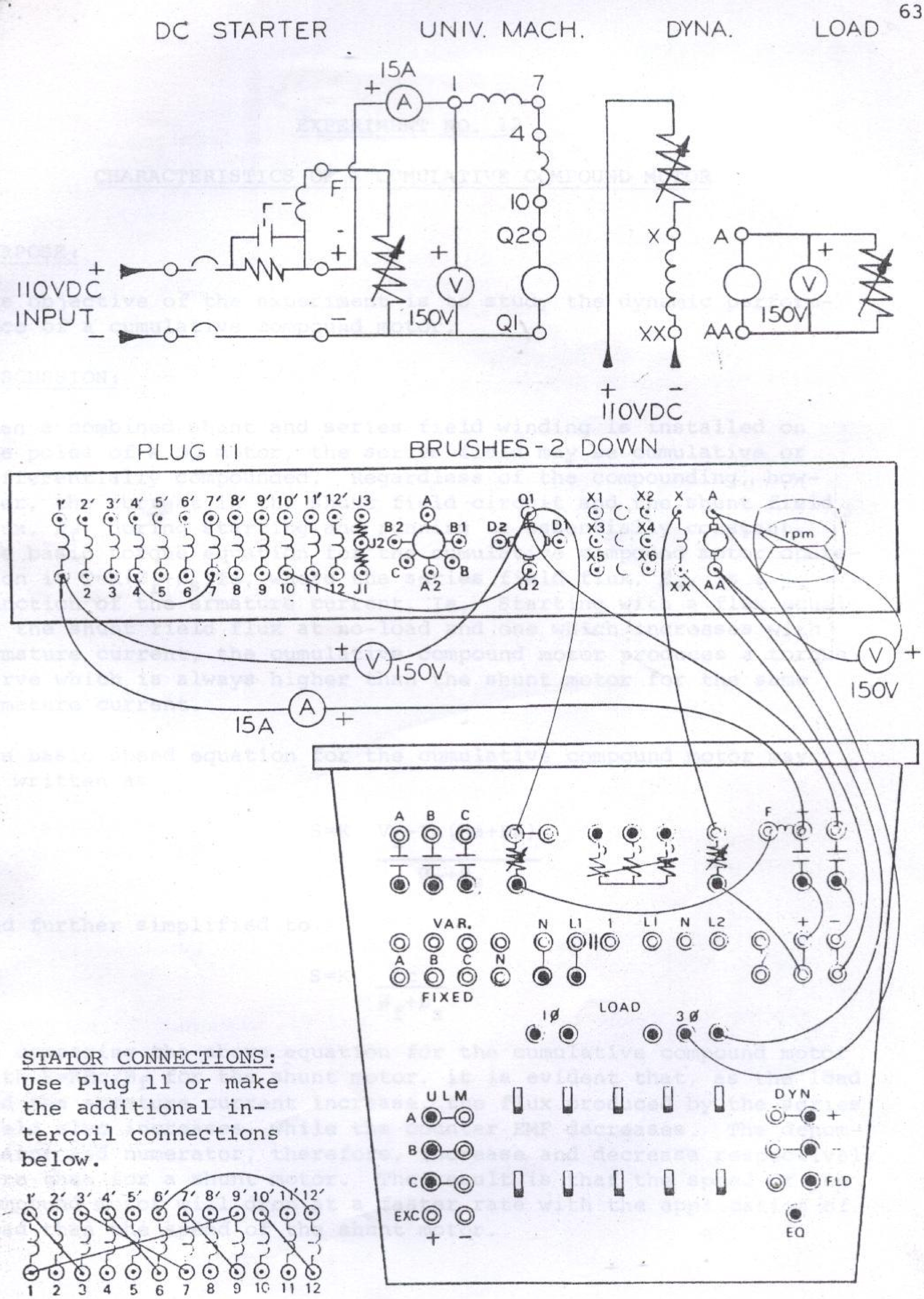

DC STARTER
UNIV. MACH.
DYNA.
LOAD
15A
110VDC
INPUT
150V
Q2
Q1
X
XX
A
AA
110VDC
PLUG 11
BRUSHES-2 DOWN
rpm
150V
15A
150V
VAR.
FIXED
N
L1
L2
LOAD
1Ø
3Ø
ULM
DYN
FLD
EXC
EQ
STATOR CONNECTIONS:
Use Plug 11 or make
the additional in-
tercoil connections
below.

EXPERIMENT NO. 12

CHARACTERISTICS OF A CUMULATIVE COMPOUND MOTOR

PURPOSE:

The objective of the experiment is to study the dynamic performance of a cumulative compound motor.

DISCUSSION:

When a combined shunt and series field winding is installed on the poles of a DC motor, the series field may be cumulative or differentially compounded. Regardless of the compounding, however, the current in the shunt field circuit and the shunt field flux, $\emptyset_f$, during starting and running is essentially constant. The basic torque equation for the cumulative compound motor operation is $T=K(\emptyset_f+\emptyset_s)Ia$, where the series field flux, $\emptyset_s$, is a function of the armature current, Ia. Starting with a flux equal to the shunt field flux at no-load and one which increases with armature current, the cumulative compound motor produces a torque curve which is always higher than the shunt motor for the same armature current.

The basic speed equation for the cumulative compound motor may be written as

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

and further simplified to

$$S=K\,\frac{Ec}{\emptyset_f+\emptyset_s}$$

On comparing the above equation for the cumulative compound motor with $S=KEc/\emptyset_f$ for the shunt motor, it is evident that, as the load and the armature current increase, the flux produced by the series field also increases, while the counter EMF decreases. The denominator and numerator, therefore, increase and decrease respectively more than for a shunt motor. The result is that the speed of the compound motor will drop at a faster rate with the application of load than the speed of the shunt motor.

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 compound motor as shown in Figure 15. Adjust its rheostat to the minimum resistive (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 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 15, the armature volts and amps, field amps and speed of the motor and the torque of the Dynamometer for each of the ten load steps.

6. Remove the connection between 2' and 8'. Connect 2' to 8 and 2 to 8'. Repeat Step 5 and record your new data in Table 16.

REPORT:

Prepare a formal report. From Tables 15 and 16, plot the motor's speed, voltage, and current as ordinates versus the output torque as abcissa for the two different degrees of compounding. Discuss the relationship of the curves to the fundamental speed and torque equations. Discuss the difference in performance of the motor for the two different degrees of compounding.

QUESTIONS:

1. What would happen if the shunt field circuit of a cumulative compound motor were suddenly opened?

2. Give the definition of a compound wound motor. Illustrate by a simple sample diagram.

3. What is the speed regulation of the cumulative compound motor?

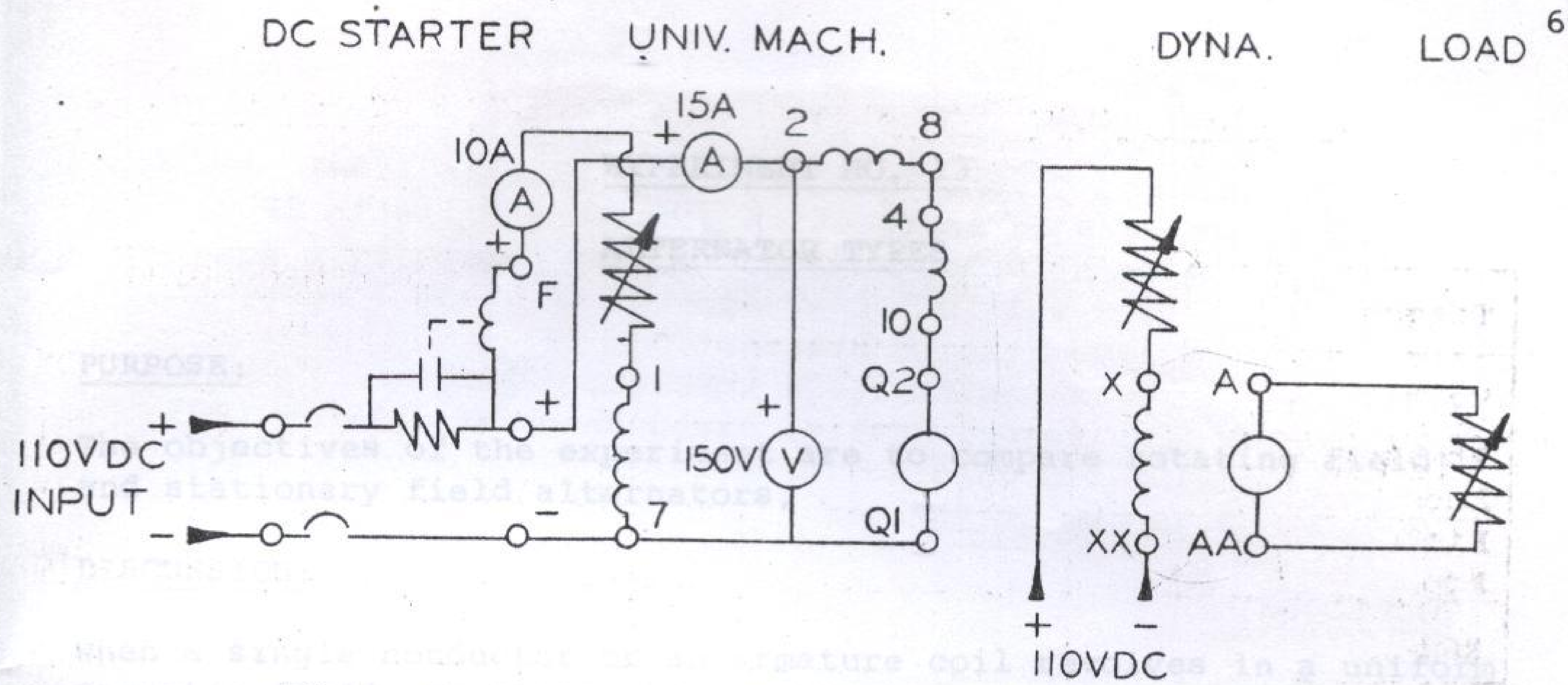
4. Give some practical applications where cumulative compound motors would be used.

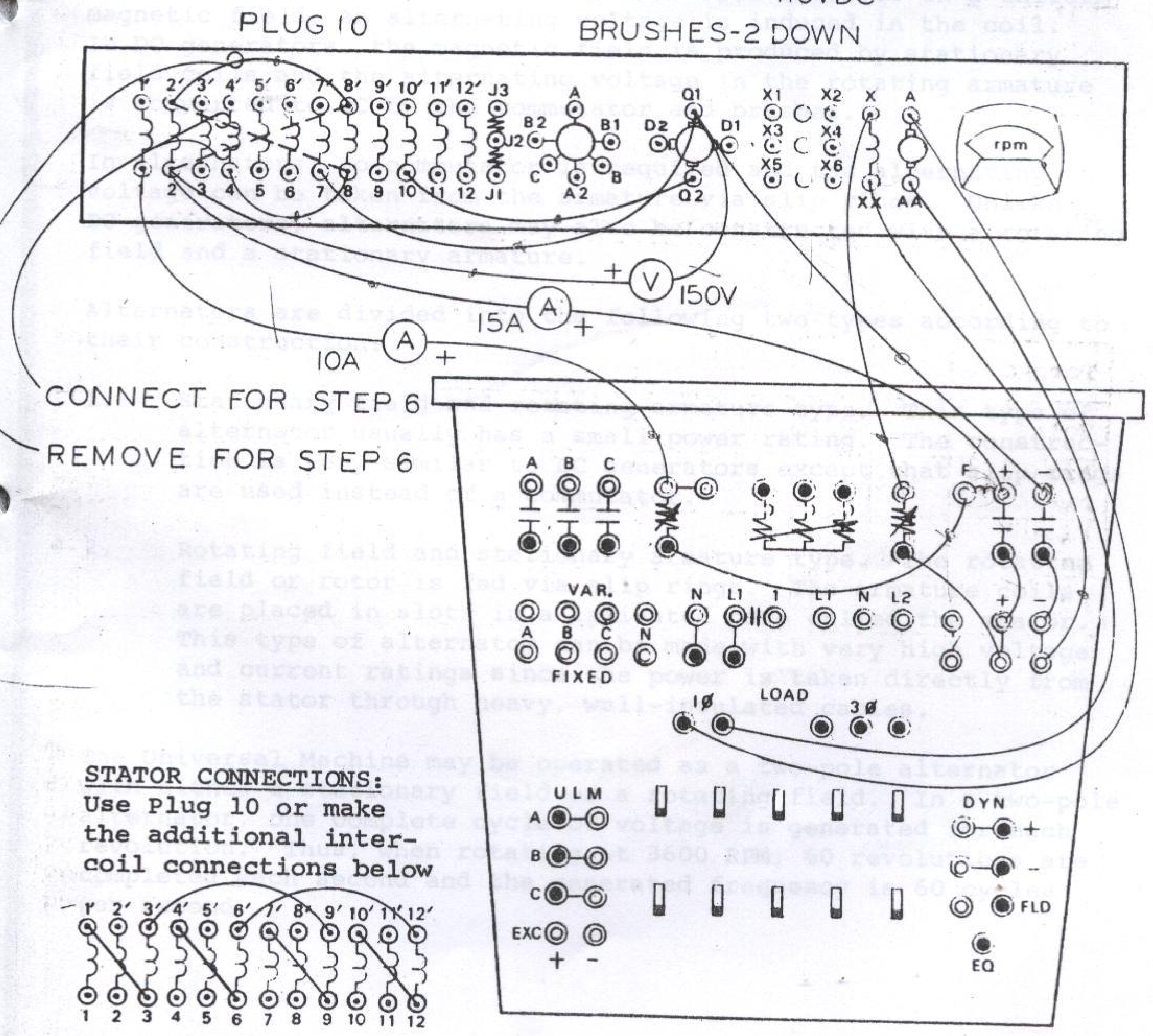
TABLE 15: LOAD TEST WITH SERIES CONNECTED COMPOUNDING

Torque											
Volts											
Armature Amps											
Field Amps											
RPM											

TABLE 16: LOAD TEST WITH PARALLEL CONNECTED COMPOUNDING

Torque											
Volts											
Armature Amps											
Field Amps											
RPM											





STATOR CONNECTIONS:
Use Plug 10 or make the additional inter-coil connections below

EXPERIMENT NO. 13

ALTERNATOR TYPES

PURPOSE:

The objectives of the experiment are to compare rotating field and stationary field alternators.

DISCUSSION:

When a single conductor or an armature coil revolves in a uniform magnetic field, an alternating voltage is induced in the coil. In DC generators, the magnetic field is produced by stationary field coils and the alternating voltage in the rotating armature is converted to DC by the commutator and brushes.

In alternators, no commutator is required and the alternating voltage can be taken from the armature via slip rings. Unlike DC generators, alternators may also be constructed with a rotating field and a stationary armature.

Alternators are divided into the following two types according to their construction:

1. Stationary field and rotating armature type. This type of alternator usually has a small power rating. The construction is very similar to DC generators except that slip rings are used instead of a commutator.

2. Rotating field and stationary armature type. The rotating field or rotor is fed via slip rings. The armature coils are placed in slots in a laminated core called the stator. This type of alternator can be made with very high voltage and current ratings since the power is taken directly from the stator through heavy, well-insulated cables.

The Universal Machine may be operated as a two-pole alternator with either a stationary field or a rotating field. In a two-pole alternator, one complete cycle of voltage is generated for each revolution. Thus, when rotating at 3600 RPM, 60 revolutions are completed each second and the generated frequency is 60 cycles per second.

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)
1 0-150-300 volt AC Voltmeter
1 0-10 amp DC Ammeter

PROCEDURE:

1. Connect the Dynamometer to operate as a shunt motor as shown in Figure 16. Adjust the Dynamometer Field Rheostat to its minimum resistance (fully counter-clockwise) position and auxiliary resistance switch to "out".

2. Connect the ULM to operate as a stationary field alternator as shown in Figure 16. Adjust the ULM Field Rheostat to its maximum resistance (fully clockwise) position.

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

4. Start the Dynamometer by switching on the main AC, DC supply and DC starter circuit breakers and pushing the start button of the DC starter. Adjust the speed to 3600 RPM (switch auxiliary resistance "in"). Increase the ULM Field current to 2.5 amps. Record the various rotor voltages in Table 17.

5. Connect the ULM to operate as a rotating field alternator as shown in Figure 17. Start the Dynamometer and adjust the speed to 3600 RPM. Adjust the ULM Field current to 4.5 amps. Record the various stator voltages for plug 3 connections and plug 5 connections.

REPORT:

Prepare a formal report. Analyze the data in the tables and discuss the theory of operation of stationary and rotating field alternators.

QUESTIONS:

1. Compare alternators using a cylindrical rotor and a salient pole rotor. Where is each type applied?

2. Why are field discharge resistors used?

3. Write a formula equating frequency speed and number of poles.

4. Give five advantages of a revolving field alternator over a stationary field alternator.

TABLE 17: STATIONARY FIELD ALTERNATOR

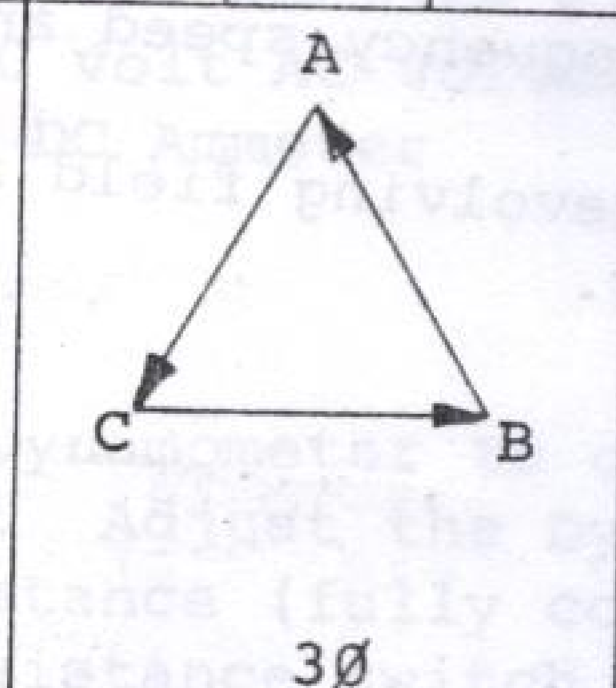
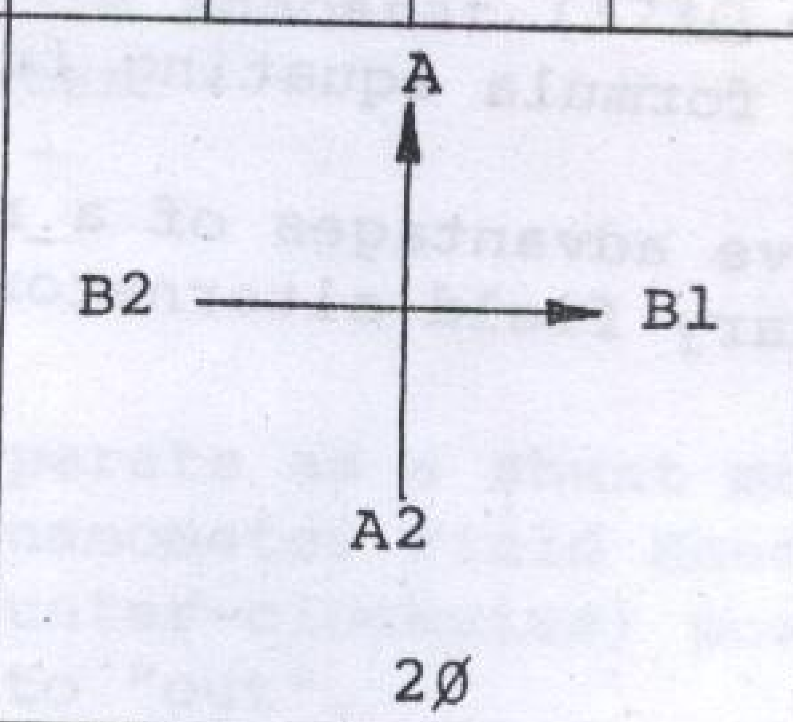
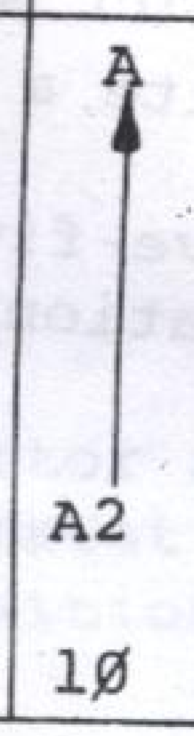
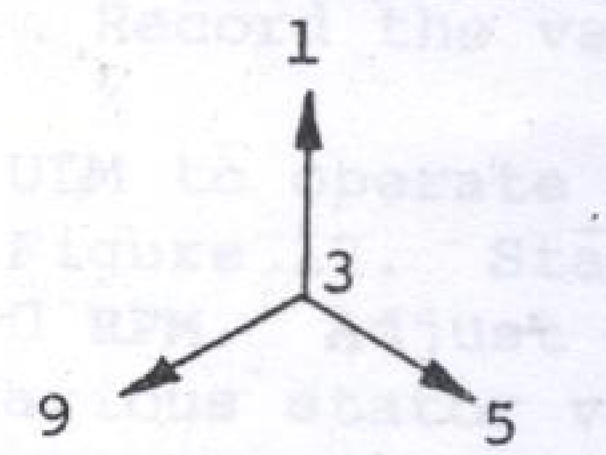
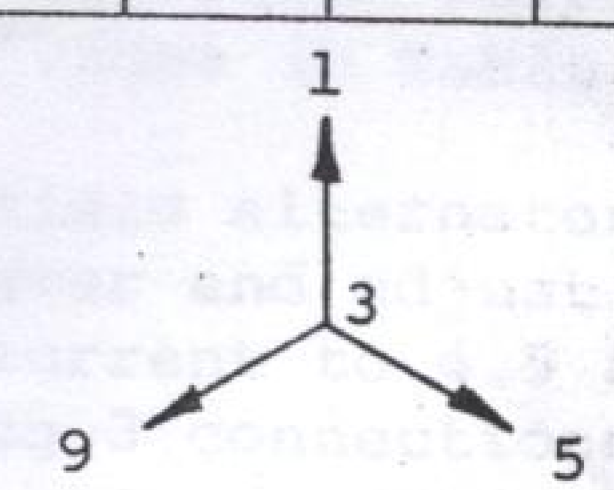
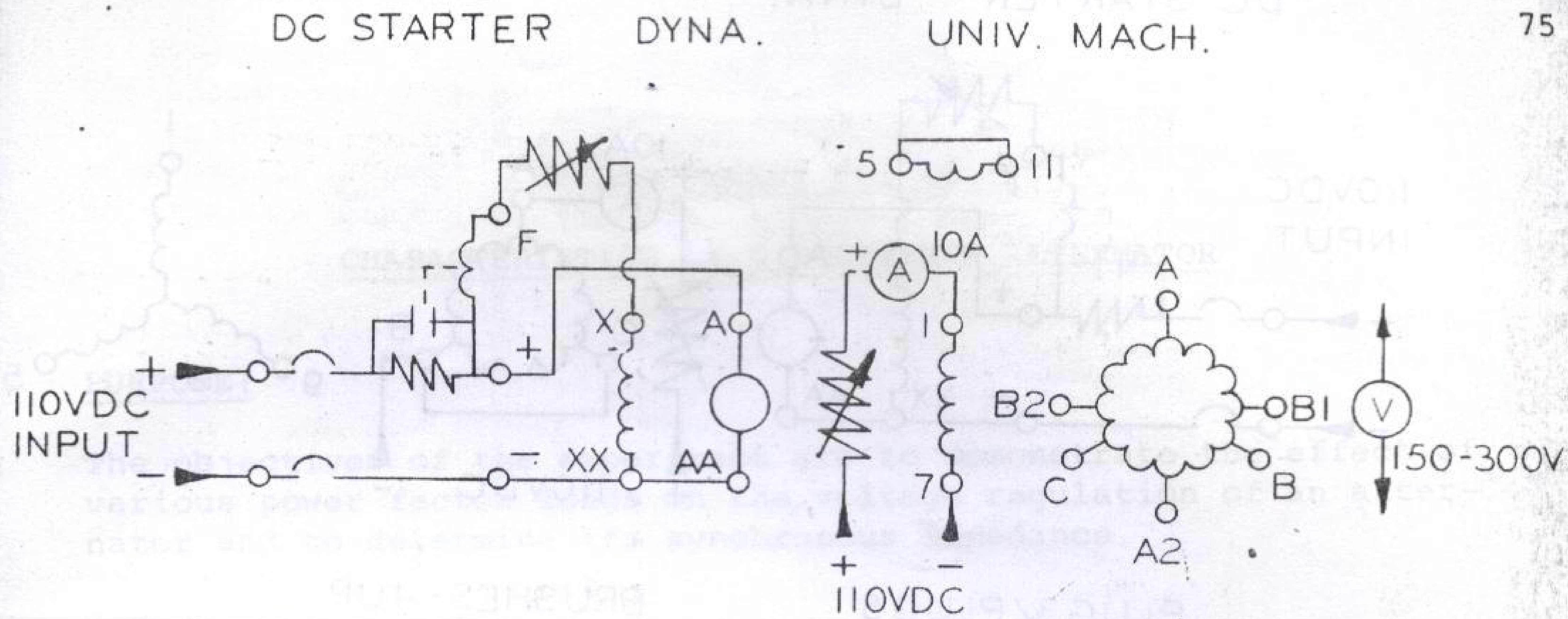
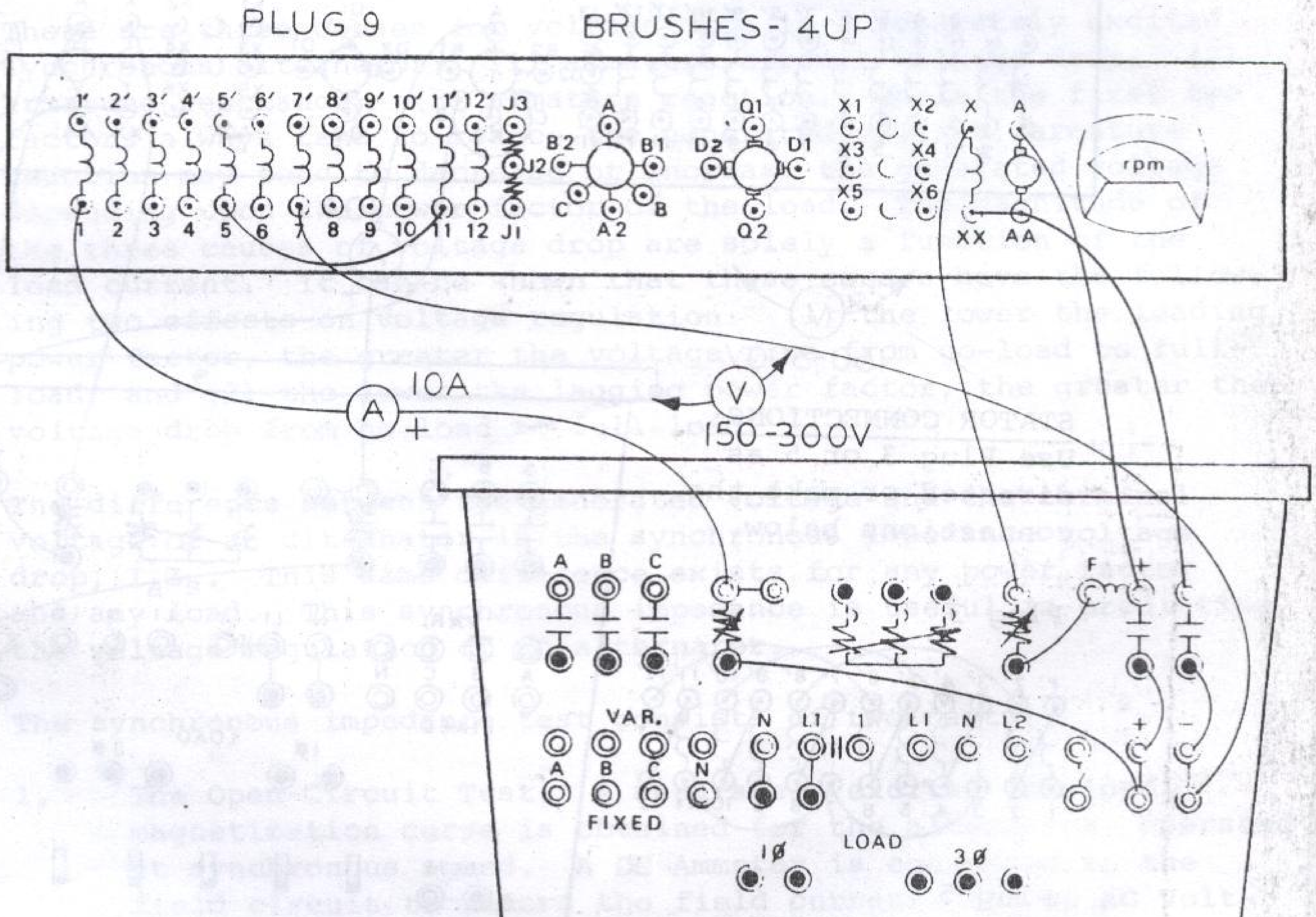
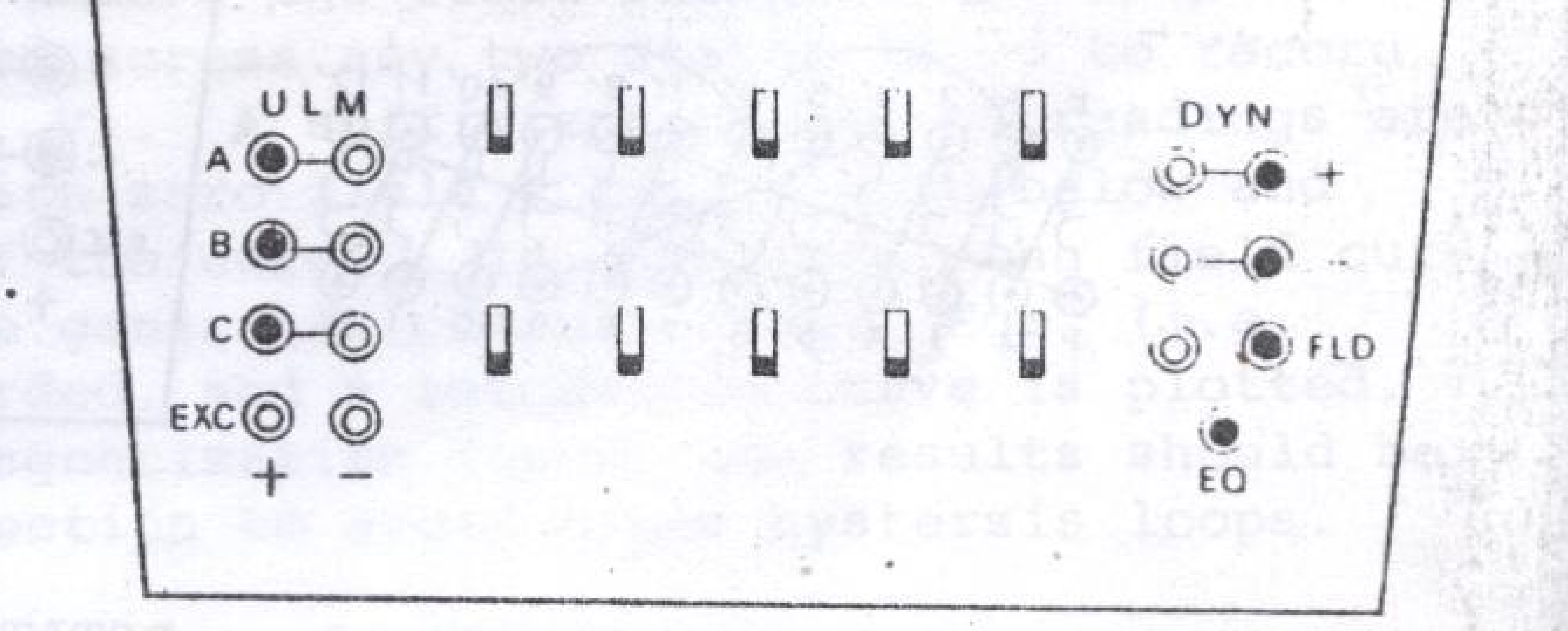
Terminals	A-B	B-C	C-A	A-A2	B1-B2	A-B1	A-B2	A-A2
Voltage								
Vector Diagrams	 3Ø			 2Ø				 1Ø

TABLE 18: ROTATING FIELD ALTERNATOR

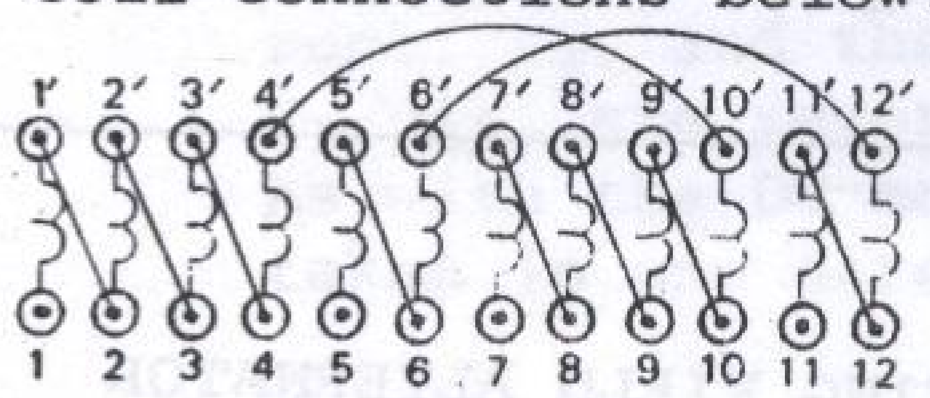
Terminals	1-5	5-9	9-1	1-3	5-3	9-3	1-5	5-9	9-1	1-3	5-3	9-3
Voltage												
Vector Diagrams	 Plug 3						 Plug 5					

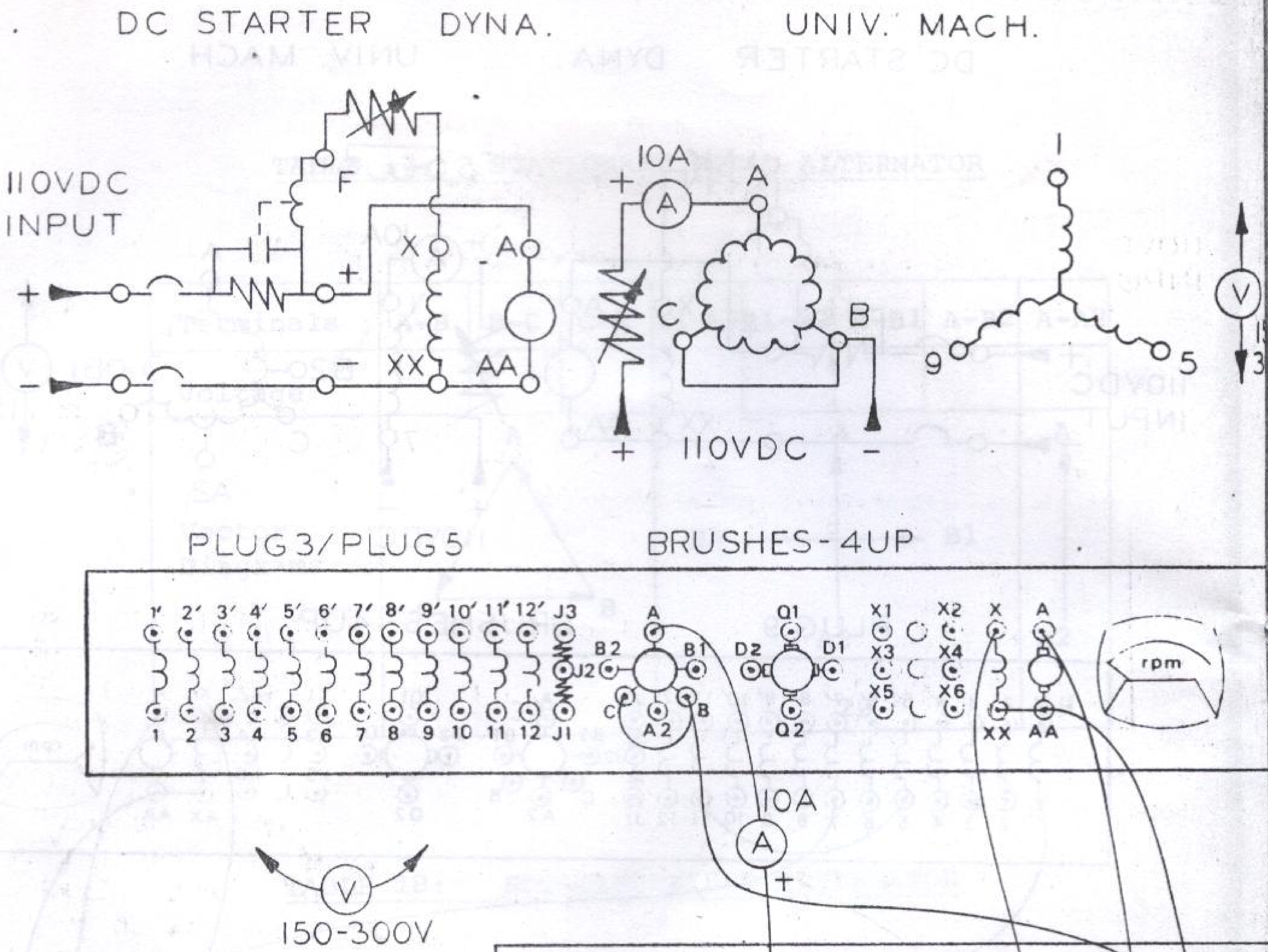






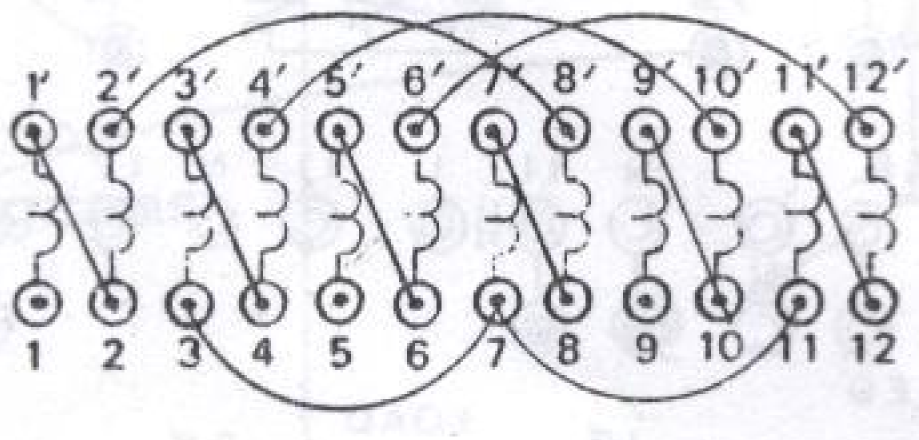
STATOR CONNECTIONS:
Use Plug 9 or make the additional inter-coil connections below.



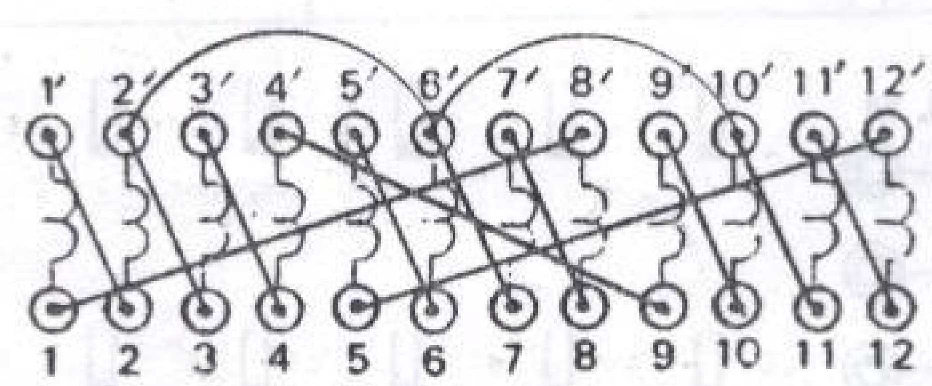


STATOR CONNECTIONS:
Use Plug 3 or 5 as directed or make the connections below.

Plug 3



Plug 5



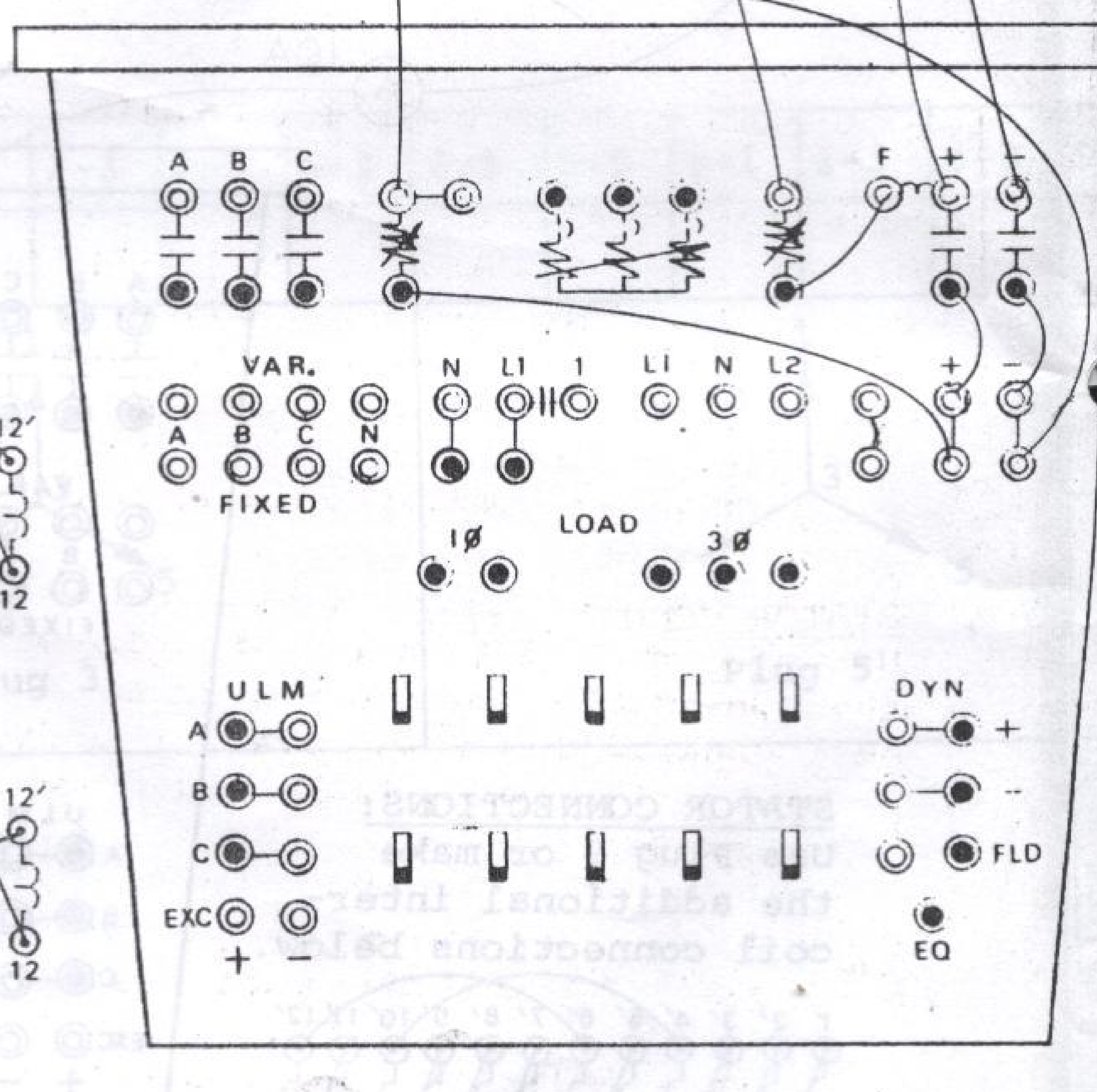


FIGURE 17: ROTATING FIELD ALTERNATOR

EXPERIMENT NO. 14

CHARACTERISTICS OF A POLYPHASE ALTERNATOR

PURPOSE:

The objectives of the experiment are to demonstrate the effect of various power factor loads on the voltage regulation of an alternator and to determine its synchronous impedance.

DISCUSSION:

There are three causes for voltage drop in a separately excited synchronous alternator: (1) armature circuit voltage drop; (2) armature reactance; (3) armature reaction. While the first two factors always tend to reduce the generated voltage, armature reaction may tend to decrease or increase the generated voltage depending upon the power factor of the load. The magnitude of the three causes of voltage drop are solely a function of the load current. It can be shown that these causes have the following two effects on voltage regulation: (1) the lower the leading power factor, the greater the voltage rise from no-load to full-load; and (2) the lower the lagging power factor, the greater the voltage drop from no-load to full-load.

The difference between the generated voltage and the terminal voltage of an alternator is the synchronous impedance voltage drop, I_aZ_s. This same difference exists for any power factor and any load. This synchronous impedance is useful in predicting the voltage regulation of an alternator.

The synchronous impedance test consists of two parts:

1. The Open-Circuit Test. A separately excited (no-load) magnetization curve is obtained for the alternator, operated at synchronous speed. A DC Ammeter is connected in the field circuit to record the field current, and an AC Voltmeter is connected across any two stator leads to record the line voltage, V_1. A sufficient number of readings are taken starting with zero field current, both below and above the knee of the curve. In each case, the field current, I_f, and the generated phase voltage, Egp, (i.e., $V_1/\sqrt{3}$), are recorded, and a saturation curve is plotted. As with the DC magnetization curve, the results should be taken in one direction to avoid minor hystersis loops.

2. The Short-Circuit Test. The short-circuit characteristic is taken by connecting ammeters in the line to record the phase current. The field current is adjusted to zero, and the alternator is brought up to speed. Readings are taken of DC field current versus AC short-circuited armature current.

The synchronous impedance may then be determined by the following equation:

$$Egp = I_a Z_p$$

where I_a is the rated full load current per phase
Egp is the open-circuit voltage produced by the same field current that caused the rated short-circuit current
Z_p is the synchronous impedance per phase.

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)
1 Loading Section of a Hampden Switchboard
1 AC Control Section of a Hampden Switchboard
1 0-150 volt AC Voltmeter
3 0-10 amp AC Ammeters
1 0-10 amp DC Ammeter

PROCEDURE:

1. Connect the Universal Machine to operate as an alternator as shown in Figure 18. Adjust its field rheostat to the maximum resistance, fully clockwise position.

2. Connect the Dynamometer to operate as a shunt motor as shown in Figure 18. Adjust its field rheostat to the minimum resistance, fully counter-clockwise position and the auxiliary resistance switch to "out".

3. Connect the switchboard as shown in Figure 19. Switch off all circuit breakers and instrument, field, and load switches. Place the AC input switches to the 208V-3Ø position.

4. Have the instructor check your machine and switchboard connections before proceeding.

5. Start the Dynamometer by switching on the Main AC, DC supply and DC Starter circuit breakers and pushing the start button of the DC Starter. Adjust the speed to 3600 RPM (auxiliary resistance "in"). Adjust the alternator field current to yield an output voltage of approximately 150 volts.

6. Keeping the speed and alternator field current constant, perform a load test for several values of load from 0 to 10 amps. Obtain three sets of data for (1) unity power factor, (2) .8 lagging power factor (3) .8 leading power factor. Record the data in Tables 19-21.

7. Change the alternator connections to those shown in Figure 20, and perform an open-circuit test on the alternator. Record the data in Table 22.

8. Change the alternator connections to those shown in Figure 21, and perform a short-circuit test on the alternator. Record the data in Table 23. Use the same values of field current as you did in Step 5.

REPORT:

Prepare a formal report. Using the data in Tables 19-21, plot voltage regulation curves for the different power factors on the same set of axes. Account for the difference in these curves. On another set of axes, plot the open-circuit and short-circuit characteristics of the alternator using the field current as abcissa. Calculate and plot the synchronous impedance. Explain your results.

QUESTIONS:

1. Compare the causes and magnitude of voltage regulation of an alternator to that of a separately excited generator.

2. What is the output frequency of this alternator at 1800 RPM? Why?

3. What advantages does the synchronous impedance method for predicting voltage regulation have over an actual no-load to full-load test?

TABLE 19: UNITY POWER FACTOR

Volts	Amps	Watts	Power Factor

I_{fld} = ______ Amps

TABLE 20: LAGGING POWER FACTOR

Volts	Amps	Watts	Power Factor

I_{fld} = ______ Amps

TABLE 21: LEADING POWER FACTOR

Volts	Amps	Watts	Power Factor

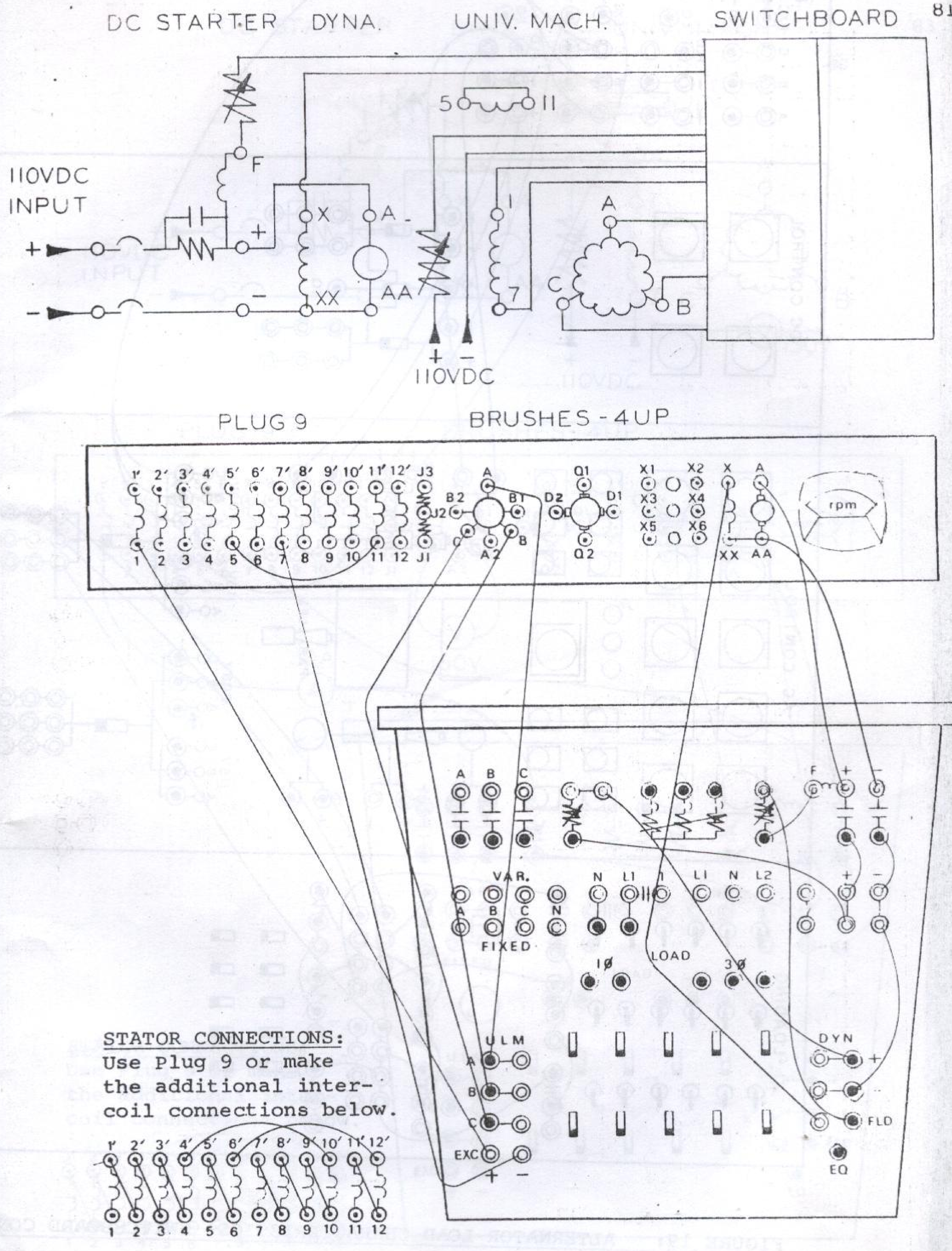
I_{fld} = ______ Amps

TABLE 22: OC CHARACTERISTIC

I_{fld}	Egp

TABLE 23: SC CHARACTERISTIC

I_{fld}	Ia


DC STARTER
DYNA.
UNIV. MACH.
SWITCHBOARD
110VDC INPUT
110VDC
PLUG 9
BRUSHES - 4UP
rpm
VAR.
FIXED
LOAD
ULM
EXC
DYN
FLD
EQ
STATOR CONNECTIONS:
Use Plug 9 or make the additional inter-coil connections below.

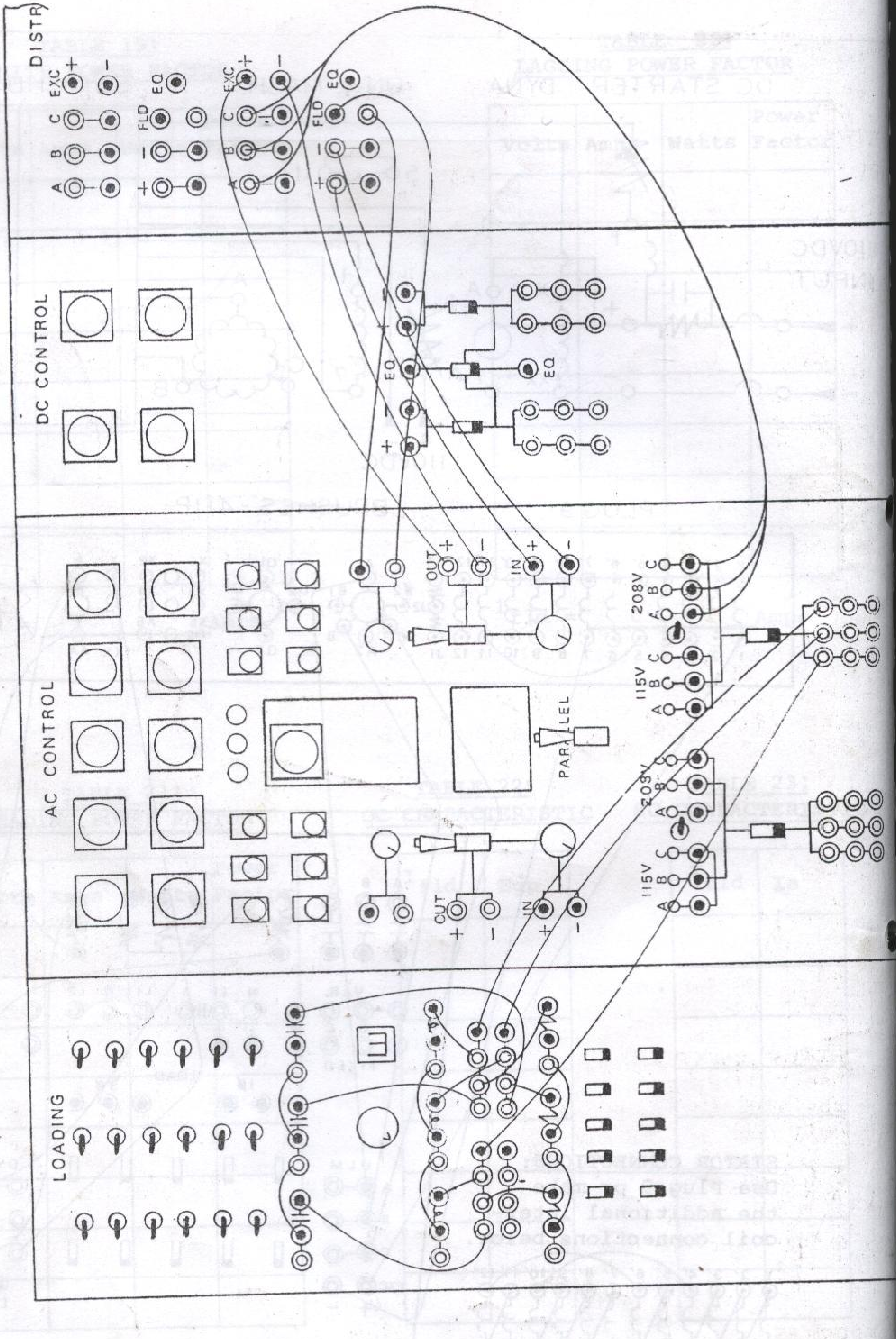
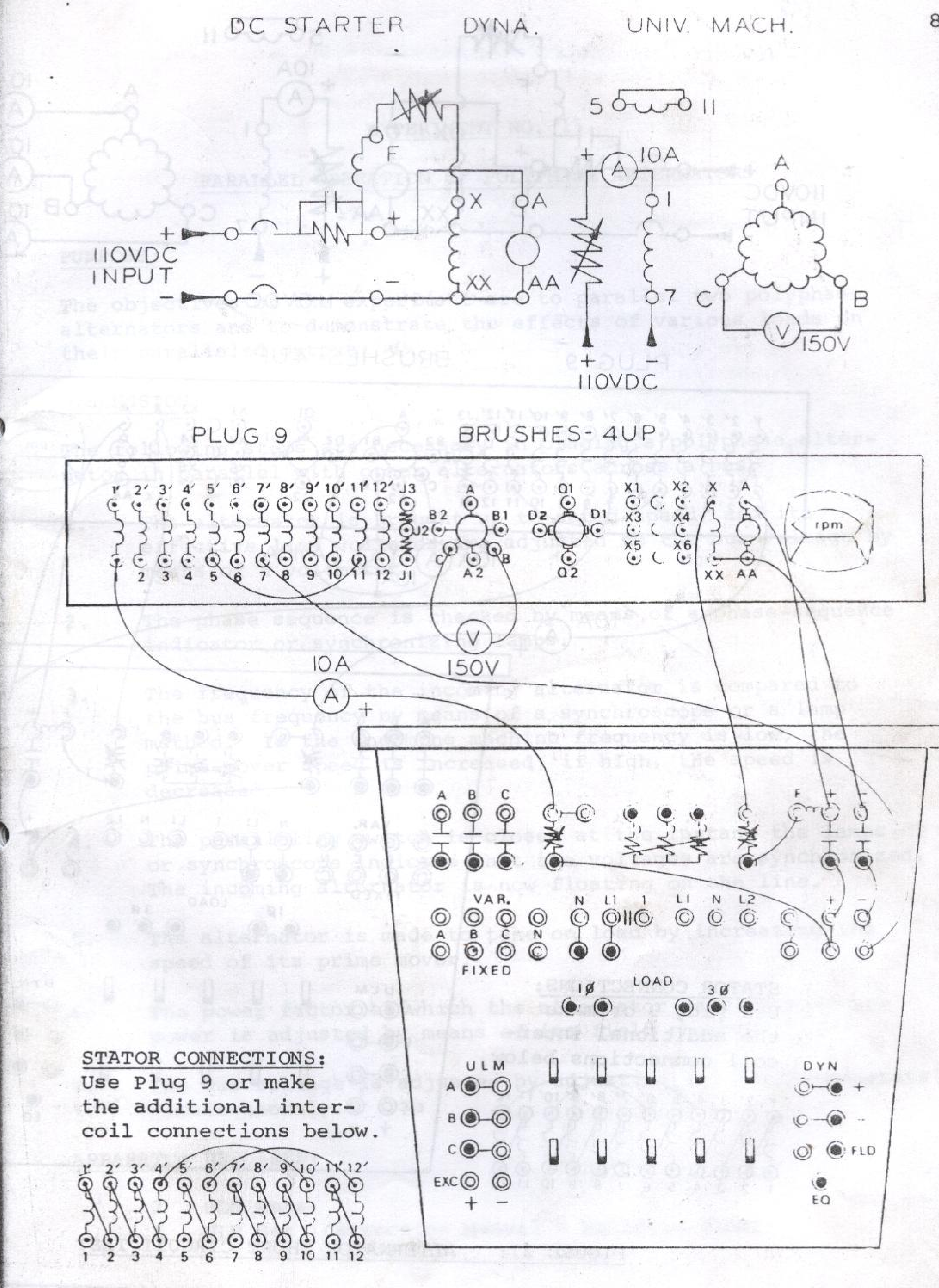


FIGURE 19: ALTERNATOR LOAD CHARACTERISTICS- SWITCHBOARD CONNE


DC STARTER
DYNA.
UNIV. MACH.
F
X
A
XX
AA
+
−
110VDC
INPUT
5
11
10A
1
7
+
−
110VDC
A
B
C
150V
PLUG 9
BRUSHES-4UP
1′ 2′ 3′ 4′ 5′ 6′ 7′ 8′ 9′ 10′ 11′ 12′ J3
J2
1 2 3 4 5 6 7 8 9 10 11 12 J1
A
B2
B1
C
A2
B
Q1
D2
D1
Q2
X1
X2
X3
X4
X5
X6
X
A
XX
AA
rpm
V
150V
10A
A
+
A B C
F + −
VAR.
N L1 1 L1 N L2
+ −
A B C N
FIXED
LOAD
1Ø
3Ø
ULM
A
B
C
EXC
+ −
DYN
+
−
FLD
EQ
STATOR CONNECTIONS:
Use Plug 9 or make
the additional inter-
coil connections below.
1′ 2′ 3′ 4′ 5′ 6′ 7′ 8′ 9′ 10′ 11′ 12′
1 2 3 4 5 6 7 8 9 10 11 12

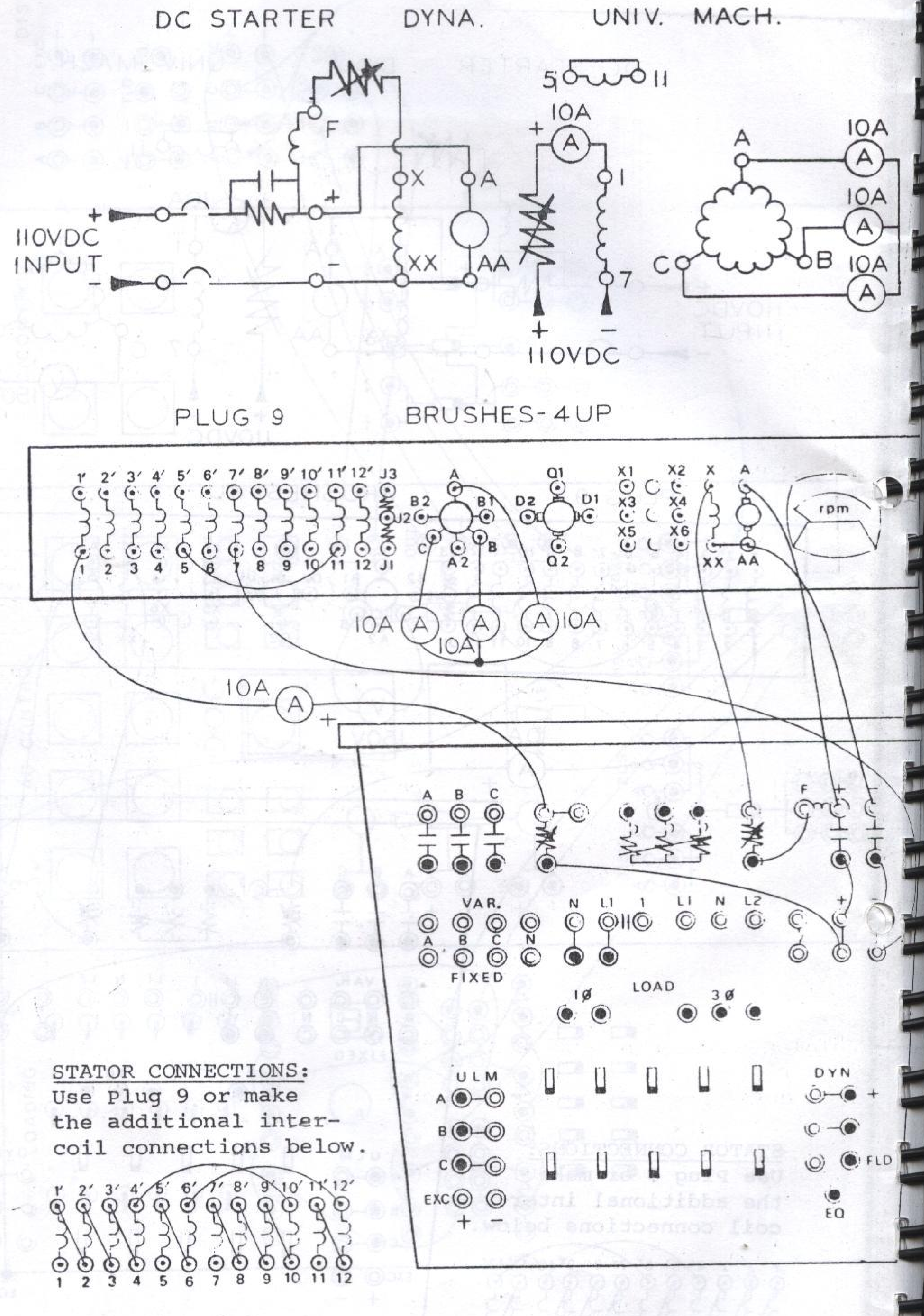


FIGURE 21: ALTERNATOR SHORT CIRCUIT TEST