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FINAL

RESEARCH and DEVELOPMENT

REPORT

for

Governed Speed

12 Volt - DC Motor

Report No. R-12

The work has been performed in accordance with
The Contract and [redacted] 25X1
Proposal dated 1-28-59.

Approved by [redacted] 25X1

Chief Engineer

[redacted] 25X1

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ABSTRACT

This is the final report on the research and development contract on a governed speed DC motor submitted in fulfillment of The Contract. (See note below.)

The purpose of The Contract was to do research and development on the design and method of control for producing a DC motor, 1-1/2" in diameter by 2-7/16" long, to meet the requirements outlined in the "12 V. Motor Requirement and Measurement Specification". This research and development has been finished, and this final report will be a complete description of the experimentation and results of this study.

Note: The contract number against which this program is being performed is classified SECRET and will simply be referred to as The Contract for the purposes of this report.

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1 PURPOSE

The purpose of the subject program is to perform studies and tests to improve the regulation of the governor and to improve the general characteristics of the motor.

2 DESCRIPTION OF WORK PERFORMED

2.1 General

The description of the aims of the program are described in [redacted] Proposal dated 1-28-59, which is appended for reference. These aims will be listed individually with a description of the work performed and the conclusions reached. 25X1

2.1.1 Evaluation of Contact Material in the Governor

A study was made of the various materials in use for contact purposes and their advantages and disadvantages. These are tabulated below.

(a) Coin silver. This material has a good contact characteristic and a good mechanical hammering characteristic and is resistant to arc damage but is below average in resistance to corrosion. A thin film of silver oxide will increase the contact resistance and, at the low voltages encountered in this motor, the contact drop will be appreciable.

(b) Gold. This material is excellent in all respects except resistance to the hammering effect of a vibrating contact. This may be offset by alloying with platinum or paladium.

(c) Silver with nickel and rhodium plating. The addition of nickel and rhodium plating to silver will correct the corrosion defect but, under pressure or pounding, the plating will crack and peel off.

(d) 90% silver 10% indium alloy. This alloy is excellent in all respects and will not tarnish under humidity or salt conditions. In addition, its frictional characteristics make it excellent for a wiper contact.

For the purposes of this program, it was decided that the indium silver contact would be used. No contact could be obtained of the proper size for the prototype; so a silver contact was coated with a thin film of pure indium by fusion. The contact was then heated since indium will alloy itself to a base metal under low heats.

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2.1.1 Evaluation of Contact Material in the Governor (Contd.)

The fixed contact was beryllium copper with an indium overlay fused on the striking surface.

2.1.2 Selection of a Zero Coefficient Spring Material

A material was found which is produced by the H. A. Wilson Co. of Union, New Jersey called Wilco Ni-Span C. This material is a special nickel-chromium-iron-titanium alloy which has a constant modulus of elasticity over the temperature range of -50°F to +150°F. This material has very good spring characteristics for the desired use. We were able to obtain sheets in the thicknesses of .004 and .007 inches.

2.1.3 Design of Governor Spring-Mass Relations

In the design of a governor employing a centrifugally operated spring to open and close a contact, the basic type of governing is a function of the frequency of the spring-mass of the blade. If a unit is designed so that the frequency of the spring is much greater or less than the rpm at the point of governing, the contacts will open at a given speed and close again at a lower speed. This will cause the motor to "hunt" between these speeds. The contact will open, causing the motor to slow down, then close, causing it to speed up. If the spring-mass combination has a frequency at or near the desired control speed, the contacts will vibrate when the speed range is encountered. This will cause a smooth change in governing resistance and the motor will speed up until oscillation is started; then the resistance will slowly increase as the speed increases until a balance is reached; then the motor will hold constant at that speed. An examination of Figure 1 and the explanation below will show the reason for the gradual increase in resistance for the governor.

The sinusoidal line of Figure 1 indicates the oscillation of the spring contact and the dotted lines indicate the positions of the fixed contact in relation to the oscillation at different speeds. In reference to line "A", picture the spring contact forced up from the fixed contact by centrifugal force but restrained against the contact by the initial spring setting of the contact. The spring has a tendency to oscillate as shown but the positions below line "A" cannot be met because the fixed contact prevents this movement. The positions above line "A" can be met though; so the contact opens for the brief periods that the oscillation is above the line giving a contact opening curve as shown at "D" with the effective resistance shown by the dotted line. Referring to line "B", the centrifugal force has increased due to increased speed so that now the contact can open half of the time as shown in "E" and the effective resistance is half the resistor value. In line "C", the contact can remain

2.1.3 Design of Governor Spring-Mass Relations (Contd.)

open most of the oscillation and the effective resistance is almost as high as the total resistance as seen in "F".

This type of governor will provide the least hunting or flutter in a unit; therefore, the governor spring was designed for oscillation at or near the governed speed. The speed of 2100 rpm gives a frequency of 35 cps for the spring. For a cantilevered spring of uniform thickness, the natural frequency is:

$$W_n^2 = \frac{1.033\ E t^2 g}{2\pi\ \ell^4\ \rho}$$

For the spring metal used:

$$W_n = 35 \qquad W_n^2 = 1225$$

$$E = 26.5 \times 10^6$$

$$g = 32.2$$

$$\rho = .294$$

Therefore:

$$\ell^4 = \frac{1.033 \times 26.5 \times 10^6 \times 32.2}{2\pi \times 1225 \times .294}\ t^2$$

$$\ell^4 = 386000\ t^2$$

$$\ell^2 = 621\ t$$

For .004 material $\ell = 1.58''$

For .007 material $\ell = 2.08''$

In a 1-1/2" diameter motor, neither of these values is very usable; so heavier contacts must be used. This will help also to provide a greater centrifugal force for contact opening under the low speeds encountered in this unit.

2.1.4 Evaluation of Field Control vs Armature Control

The concept of field control has great merit in that the currents controlled may be small and it is easier to filter the radio noise from the field circuit but, with a

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2.1.4 Evaluation of Field Control vs Armature Control (Contd.)

motor the size of this one, the field structure is too small to add the necessary coils for field control. If size could be increased, this would be worth re-evaluating.

2.1.5 Evaluation of Total Armature Control vs Split Internal Armature Control

In total armature control, a single governor blade is attached to two slip rings or to a two section commutator and wipers or brushes carry the currents to and from the governor. The advantages of this control are that the resistor may be mounted on a fixed member, only one governor spring is needed, and it is simple to see the breaker action on an oscilloscope for adjustment purposes. The disadvantages include a friction of wiper contact which will vary with age, brush life and atmospheric conditions, all control dependent on one contact in case of variations or inoperation, and high currents through the breaker points.

In the split internal armature control, two windings symmetrically opposite on the armature are opened and brought back to the governor to two blades. The advantages of this control are that there are no slip rings for friction, the current through each contact is half the total current, and two blades are operating so that, in case of failure of one blade, a certain degree of control is still maintained. The big disadvantage is that two blades and the resistors must be mounted on the governor.

It was decided for this application that the split internal governing would be used.

2.1.6 Evaluation of Friction Losses for Field Control

Since field control cannot be used due to other considerations, no evaluation was made.

2.1.7 Elimination of Stray Field

The original motor produced to this specification and sent to us as a sample had a high degree of external field. The motor had a cast ring magnet for the field, and this type of magnet will produce a greater external field due to the method of charging after assembly. It was therefore decided to use soft iron poles with snap on semicircular magnets for our investigation. This will help but there will be a stray field in proportion to the air gap distance. Therefore, this must be made as small as practical and shielding must be used to eliminate the rest.

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2.1.8 Consideration of Acoustical Noise

The noise of the brushes must be controlled by having the brushes fit snugly in the guides so that no chatter may occur, by having the brushes span about 1-3/4 commutator bars so that the brush slides over the slot without striking the edge of the next bar and by eliminating burrs at the edge of the bar. A magnetic "cogging" noise will also occur unless the rotor laminations are mounted on the shaft in a spiral form to allow a smooth change of magnetic area under the poles.

2.1.9 Investigation of Damper Winding Speed Control

An investigation was made for using an isolated winding to be shorted out at the control speed so that generated currents in this winding would cause a load torque to slow the motor down but, due to the low speed and small field strength, the control would not maintain the motor within the prescribed limits.

2.2 Description of Prototype Test Motor (See Figures 2 and 3)

A motor was constructed using the features found in the above investigation. No attempt was made to exactly meet the envelope of the specifications because this unit had to be open so that the governor action could be observed and changes made to try the various investigations. This motor operates at a lower voltage than the specified value but this was not changed because the tests could be run at this value and compensation made for a winding change to the prescribed value. There is some cogging and cogging noise due to a small amount of skew or spiraling of the laminations. Skew would be greater in a finished version of the unit, but it was necessary to have the slots almost straight in this model to facilitate changing the damper winding and governor connections in investigating the effects. A slight amount of hunting is present because of this skew also. Portions of this motor are worn due to the hundreds of hours of test running and the many adjustments made while trying the various combinations of control and conditions.

3 RESULTS OF RESEARCH AND DEVELOPMENT

3.1 Field Structure

Soft iron poles with semicircular magnets applied to both sides are recommended. Maintain the air gap at .003 to .005 inches on each side. Cover the field structure with a non-magnetic shell of .060 inch thickness and then a .010 inch thick mu-metal shield.

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3.2 Armature

A seven slot armature of 7/8 inch diameter with a 14 bar commutator. Skew the laminations 1/2 slot in the length of the armature. Split internal armature governor control on first and eighth coils.

3.3 Governor

Use .006-.007 thick Ni Span C alloy blade heat treated at 1250°F for 8 hours. Use semicircular shape for blade to get maximum length in the small diameter allowed. Use silver-indium contacts. Pre-inspect blades for frequency of 30 to 60 cps and adjust frequency by adding mass to the contact. Use screw adjustment to set the pressure of contact.

4 TEST RESULTS

A copy of the test data sheet is appended.

The unit maintained speed control through the full temperature and voltage ranges of the specification but, as may be seen from the data sheet, the equivalent current at 10.8 volts in a revised winding is above the .120 amp maximum allowed by the spec. This current would be decreased somewhat by a reduction in air gap from the .008 inch gap in the prototype and also it will be decreased by skewing the laminations. Tests were run on this motor before installing the governor plate and, at the prescribed speed and load, the equivalent current was .100 amps. The increase in amperage when governing is due to the governor absorbing the extra watts. If it is impossible to accept the extra current, some "hunting" may be encountered in decreasing the power required by the governor.

A test data sheet for the sample motor furnished by the procuring agency is also appended.

5 CONCLUSIONS

Speed control of 2% can be maintained using the design methods described in this report and, with thermister compensation, it is within reason to expect equal results with a greater temperature range. Control of 1% regulation may be accomplished in a larger motor but efficiency must be sacrificed to some extent to provide this control.

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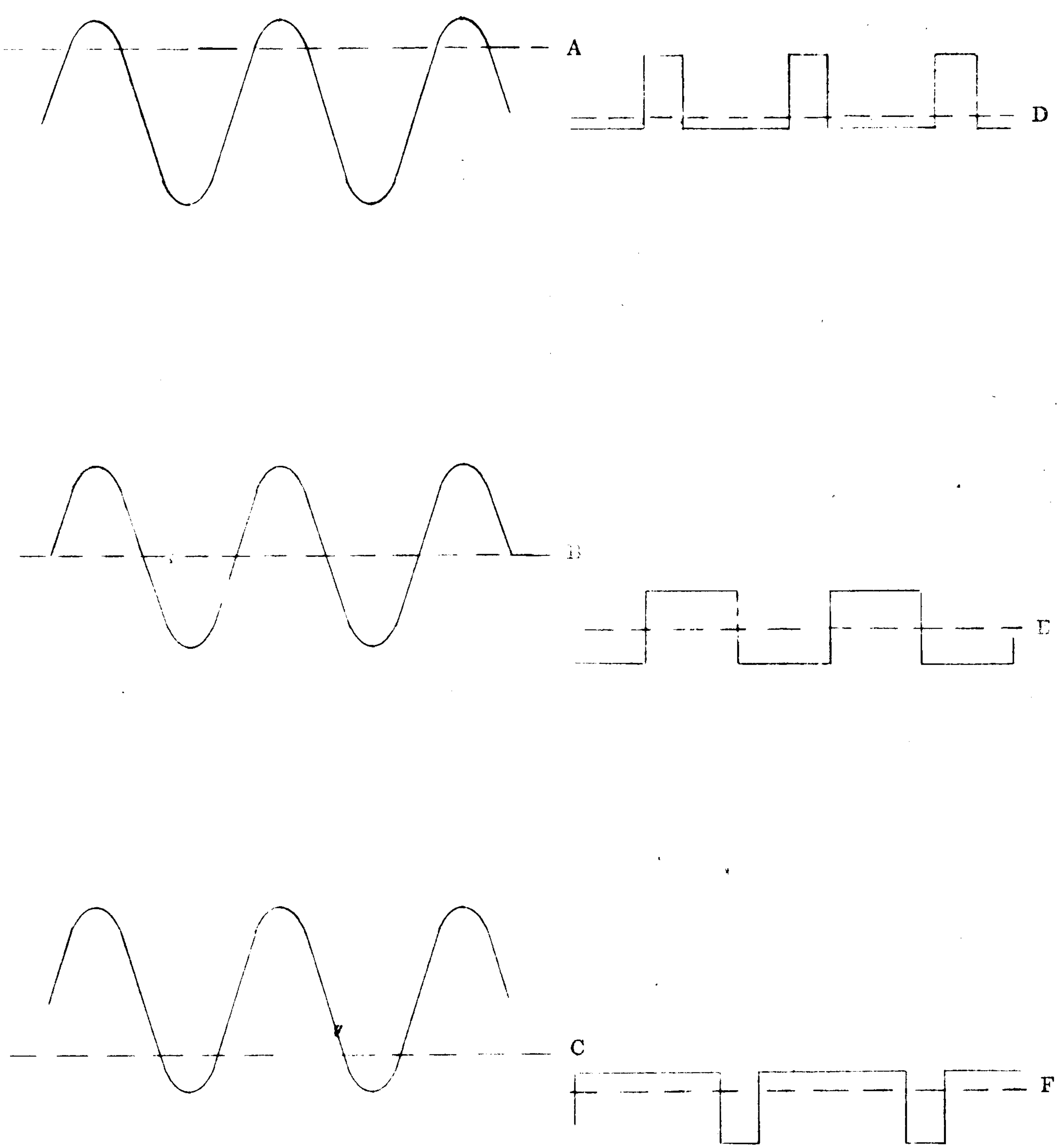

SPRING CONTACT OSCILLATIONS

Figure 1

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PROPOSAL FOR R&D ON GOVERNOR CONTROL FOR MINIATURE MOTOR

The object of the research would be to improve on a governor system to hold a miniature motor at approximately 2000 rpm or in that range as desired. The present approach utilizes a centrifugally controlled contact spring member which opens the armature current when the motor reaches a pre-determined speed. The problem is that the contact is of such light force and so momentary along with being greatly affected by temperature and other considerations that the regulation is relatively poor.

It is our thought that a further study should be made on the contact material, the spring material of the governor, and the entire approach and velocity of governing such a motor at these lower speeds. Certainly, it is difficult to take a standard motor designed for high speed governor control and have it come out as satisfactory in the lower speeds as can otherwise be obtained.

Our approach would be to study the following and make a prototype motor with any improvements that these studies produce.

1. Evaluate the contact material used on the governor.

2. Select a zero coefficient spring material that would be unaffected by the temperature ranges necessary.

3. Study the application of a mass or weight added to the spring at the desirable point to be more effective at the lower rpm over which the motor is to be governed.

4. Evaluate between the present concept of armature speed control which consists of opening the contact by centrifugal force when the motor has reached a certain speed versus a field control wherein one field is of permanent magnet design, which basically supplied the necessary field for operation, with a second field which is wound and controlled by closing a contact when the motor reaches a certain pre-determined speed.

5. Evaluate the friction losses in having the present concept design use brushes or wiper contacts on the governor versus having the governor attached to a mid section of the armature winding without the use of any wiping contacts. The friction losses in this case become appreciable and, if nothing is accomplished by having this method of feeding the governor, then it should be eliminated.

6. Using the field control will still require a wiping contact to the governor; so, consideration will have to be given as to the friction loss versus the speed control.

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7. Either design the motor to more effectively confine the external field or work out a shielding method as a part of the motor to eliminate the stray field from disturbing proportions.

8. In any approach on the motor, all consideration will be made as to acoustical noise which is caused by the commutator bars passing the brushes along with the contact noise of the governor itself.

There are also other items that would be observed and recommendations made on improved regulator and motor design although I believe that the above items would effectively take care of the regulation and bring it within the 2% or less desired tolerance over the temperature ranges and load requirements. I am estimating the time to do the above items at 6 weeks to 2 months, and the reason for the last 2 weeks on the project would be the life test of the contact material and wipers or brushes or sliprings or whatever else method is used to tie the governor to the motor. I would presume that the object of the R&D work would be to come up with a dependable motor design that we could build relatively inexpensively and that could be used on many of the DC operated devices, whether they be recorders or other instrumentation equipment, and to furnish power sources that could be better than $\pm 1\%$ regulation over the temperature and load requirements encountered in this type of equipment.

TEST DATA SHEET

Sample Motor (Dalmotor Co.)

Room Temperature Test

When first turned on

10.8 V	.112 A	2170 rpm
12 V	.115 A	2205
13.2 V	.118 A	2240

After 5 minute run

10.8 V	112 A	2180
13.2 V	118 A	2260

After 10 minute run

10.8 V	112 A	2170
13.2 V	118 A	2260

Spec limit is 80 rpm spread through voltage and temperature limits. This unit at room temperature showed a 90 rpm spread and a tendency to drift farther with warm up. No test was made at high or low temperature since the drift was beyond spec at room temperature.

TEST DATA SHEET

Prototype Motor

Room Temperature

12.1 V	.158 A	2135 rpm
11 V	.155 A	2110
9.9 V	.150 A	2080

+40° C

12.1 V	.153 A	2138
11 V	.150 A	2100
9.9 V	.145 A	2065

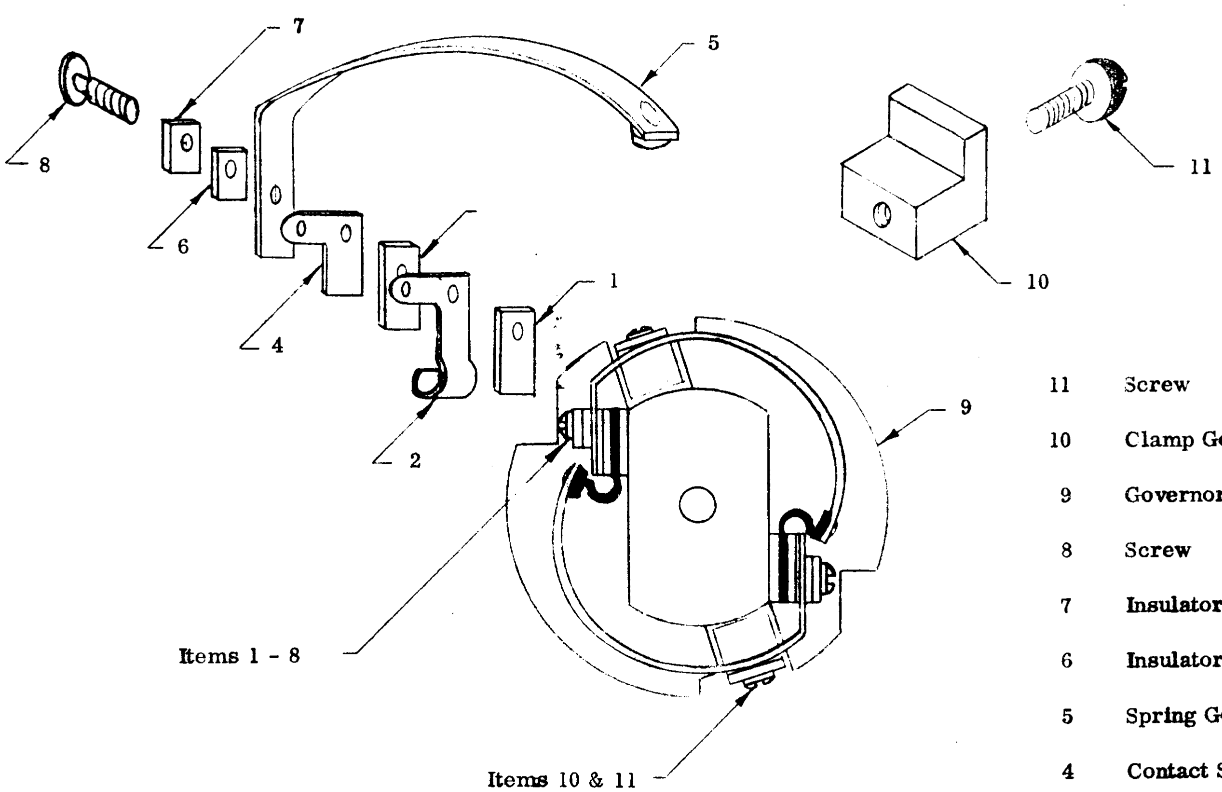
-10° C

12.1 V	.162 A	2135
11 V	.159 A	2097
9.9 V	.153 A	2060

With winding scaled to operate at 12 ±10% voltage the current for low voltage operation would be:

Current @ 9.9 V		Current @ 10.8 V
.145	=	.133
.150	=	.137
.153	=	.140

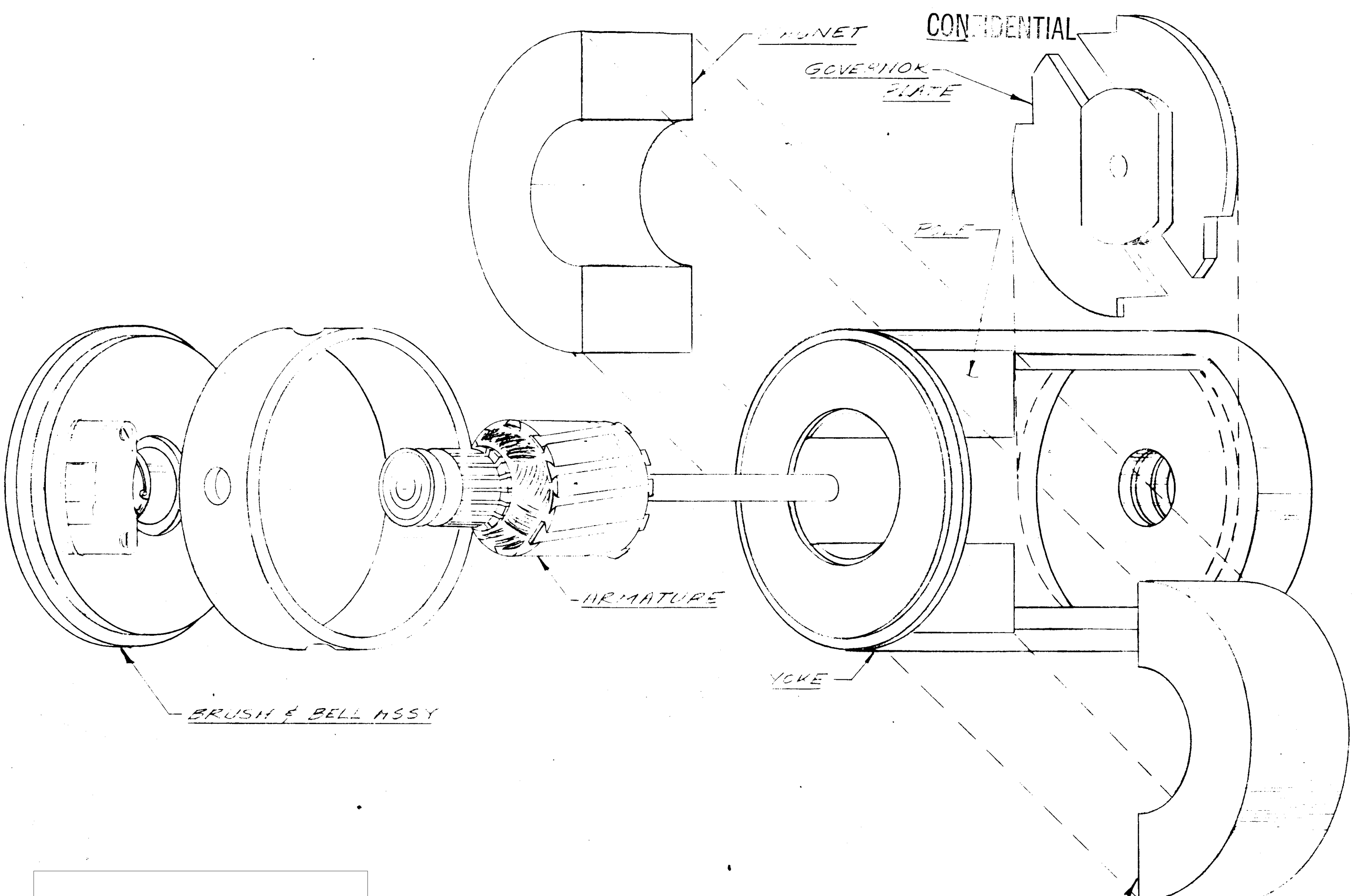
Allowing tolerance for production manufacture, maximum current @ 10.8 V should be .150 A.



11	Screw
10	Clamp Governor Adjust
9	Governor Plate
8	Screw
7	Insulator
6	Insulator
5	Spring Governor
4	Contact Spring
3	Insulator
2	Contact
1	Insulator

GOVERNOR - MOTOR

Figure 3



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MOTOR - GOVERNOR

FIGURE 2