Miller and Welch

Construction and Test Of a Slip Meter

Electrical Engineering

B. S.

1908

CONSTRUCTION AND TEST

OF A

SLIP METER

BY

CLARENCE BENWELL MILLER

AND

GEORGE RICHARD WELCH

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

ELECTRICAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE, 1908

UNIVERSITY OF ILLINOIS

June 1, 1908

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

CLARENCE BENWELL MILLER and GEORGE RICHARD WELCH

ENTITLED CONSTRUCTION AND TESTS OF A SLIPMETER

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Electrical Engineering

Ellery B. Paine
Instructor in Charge.

APPROVED: Morgan Brooks

HEAD OF DEPARTMENT OF Electrical Engineering

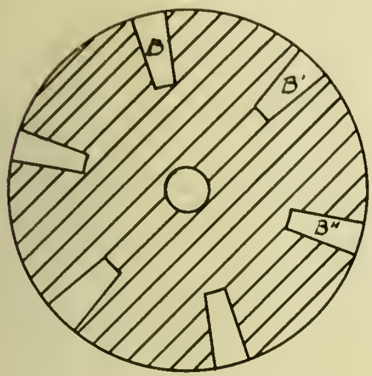
SLIP METERS

Induction motors depend upon a rotating magnetic field for the movement of the revolving part or rotor.The speed of this rotor is always lower than that of the rotating field.This is necessary in order that the lines of force may cut the rotor conductors and develope with in them the currents which will produce torque tending to aid the rotation.The difference in speed between that of the rotating field and that of the rotor is called the slip of the motor. Slip is usually measured in per cent of the speed of the rotating field or synchronous speed.Thus if the speed of the rotor was 1140 revolutions per minute and the speed of the rotating field was 1200 revolutions per minute then the slip would be $\frac{1200 - 1140}{1200} = 5$ per cent.The slip of a given induction motor depends on the load of the motor and is directly proportional to it over the working range of the motor.At no load the motor runs almost synchronously but as the load increases the slip also increases and the motor runs more slowly and the induced currents become greater.When the load exceeds a certain fixed limit the motor stops.A device for measuring the amount of slip is called a slipmeter.It is the purpose of this thesis to investigate different types of slipmeters and to construct a meter which will automatically record the slip.

There are several forms of slipmeters but they all may be grouped under two general heads,the stroboscopic and commutator types of slipmeters.

Stroboscopic slipmeters are meters which depend upon the peculiar faculty of the eye to keep a continuous impression when the frequency of flickering of the light exceeds a certain limit. A very simple slipmeter of this style is called a sectored-disk

slipmeter. This motor consists of a pasteboard disk A with white sectors B,B',B'',etc.,painted on it and mounted on the shaft of the induction motor which is to be tested. The number

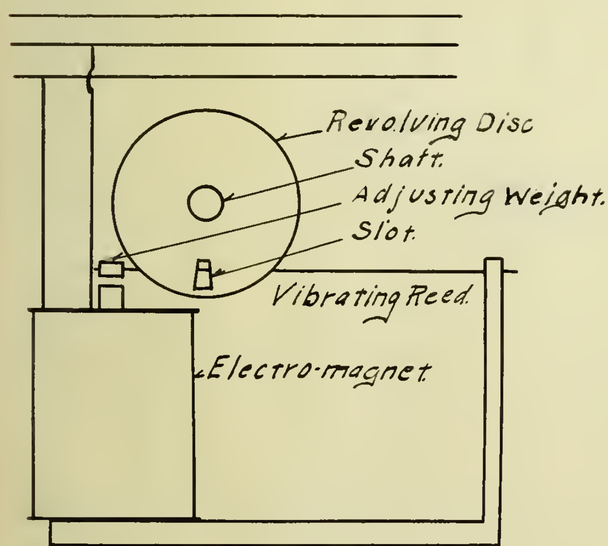


of these sectors equals the number of poles of the motor. Light is thrown upon the disk from an alternating current arc lamp which receives its current from the same source as the motor. If the motor was revolving synchronously the sectors would appear stationary but since it revolves at a few per cent below synchronism the sectors appear to be slowly rotating in a direction opposite to that in which the shaft is turning. This phenomenon is explained by the fact that the light from the lamp is actually extinguished once during each alternation. When the disk is rotating synchronously each sector has just enough time during one alternation to get into the position of the preceeding sector. Therefore when the lamp lights again the observer notices no change in the position of the sector. Now if the rotor runs at less than synchronous speed the sectors have not enough time to move through one division and hence when the lamp lights up the sector is seemingly in a new position. This lagging occurs continuously and consequently the sectors appear to the eye to be moving slowly backward, but in reality they are revolving in the same direction as the shaft. The greater the slip of the motor the faster do the sectors appear to rotate. From the number of apparent revolutions of the sectors the slip may be obtained. For example, suppose that 100 sectors appear to have passed before the eye in one minute when the speed of the rotor was 1705 revolutions per minute. Suppose the motor to be a four pole, 60 cycle machine. Now the motor skipped 100 alternations of the supply. Since the motor

has four poles it took $\frac{100}{4}$ = 25 slip revolutions to skip these 100 alternations. Therefore the synchronous speed of the motor equals 1765 + 25 = 1790 revolutions per minute. and the slip equals $\frac{25}{1790}$ = 1.39 per cent.

This meter is more applicable to low frequency and light loads than it is for high frequency and heavy loads, otherwise the sectors appear to pass before the eyes to rapidly to count. This meter is also deficient in that it does not automatically record the slip.

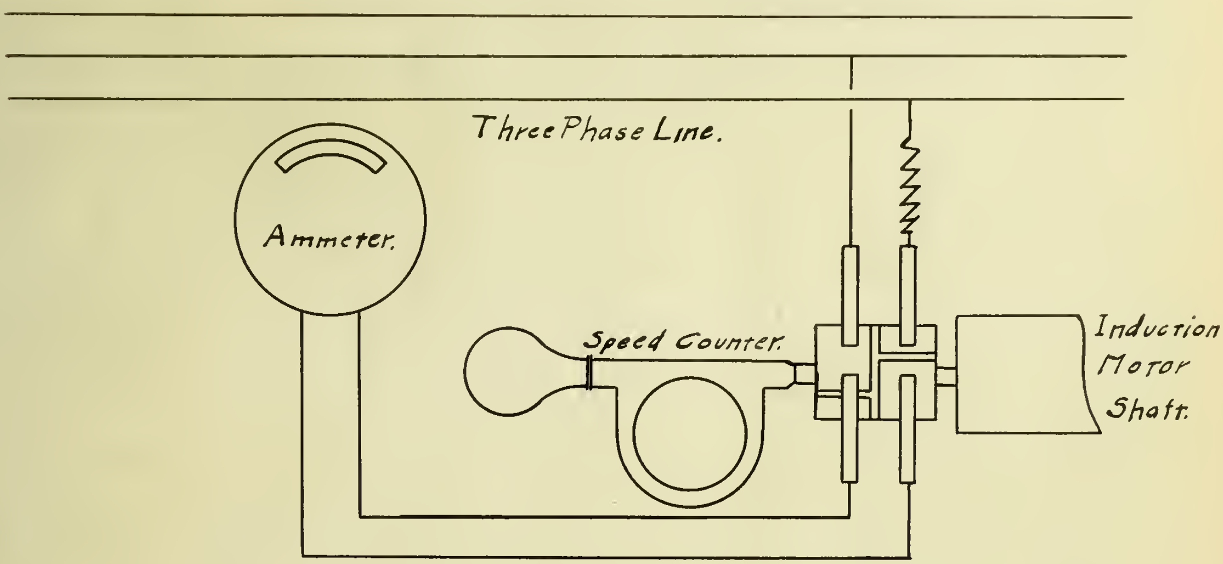
Another form of the stroboscopic slipmeter is the vibrating reed meter. This instrument consists of an alternating current electro magnet connected to some source of current and provided with a steel rod or reed near one of its ends. As alternating current flows



through the magnet the reed is set in synchronous vibration. The natural period of the reed is made to correspond to that of the supply current by means of a weight near one of its ends. A disk with a slot in it is placed upon the motor shaft and the observer looks at the vibrating reed through this slot. If the rotor was running at synchronous speed the vibrating reed would not appear to change position at all because the observer would always see the reed at the same part of its vibration. But since the rotor lags behind synchronous speed the reed appears to be slowly moving up and down. The number of strokes per minute is proportional to the slip. This meter does not record the slip automatically, the movement of the reed would be hard to count at high fre-

quencies and heavy loads and the instrument must be callibrated to get a constant by which to multiply the number of strokes in order to find the number of alternations skipped a minute.

The commutator style of slipmeter maybe used where many induction motors must be tested regularly and where the stroboscopic slipmeter would be inapplicable.This slipmeter consists of a commutator with as many segments as the motor has poles.This commutator

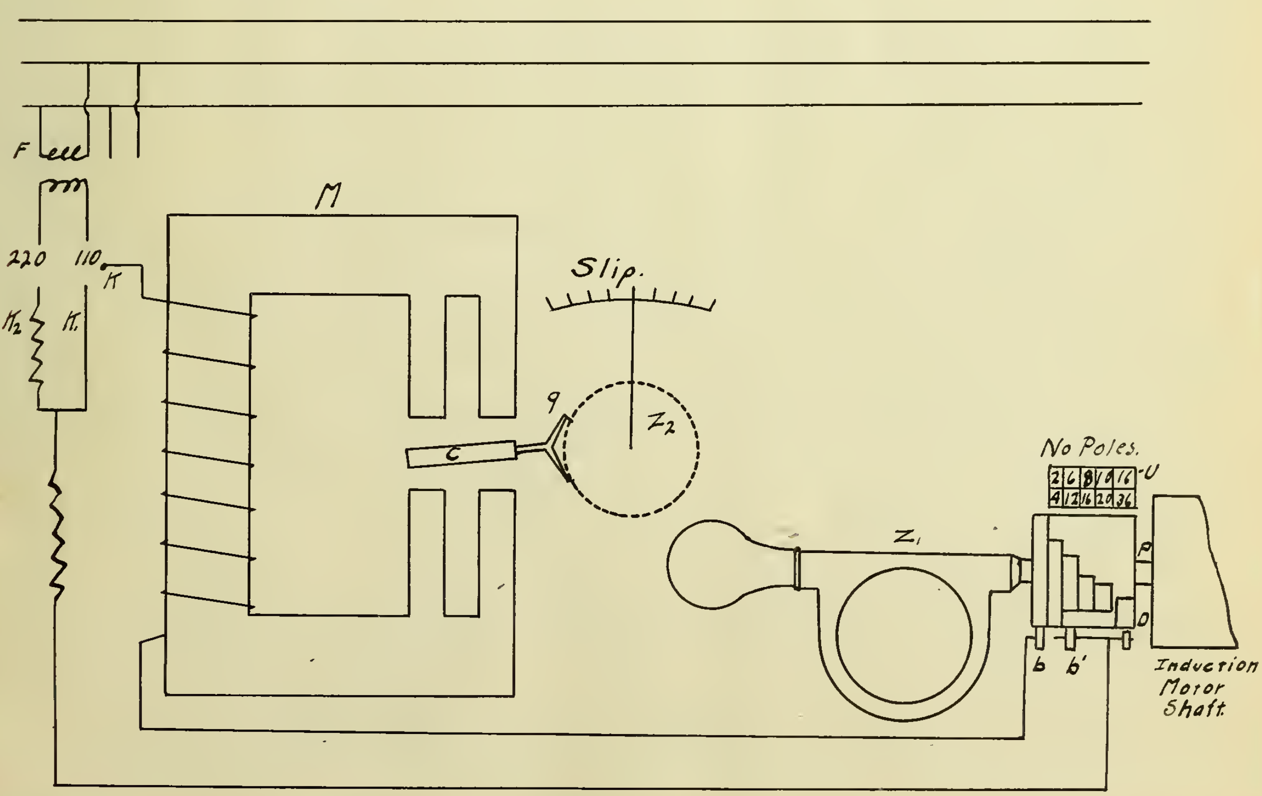


is attached to an ordinary speed counter and pressed against the rotor shaft,while at the same time it is connected electrically, through a resistance to the source of current.The commutator is also connected electrically to an ammeter as shown in the sketch above. If the rotor revolves at synchronous speed the impulse sent through the commutator into the ammeter would always come on the same point of the alternating voltage wave,and the ammeter would show no indication.As the rotor lags however,these impulses are of various values and the needle of the ammeter swings at a speed equal to the difference between the synchronous speed and the speed of the rotor.For low frequencies

and light loads the number of swings may be counted and the slip calculated.Sometimes a polarized bell is used instead of the ammeter and the number of strokes per minute counted.This slip meter can only be used satisfactorily with low frequencies and light loads.

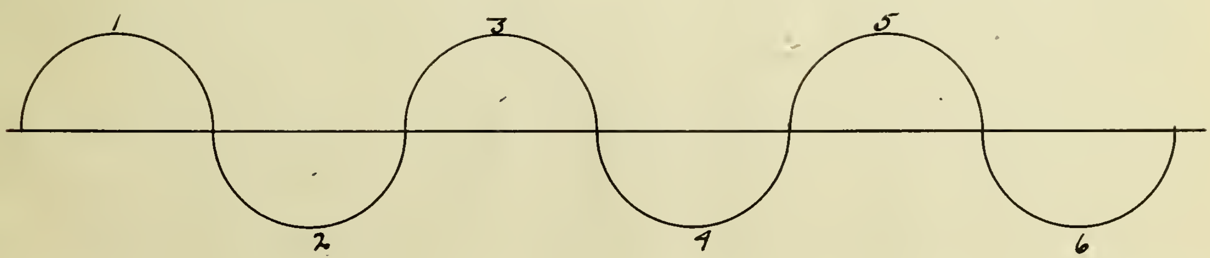
In all of these meters the slip can be found with fair accuracy for motors of low frequency and light loads but they will mot operate successfully for high frequencies and heavy loads.Neither will any of these meters record the slip automatically.Those difficulties are overcome by the use of the Bianchi slipmeter a description of which follows.

The Bianchi slipmeter is a meter of the commutator type and consists,as shown by the sketch,of a revolving commutator D,which produces impulses which instead of being counted by an observer as they must be in most slip meters,are sent through an electro magnet M which actuates a ratchet and pawl recording mechanism q through the permanent magnet C.

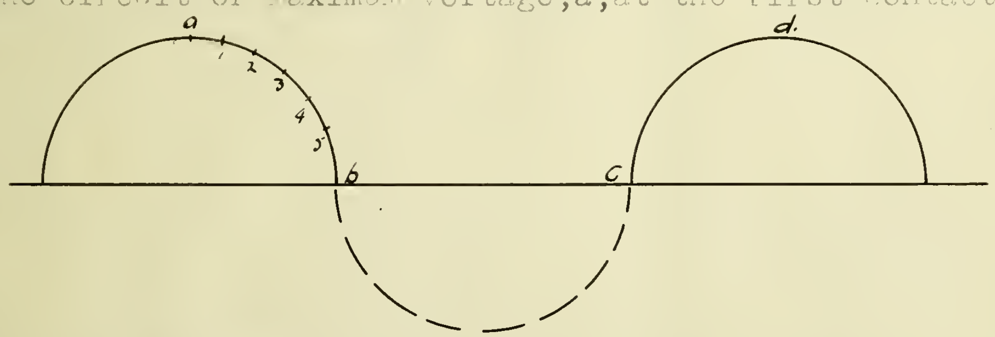


M consists of strips of sheet iron held closely together.The number of revolutions of slip is thus recorded on the dial Z.The recording mechanism is driven by a spring and controlled by an escapement controlled by the magnet C.At the time the slip is recorded the number of revolutions per minute of the rotor is also shown on the dial Z. which consists of an ordinary speed counter to which is attached the commutator D .The operation of this meter is entirely automatic.The speed counter is pressed against the shaft of the motor at r and is held there for,say,one minute.The reading on the dial Z gives the actual speed of the rotor and the reading on dial Z gives the slip in revolutions per minute.If the two are added together the synchronous speed of the motor is obtained.

If we know the number of poles on the motor the frequency of th supply current from the alternator may be found.The meter may be connected to the line either between K and K or K and K according to what voltage the motor is being run on.If very high line voltages are used a small transformer F may be used to reduce the voltage.The commutator or drum D is made with combinations of contacts so that the meter may be used with various number of poles.The adjustment of the brushes or rollers b and b, ,is accomplished by means of the screw S .The scale U gives the number of poles for which the meter is applicable.For a six pole induction motor a three sector commutator is used.The circuit through the magnet coil M



will close at 1,3,5,or 2,4,6,for one cycle.In this case the poles of the magnet will remain of the same polarity throughout the test, and the armature,being a permanent magnet,will always be attracted in the same direction.During operation this keeps the armature set in one position because the alternations occur too quickly to allow the escapement to move.The rotor speed is proportional to the alternations or cycles in the rotor and when the closing of the circuit by the commutator occurs on the axis,(point of zero voltage on the curve) the escapement is released and registers one scale reading or records the slip of one pole.As an illustration of this action we will consider a six pole induction motor which slips one pole in ten revolutions or one pole per 30 cycles.Suppose the commutator closes the circuit of maximum voltage,a,at the first contact.The



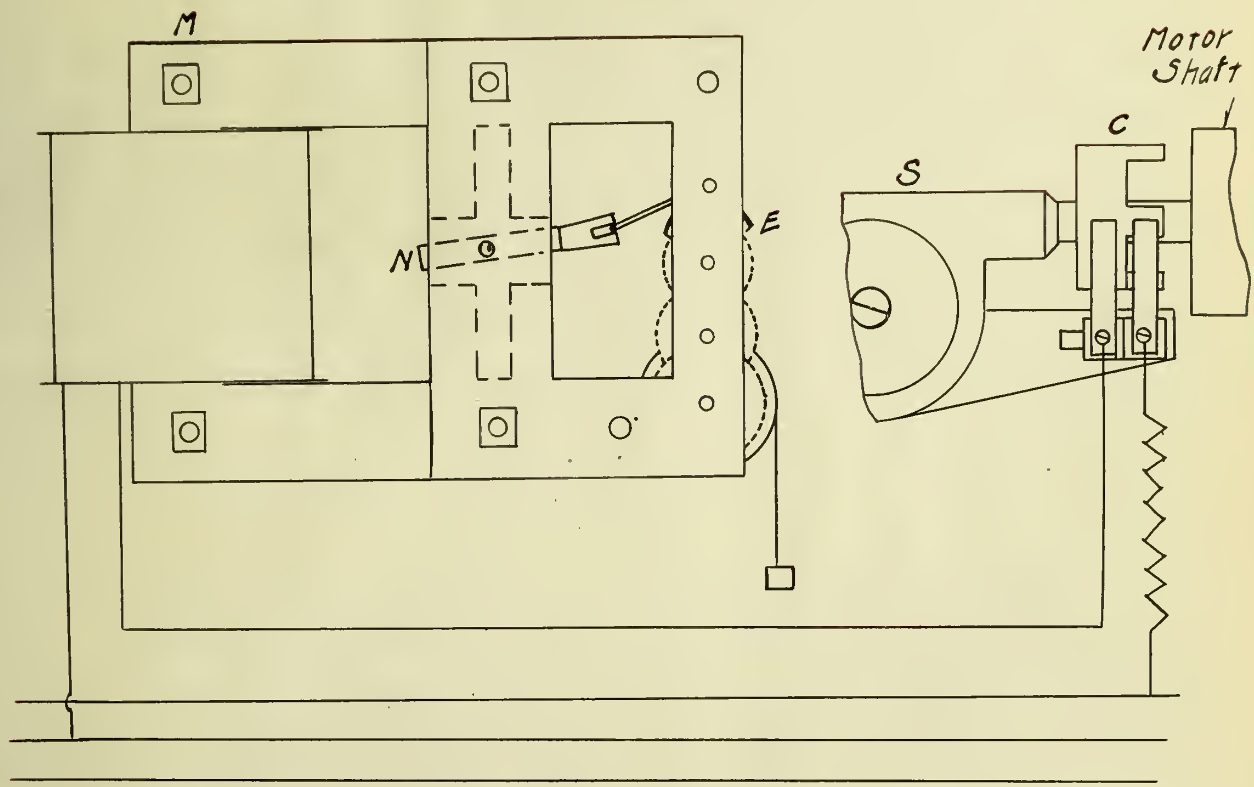
armature would be drawn into position and the escarement held.The next contact would occur at point 1,of less voltage,and so forth until at the fifteenth contact which would occur at a point of no voltage on the curve,the armature is released and the escarement allowed to turn one point.At C the voltage will increase again to a maximum at D which,by assumtion occurs at the thirtieth contact.

The slipmeter as constructed by the authors differs from the Bianchi slipmeter in that the slip must be counted instead of being recorded automatically.The Bianchi meter also has an adjustment whereby the meter can be used for various numbers of poles

while the motor as constructed is applicable only to a machine having six poles.

Description of Motor.

The motor consists of an electro magnet M ,a commutator C attached to a speed counter S ,an escapement movement E and a permanent magnet N .

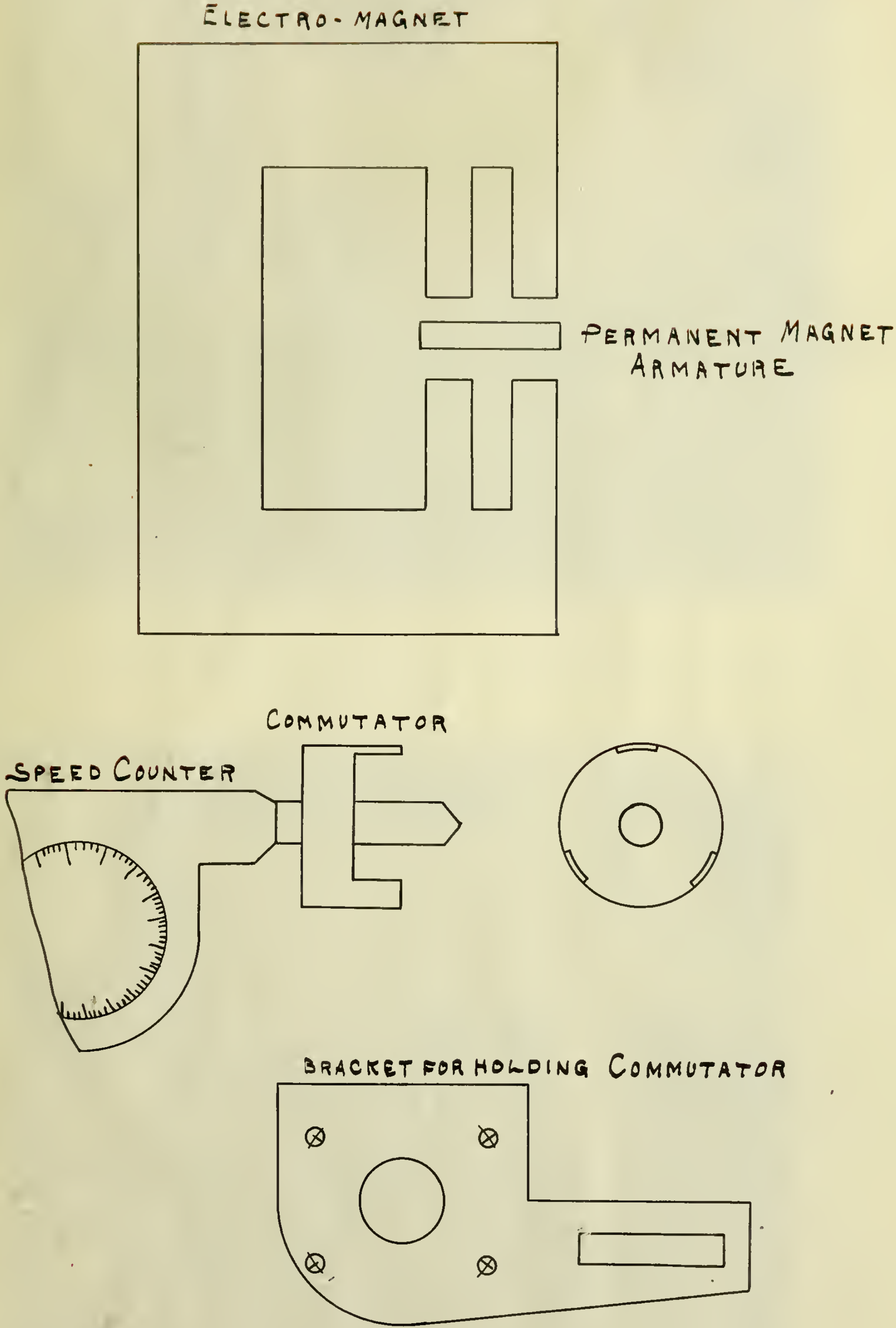


The electro magnet M consists of thin sheets of sheet iron firmly held together by bolts.Around this core is wound a coil of number 20 cotton covered wire.This coil is connected between two phases of the three phases supply line.This circuit also includes the resistance for controlling the current,and the brushes which bear on the commutator C ,which is slipped upon the shaft of an ordinary speed counter.The recording device consists of a permanent magnet N accuated by an escapement movement similar to that of a clock except that a weight is used instead of a spring it having

been found that the weight gives a more accurate adjustment than the spring and the permanent magnet does not have to be so highly magnetized when a weight is used as when a spring actuates the movement. The details of the different parts of the meter are shown by sketches and photographs on page 10 and 11.

In order to test the accuracy of the slipmeter as constructed the slip of an induction motor was measured by means of the slipmeter and also by comparison of actual generator and motor speeds. Tests were made at various loads on the motor, namely, no load, quarter load and three quarter load. The generator used had six poles and furnished three phases current for a 5 horse power induction motor upon which the tests were made. The tests were made one man taking the speed and time at the generator while the other counted the slip as registered by the slipmeter and at the same time noted the revolutions per minute of the rotor of the induction motor. The slip was counted by noting the number of times the permanent magnet N released during one minute. The slip might have also been taken by noting the number of times the spark on the commutator reached its maximum brilliancy. This number gives the number of alternations which divided by two gives the slip. This sparking does not injure the commutator because of the light current flowing. Several such sets of readings were taken at the various loads mentioned above. The table below gives the results of these tests.

It is seen from the table that at no load the difference between the slip as actually measured by a speed counter and that registered by the slipmeter is about 20 per cent, at one quarter load about 9 per cent, at three quarter load about 8 per cent. These differences may be due to several causes. First, the two speed counters



Details. Full Size.

Speed of Generator	Speed of Motor	Generator minus Motor Speed	Slip from Slipmeter	Load on Motor	o/o Slip Actual	o/o Slip By meter	o/o Error
1288 r.p.m.	1280 r.p.m	8 r.p.m.	10 r.p.m.	No load	.60	.80	20
1350 "	1336 "	14 "	12 "	"	.10	.09	14
1339 "	1323 "	16 "	12 "	"	.11	.08	25
1332 "	1339 "	7 "	9 "	"	.63	.72	22
1339 "	1326 "	13 "	14 "	1/4 Load	.11	.12	7
1325 "	1310 "	15 "	14 "	"	.12	.09	6
1331 "	1315 "	16 "	14 "	"	.11	.08	13
1320 "	1282 "	38 "	40 "	3/4 Load.	2.9	3.0	3
1325 "	1290 "	35 "	39 "	"	2.6	2.9	11
1329 "	1293 "	36 "	38 "	"	2.7	2.8	3.5

may not have been started and stopped at exactly the same time and this error alone might have caused a difference of one revolution for a minute. Second, the meter is so constructed that for accurate work the test should be run over a period of several minutes. Third, the motor may be just on the point of slipping a pole when the test is started or it may be only have way between the two poles. This introduces an error which is inherent in the machine and can only be eliminated by taking a reading covering several minutes. Fourth, the differences as shown for loads may be explained in part by the fact that it was not possible for one observer to count the slip and at the same time the speed of the rotor. Consequently, the speeds of the generator and the motor were taken at different times which

might introduce an error due to the change in speed of motor driving the generator.