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NAVY DEPARTMENT

BUREAU OF ENGINEERING

Investigation of an Improved Design for a Break-in Relay for Aircraft Transmitter-Receiver Equipment

[redacted]

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WASHINGTON, D. C.

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ABSTRACT

A design of break-in relay is proposed which uses the tested principles of the Creed relay for the magnet system, operating the contact system through the angular motion of a shaft mounted on the armature. The magnet system has no springs. It depends on the magnetic relations between a permanent magnet and a soft iron armature, the flux through which is controlled from the sending key. The contact system consists of two fixed terminals for each circuit joined by the contact arm on the armature shaft.

Endurance and operating tests show reliability of performance and freedom from keying transients.

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INTRODUCTION

1. This investigation was authorized by Bureau of Engineering letter C-F42-1/52(8-9-W8) of 12 August 1937.

2. The problem was to design an improved keying relay for aircraft transmitters to provide more satisfactory break-in operation. To provide a satisfactory break-in system for aircraft communication has always presented some difficulties. The requirements of light weight, small power drain, high altitude operation, vibration and operation with antenna systems which place extremely high radio frequency voltages across the relay contacts place rather stringent demands upon the keying relay.

3. Past experience with aircraft relays has been somewhat unsatisfactory in the attempt to keep down space and weight requirements and still provide the necessary keying speeds. In an effort to reduce weight, particularly of the moving parts, the contact system has often been rather flimsy. To reduce the power necessary for operation, the springs used have also been weak, thus allowing the armature to bounce and/or cause poor contact with resulting noise and poor keying action. Light contact arms also require frequent adjustment of contacts to maintain the proper sequence for good operation. One especially bad feature due to chattering contacts is the noise introduced in the receiver which prevents hearing a "break" signal.

4. The latter types of relays in aircraft transmitters have good features although not all are combined in any one type. The Model GO-2 provides an electro-magnetic hold-in feature to eliminate bounce upon opening the key. It, however, has some rather weak contact arms and requires power continuously to insure reliable contact in the "Receive" position. The Model GP-4 relay has an excellent contact system but is rather heavy and requires an excessive amount of power for its operation.

5. A consideration of the requirements of the service and experience with the equipment indicates that the following features are essential for good operation:

- (A) Reliability of operation.
- (B) Accessibility for adjustments.
- (C) A working speed of 30 w.p.m.
- (D) Freedom from contact transients.
- (E) Minimum weight and cubic content.
- (F) Low power demand.
- (G) Flexibility of design.

These considerations led to setting up two principles as basic for the magnetic system.

- I - A magnetic lock-in for both the transmit position and for the receive position.

- II - Elimination of springs.

6. The usual relay construction, which depends on a direct magnetic pull for transmit and a spring return for receive, operates at a double disadvantage in that the spring must be compressed by the magnetic pull for transmit and it is partly extended with decreased pressure for receive. This makes necessary a more powerful magnetic field to overcome the spring tension required to get enough pressure on the receive contacts for reliable operation. The spring rebound when the key is lifted also tends to introduce a contact bounce and transient as the antenna is connected to the receiver. A firm contact, free from this disadvantage, was believed essential.

METHOD

7. The magnetic circuit of Fig. 1, Plate 6, was chosen as meeting the requirements. A and B are permanent magnets. C is a soft iron armature. E and F are iron strips to parallel A and B. M is the magnetizing coil for C through the reversing switch S from the 12 volt d-c source G. With current in the direction P through M, C takes the position shown due to the flux set up by M. With current through M in the reverse direction Q, C will take up the opposite position.

8. Since it was desirable to eliminate the reversing switch or relay S, a double winding coil was built up, as shown in Fig. 2, Plate 6, to replace M of Fig. 1, Plate 6. In the key up position coils K and L are in series and K controls. In the key down position, K is shorted out and L controls.

9. During the time of relay operation, current is taken continuously through the magnet coils from the 12 volt source. For this relay, 100 mils is drawn for key up and 400 for key down. During periods of no transmission, no current is required through the magnet coils as the permanent field is ample to keep the armature locked in the receive position.

10. The magnetic system is essentially the same as that of the Creed relay, a relay which has given long and satisfactory use in telegraph service. A further assurance of long life for this type of magnet system is the superior magnetic materials now available such as Alnico. The construction provides for a continuous short or keeper across both permanent magnets in both the key up and the key down positions so as to maintain their field strength. This condition is even more favorable to stability of the magnets than is found in d-c meters where there is a slight air gap in the magnetic circuit. Yet these meters maintain their calibration over long periods of severe service.

11. The rotary type of motion for the control element lends itself to a simple contact system as shown in Plates 2 and 3. The arms are built up of laminations of beryllium copper with silver contacts. Since the opening across the receive contacts must take the antenna voltage, they have been mounted at a double radius in a V form to give a double break of double length. Plate 3 shows the antenna receive contacts open. Contact adjustments for all circuits are made from the stationary parts of the contacts.

12. As already noted, the details of construction of both the contact system and of the magnet system are subject to change to conform to specific conditions of manufacture and use. The model here presented has been built from available material to secure operation and design information. The two permanent magnets were salvaged from discarded General Electric meters. They take up considerably more space than will magnets of equal strength manufactured for this purpose. Micalex has been used for the contact supports since it is a good insulator and can be machined. Other material, such as isolantite, will probably be cheaper and better for quantity manufacture.

13. There was designed and constructed also the relay shown in Plate 5 in an effort to incorporate in the solenoid type of relay the desirable features previously listed. The magnet system was built up with two coils, one holding the plunger in the transmit position and the other assisting the spring release to hold the plunger in the receive position. A small transfer relay operated from the hand key connected in the wanted coil. Operation proved reasonably satisfactory with almost complete freedom from contact bounce and transients. An attempt to eliminate the intermediate relay by a coil system of the type of Fig. 2, Plate 6, was unsuccessful due to insufficient winding space, but it can be accomplished by providing sufficient ampere turns and the correct proportioning of the two coils. This type of relay brings more of a problem to provide a satisfactory contact system, especially for the antenna receive contacts where the full antenna voltage must be blocked. The lever arm arrangement used with this relay to get an increased length of break over the plunger travel is subject to more danger of failure than a direct arm, and an arm having direct travel with the plunger requires a long plunger travel to get a long break even when there are two contacts in series. It is thus rather difficult to compromise in such a way as to get a wholly satisfactory final result.

14. A serious difficulty occurs if power is taken off the relay in the receive position unless the return spring is made heavy enough to maintain the receive circuit by itself. This can be done easily at the cost of a powerful magnet system. Such a type of magnet system, providing a magnetic lock in the receive position, can be utilized with any of the plunger magnet type of relays by a redesign of the coils and of the magnetic circuits so as to allow increased power for the relay operation and the greater space to add the second coil.

TESTS

15. Extensive tests were conducted on the permanent magnet type relay. An endurance test of 70 hours continuous operation was run. For 30 hours the relay was operated at a speed of 28 words per minute. For 40 hours the relay was used to key a Model GP-4 transmitter operating at full power and delivering 7 amperes at 400 kilocycles into a 0.0007 microfarad dummy antenna at a keying speed of 30 w.p.m. These tests represent approximately 2-1/2 million operations of the relay. During this time no adjustments of any kind were made on the relay. There were no failures and operation was satisfactory throughout.

16. Cathode ray observation of break-in reception through a Model RU receiver when operating on an antenna showed a square cut pattern without transients. A check of all other circuit contacts showed no transients.

17. In a test with tape keying using the Model GP transmitter and Model RU receiver, the message was copied at speeds in excess of 40 w.p.m., which is probably very close to the limits of satisfactory operation for this particular relay.

18. An operation test at altitude was made with this relay replacing the relay in a Model GP-4 transmitter, as shown in Plate 1, with the trailing wire antenna shortened to the minimum length at which the set would resonate to 355 kilocycles when using the external loading inductor. Fig. 3, Plate 6, shows the arrangement in schematic. No failure or distress occurred in the relay even when the power amplifier plate current was increased from 175 to 250 milliamperes. Reception on a Model RU receiver at the Naval Research Laboratory remained clear and sharp throughout. Referring to Plate 8, data for this test are:

Frequency 355 kilocycles
Maximum altitude 23,000 feet

A1	A2	Ip	Remarks
4 amp	3 amp	.175 amp	Normal
5 "	4 "	.250 "	Overload

19. Plate 4 shows the Naval Research Laboratory relay in comparison with the Model GP-4 relay. Physical dimensions are approximately the same but with properly designed magnets the Laboratory relay may be reduced somewhat in size. The Laboratory relay weighs 2 pounds, while the GP-4 weighs 2 pounds 12 ounces. The GP-4 relay requires 2 amperes at 12 volts while the Laboratory relay requires a maximum of 0.4 ampere at 12 volts.

SUMMARY

20. The permanent magnet relay is somewhat unusual in design. It offers advantages which seem to fulfill the requirements for aircraft operation previously outlined. The design herein described can easily be adapted to the requirements of various equipments.

21. The Laboratory does not intend that the relay described herein be used as a model for manufacture of aircraft keying relays, but rather as a type of design which provides satisfactory operation. The contractor should be permitted to work out the construction of the relay to fit his manufacturing methods so long as the features of this relay are maintained.

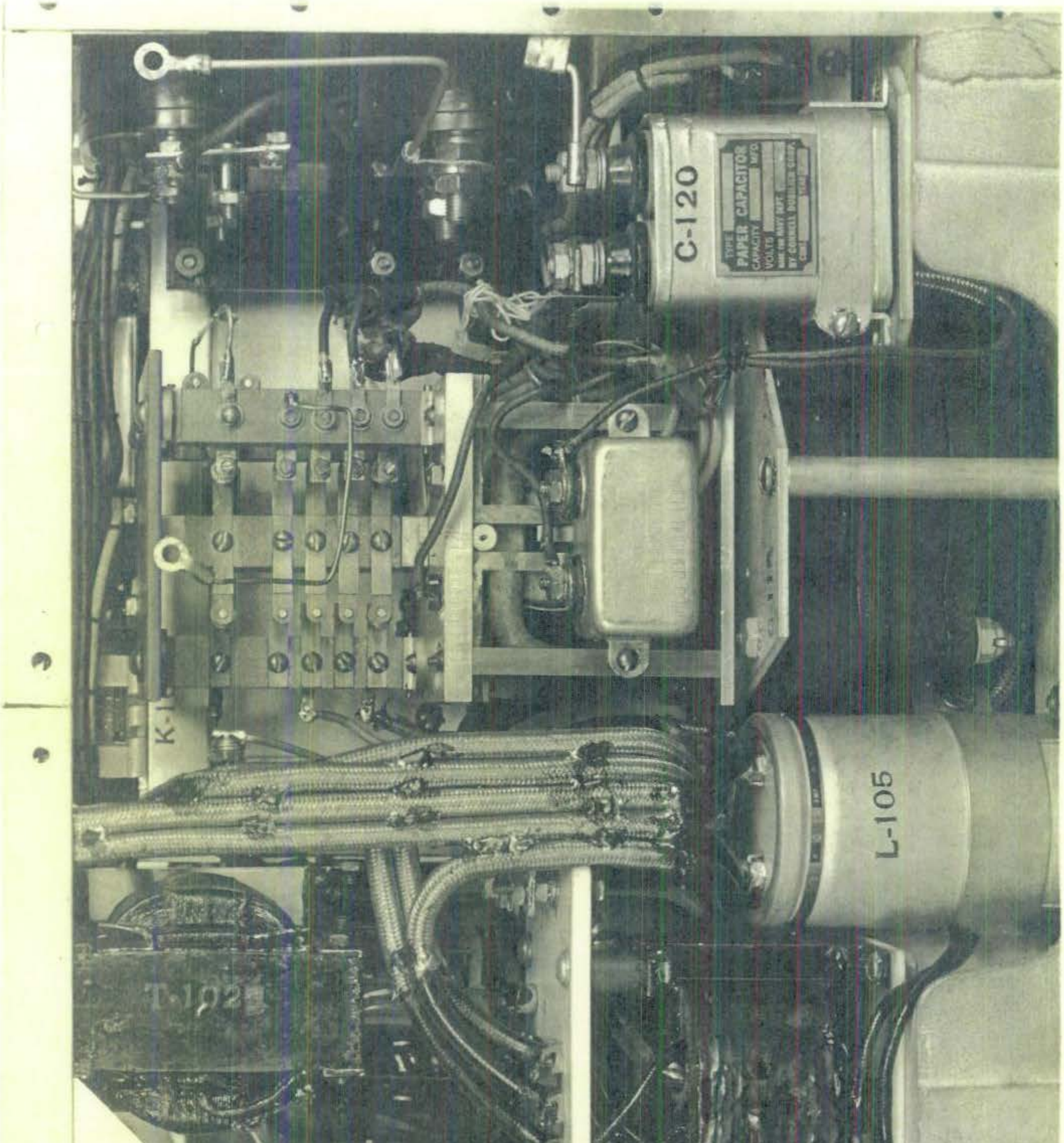

PLATE I

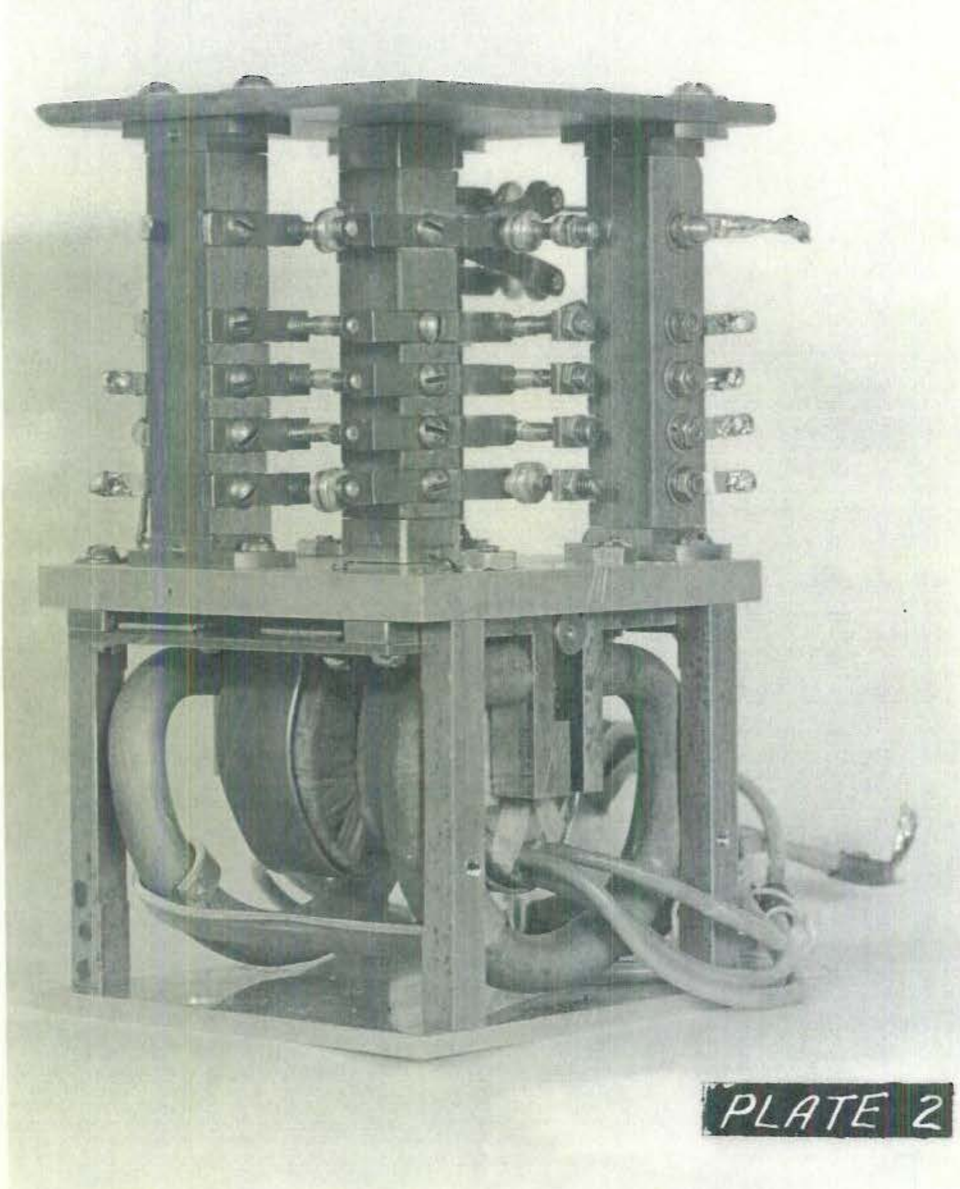
PLATE 2

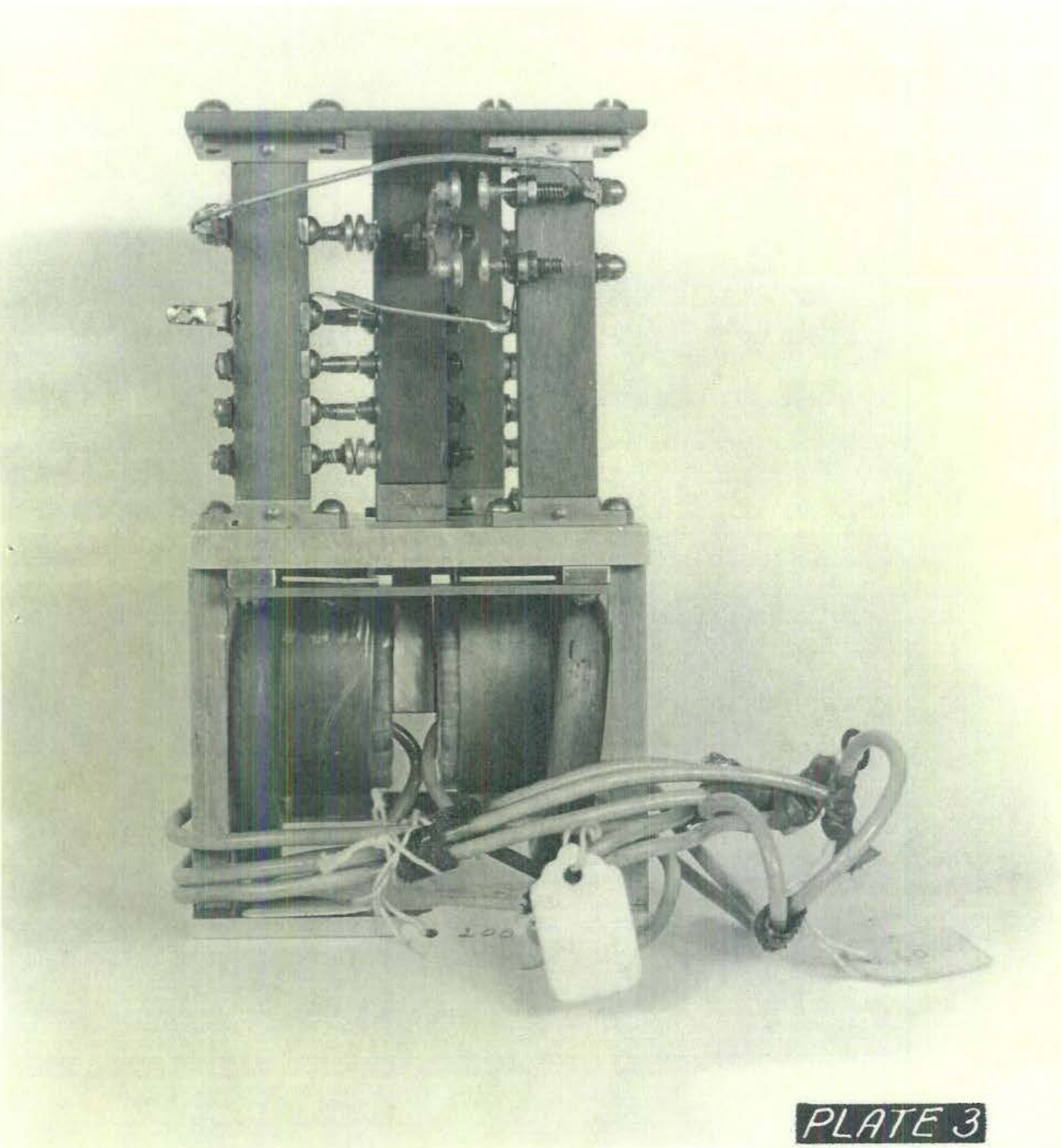

PLATE 3

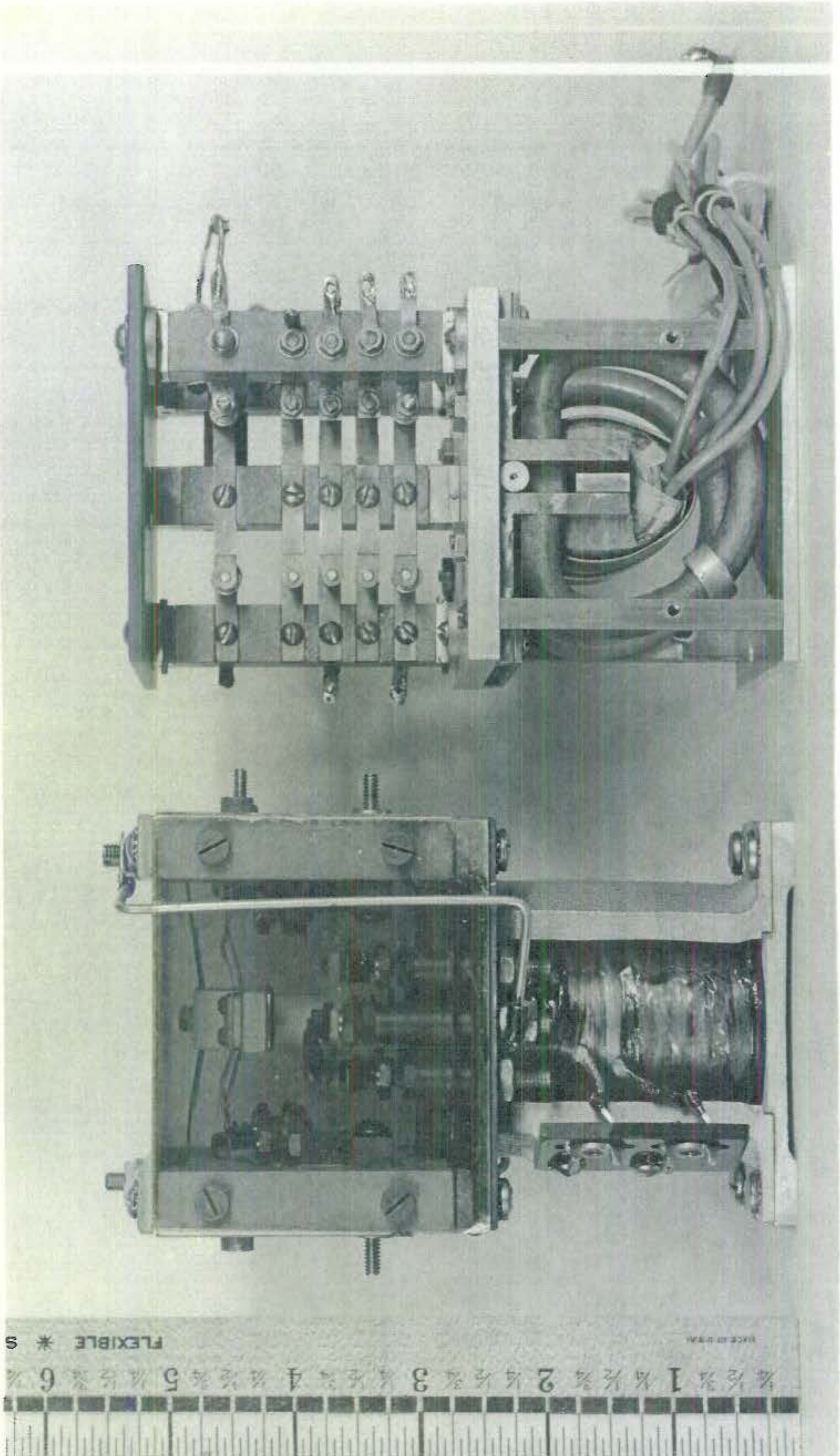

PLATE 4

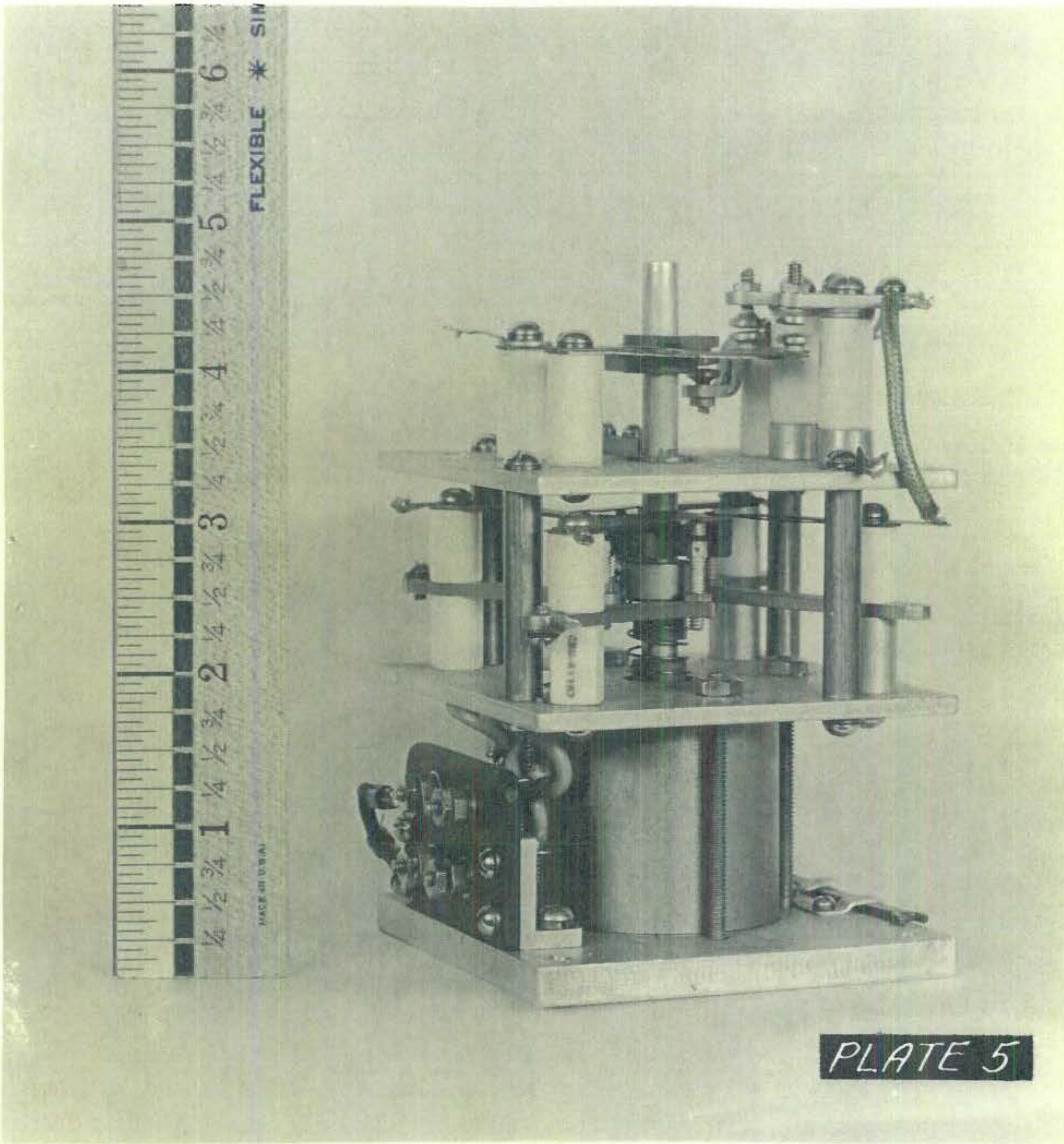

PLATE 5

FIG. 1

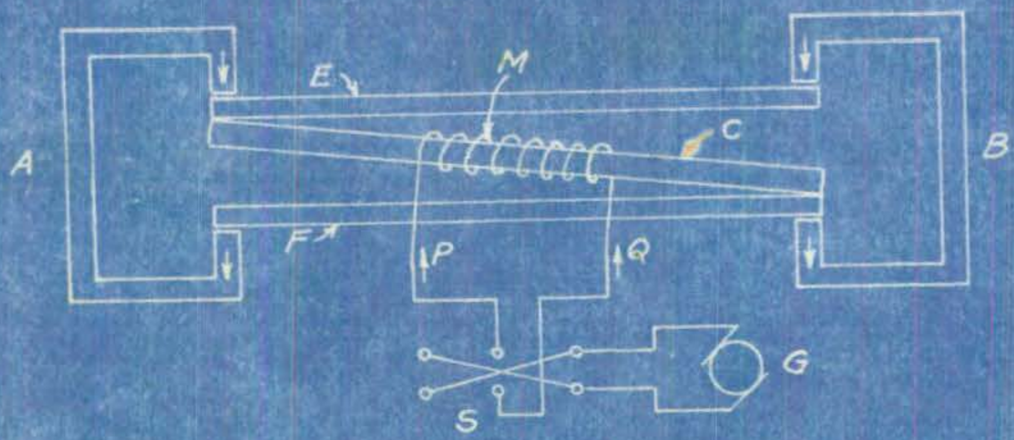

FIG. 2

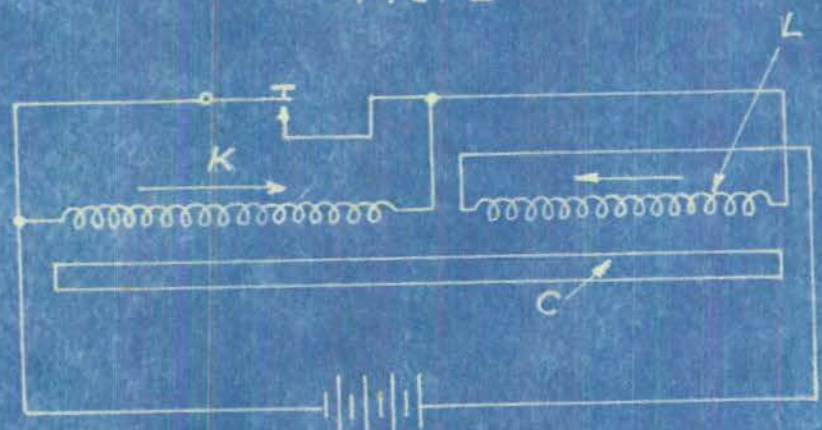

FIG. 3

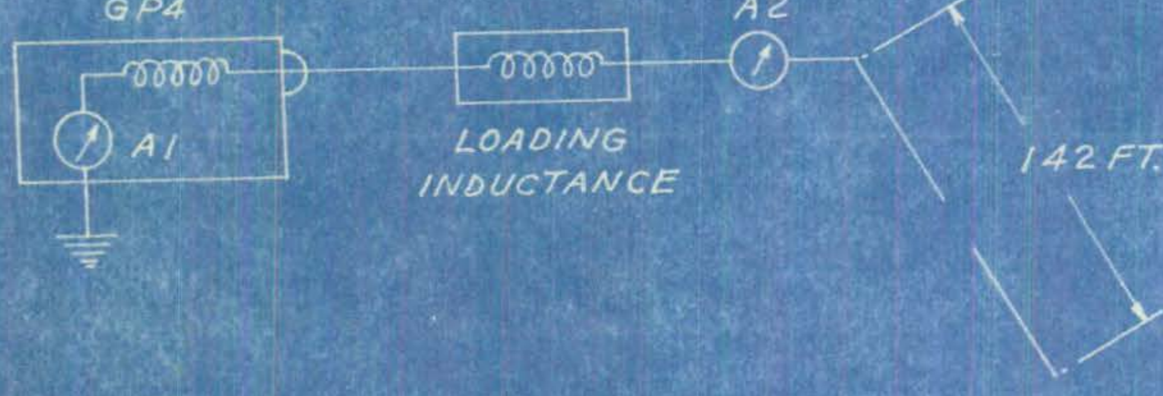

PLATE 6