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NAVY DEPARTMENT

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Report on

Band Change Switch

of

Models TBO and TBO-1 Portable Radio Equipment

General Electric Company

Contractor

NEW CONSTRUCTION

FR-1374

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

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Appendices

AUTHORIZATION FOR TEST

1. The tests herein reported were authorized by reference (a). Other pertinent data are listed by references (b) and (c).

Reference: (a) BuEng let.S67/24(1-8-W8) of 9 January 1937.
(b) BuEng conf.let.C-NOs-43256(10-18-W8) of 9 November 1936 to INM, Schenectady, N.Y.
(c) NRL Report No. R-1307(T5-21) of 21 Sept.1936.

OBJECT OF TEST

2. The object of the tests was to determine:

(a) The suitability of this design for Naval use.
(b) Whether the silver plated contacts will adequately withstand service usage.
(c) If the plating wears off and exposes the base metal, whether there would be sufficient contact pressure to maintain a low and uniform contact resistance.
(d) The mechanical wear involved during the test period.

ABSTRACT OF TEST

3. In accordance with par.7 of reference (a), a high frequency regenerative circuit was constructed (see schematic diagram). This circuit was tuned to approximately 18.2 megacycles, the regeneration being controlled by the potentiometer "R" which has a dial calibrated in units of two degrees. The subject switch was connected into the grid circuit as shown. The short test jumper was connected as shown by the dotted line and the dial setting at which the oscillation click occurred was noted. The circuit was always checked in this condition before making any tests to assure a constant reference point. The jumper was then removed and the point at which oscillation started was noted for each of the several combinations. In order to facilitate the recording of data, the switch sections were designated by A, B, C, D, the D section being closest to the mounting end and the A section being at the rear of the switch. The individual contacts were numbered in a clockwise direction, looking at the rear of the switch; i.e. 1, 2, 3. Therefore the complete roster of contacts is A1, A2, A3; B1, B2, B3; C1, C2, C3; D1, D2, D3. The circular contact rings on the movable shaft are designated by ring "A", ring "B", ring "C", and ring "D".

4. When the switch was ready for the test, the shaft was rotated by hand a few times to assure clean contacts and normal conditions to start. The reading on the oscillator control dial at which oscillations started was recorded for each contact and these values used as a standard of reference throughout the tests. These values have been placed in brackets alongside each measurement for ease of comparison.

5. After the reference values were obtained, the switch was put through various cycles of tests making measurements after each cycle. This test procedure consisted of rotating the shaft at 20 r.p.m. and during each run the direction of rotation was changed so that half of the time contacts were made from a clockwise direction and the other half from a counterclockwise direction.

6. Run No.1 was made by hand rotation of the switch in both directions to assure clean contacts. The observed values taken after this run were used as standard reference values throughout the tests. Run No.2 consisted of a total of 2400 revolutions. Run No.3 consisted of a total of 4800 revolutions. The switch now having had 9600 revolutions in each direction was removed from the circuit and given a thorough mechanical inspection which disclosed definite wear on the rotating contacts; also that the spring clicker washer was being badly worn by the looped end of the cotter pin. After this inspection the switch was placed in a humidity bath at 50° C. and averaging 90% humidity for 44 hours. These conditions were accomplished by use of a temperature controlled chamber in which was placed a pan of saturated salt solution. By applying heat to the solution, the humidity and temperature were maintained at the approximate values given. The switch was not given a spray or immersion test nor did there occur any direct condensation. Upon removal from the bath the switch was rotated by hand a few times and then the measurements made as given in Test No. 4.

7. It was replaced in the circuit and a total of 2600 more revolutions were made with results as shown by Test No. 5. The switch was then replaced in the bath for 60 hours. Upon removal the switch was rotated by hand five times each way with the results as listed for Test No. 6.

8. It was then revolved 4800 times more, removed from the circuit and photographed to show the broken clicker washer, and measured, with the results as shown by Test No. 7. It was replaced in the test circuit and rotated 8400 times more when the result of wear was definitely evident as shown by the results of Test No. 8. The switch was then replaced in the bath for an additional 34 days after which it was removed, placed in the test circuit and rotated by power for 20 revolutions with the results as given for Test No. 9.

9. Inspection after this test showed that one of the movable arms of group "A" had worn off sufficiently so that it did not make contact with A3. The switch was rotated by power without correcting this trouble for 760 rotations more and measured again as in Test No. 10.

10. It will be noted in Test No. 10 that some of the contacts are still in very good condition. The switch was then removed from the circuit, all contacts cleaned and the fixed contacts were bent to provide a reasonable contact pressure. The results then taken are listed under Test No. 11. The values thus obtained indicated that the contact resistances were in close agreement with the original values. After an additional 140 revolutions without change from normal values, the test was discontinued. The switch was removed from the test circuit, washed in

carbon tetrachloride and given a very careful mechanical inspection. This inspection disclosed that the silver surface of ring "A" was worn completely through on the contact area, ring "B" partially worn through and rings "C" and "D" just appear polished. The clicker spring washer was fractured in three places and is badly discolored. Data were taken at frequent intervals to determine when any appreciable change resulted but only a few of the measurements are submitted as the remaining data cover periods when there was no appreciable change and would add nothing to the value of this report.

Conclusions

(a) This band switch is one of sturdy construction having excellent insulating properties, unusually great contact pressure, and a reliable clicker or positioning device. It has a positive limiting stop operating on an integral part of the control shaft which does not place any strain on the rotor contacts or their ceramic drive shaft. Although the switch was operated around 20,000 complete revolutions, the probable equivalent of ten years' service, there was no sign of loosening of any of the many parts required for its fabrication.

(b) The fact that the contact area is plated, and does in the case of the brass rotor contacts wear off with relatively little use, constitutes its principal weakness. The silver plating was already worn off the ends of the rotating contact studs upon receipt of the switch at this Laboratory. This fact would in any band switch used in radio frequency circuits previously tested, prevent a recommendation for service use. In this case it was found that the silver plating on the beryllium copper contacts wore away at a surprisingly slow rate and that although the rotor or silver plated brass contacts did wear away very rapidly, the unusually great contact pressure was sufficient to clean the surfaces to permit satisfactory and normal operation continuously until the pressure was reduced by a wearing away of the brass. Although it is known that brass will corrode when exposed to saline atmospheres, it is believed that the contact pressure is great enough to assure that the contacts will be self cleaned with a few operations of the switch. The switch could be improved if the rotor contacts were made of a non-corrosive material, provided that one can be found that will not wear away excessively with the relatively great contact pressure provided.

Recommendations

It is recommended that:

(a) The clicker spring washer be silver plated or plated with some material that will retard corrosion.

(b) The rotor contacts be made of some material that will better resist wear and that this material be non-corrosive.

(c) The subject switch be considered as satisfactory for use in the Model TBO equipments, preferably with the modifications as given above and in case a suitably non-corrosive and wear resisting material cannot be found for the rotor contacts, that the instruction books advise that when the equipment has been out of use for long periods that the switch be operated a few times to assure clean contacts.

(d) The ring contact springs be soldered to their terminal lugs.

MATERIAL UNDER TEST

11. The subject switch is a three position four pole rotary type having ceramic insulation. The switch is assembled on a 1-7/8 inches diameter 3/32 inch thick circular aluminum alloy mounting plate. This plate is drilled and tapped for three 6-32 mounting screws arranged in triangular form. This plate is drilled in the center to become the front bearing for the rotor assembly and at the edges to receive the screws which hold the spacer insulators supporting the stator assemblies.

12. The rotor assembly consists of a 1/4 inch brass shaft 3/8 inch long which has its bearing in the mounting plate, a 9/32 inch long by 3/16 inch diameter extension on this shaft drilled for a securing pin and furnished with a "V" shaped keyway to receive the point of a set screw from a control knob. The shaft is also fitted with a coupling arrangement and clicker disc back of the mounting plate which is an integral shaft of the shaft. The clicker disc is 1-7/16 inches in diameter and is drilled with six holes, one on each side of the center aligning with the steel balls located in holes in the mounting plate, for each switch position. The clicker balls are retained in the holes in the mounting plate by a circular washer of what appears to be spring bronze, held in place by a washer, and a cotter pin through the shaft. There are four jaws on the back of the clicker disc that fit over the four sides of a 3/8 inch square ceramic shaft. This shaft is supported at the rear of the switch by a single steel ball mounted between the conical hole in the end of the shaft and a round hole in the center of a "Y" shaped 1/64 inch thick spring support. This support is secured to the rear ends of the three spacer insulator columns. The four rotor switch contacts consist of 3/16 inch diameter silver plated brass rods with spherical contact ends. These rods are of full diameter for about 5/16 inch and are turned down to suitable size to have about a 6-32 thread for the rest of their 7/8 inch of length. The threaded portion fits in a lateral through hole in the 3/8 inch shaft and is secured by a round nut of the 3/16 inch body side of contact rod. The contact stud and nut are further secured by soldering a silver plated bronze ring to the side of both stud and nut. This ring encircles the square shaft and provides a contact surface for connection to the rotor when contacted to a flat spring bush secured to the stator assembly.

13. The stator assembly between the mounting plate and rear end ball support, previously described, consists of two ceramic rings mounted in such position that the stator contacts mounted thereon will be properly positioned to contact the spherical ends of the rotor contacts. This positioning is accomplished by 1/4 inch diameter ceramic rods drilled and threaded at the ends for 6-32 screws. There are three columns of insulators spaced in triangular form near the outer diameter of the switch assembly. There are three insulators in each column, one between the mounting plate and the first stator contact mounting ceramic ring, the second between the two rings and the third between the rear ring and the rear ball support. Flat head screws secure the spacer insulators to the ends and threaded studs passing through the ceramic contact supporting rings permit the spacer insulators to be screwed tightly in place. Fiber washers have been furnished between all ceramic to metal and ceramic to ceramic abutments. The stator contacts

appear to be made of silver plated beryllium copper .02 inch thick. Those contacting on the rings leading to the rotor contacts have a spring length of approximately 1/2 inch are 7/32 inch wide and are so formed as to provide contact at the end of the cross section area of the spring with an angular displacement to provide a self-wiping contact. Circuit connection to these springs is through a terminal lug bolted to the spring by a screw passing through the ceramic ring, the terminal, and the spring. The nut is soldered to the spring but the spring is not soldered to the terminal thus providing only pressure contact. The lug is so bent as to prevent accidental rotation but this does not prevent possible accidental rotation of the fixed contact should the clamping pressure of the through bolt be insufficient to hold the assembly in place. The stator contacts which make contact with the spherical ended studs are "U" shaped having a maximum spring length of close to 1/2 inch. One side of the "U" forms the contact and the other the terminal connection, while the bottom of the "U" is bolted to the ceramic supporting ring. Its shape and method of mounting prevent rotation. The clamping screw and nut are soldered to the spring. The contact end of the spring is so bent as to give a turned back edge as the contact comes into the make or break position with a slight recess at the center position thus assisting in clicker action or switch positioning.

14. Plates 1 and 2 are photographs and schematic diagram respectively.

15. Close inspection of the switch prior to the start of tests revealed that the silver plating on the tip ends of the spherical rotor contacts had already been worn through exposing the brass. Considering the pressure on the contacts and the thickness of the plating, it is probable that this could have been the result of a relatively few switch operations.

METHOD OF TEST

16. For purposes of reference each switch section has been lettered "A" to "D" inclusive, the "A" section being the section farthest from the mounting end, while the "D" section is next to the mounting end. This was found to be most convenient for test procedure. Each contact could then be given a number; viz., A1, A2, A3, B1, B2, B3, C1, C2, C3, D1, D2, D3. Looking at the rear of the switch assembly and assuming a clockwise rotation the notation would run Section "A" Contact #1, #2, #3, or A1, A2, A3, etc. Section "A" is contacted by a double movable contact arm so that when the switch is set on the #1 contacts, #2 contact of "A" section is also engaged. Similarly when the switch is on #2 contacts, A2 and A3 are engaged. When the switch is in position #3 each group has a single contact engaged. By reference to the schematic diagram it will be noted that the switch has a total of 16 contact surfaces which were all connected in series to facilitate the detection of any change from normal by a single check.

17. The test circuit in which the switch was connected consisted of a single tube regenerative oscillator, using the potentiometer "R" for the oscillation control. The tuned grid circuit was opened and the subject switch connected in circuit as shown. An audio amplifier and speaker were used to amplify the click or howl, whichever occurred, when the circuit went into oscillation. If the circuit was normal a sharp click was heard.

If there was resistance in the circuit, the oscillation click moved up the scale or a howl resulted. With the hook-up shown, it was a simple matter to determine just which contact was causing trouble. The contacts being all in series, a defective one would show up at once either by the point of oscillation moving up the scale or by a howl.

18. The oscillator circuit frequency was 18.2 megacycles.

19. The jumper "S" was used to short circuit the switch so that the reference point of oscillation could be set prior to taking any measurements on the switch proper. After this reference point was established on the dial of potentiometer "R", the jumper was removed and the test prod "T" was clipped on to contact A1 and the setting for the point of oscillation noted on "R". This procedure was repeated for each contact separately. The reference points used in the test were as follows:

Short Test Point of Oscillation 39°

A1 - 39.5°	A2 - 40.5°	A3 - 42°
B1 - 50.5	B2 - 51.5	B3 - 53
C1 - 51	C2 - 52	C3 - 51
D1 - 76	D2 - 69	D3 - 66

This means that in Group "A" contact #1 oscillations started at 39.5° etc. Should no change in contact resistance take place, these readings should repeat.

20. The switch assembly was coupled to a synchronous motor having a reduction gear which rotated the switch arm at 20 r.p.m.

DATA RECORDED DURING TEST

21. The first test consisted of obtaining the reference point with the switch shorted out of circuit. This was noted at 39° on the dial "R". Prior to every test this adjustment was made. The oscillation point under normal circuit conditions was indicated by a sharp click from the speaker.

22. Test #1. Contact data after the switch was rotated a few times to insure clean contacts.

Contact	Osc.Pt.	Cont.	Osc.Pt.	Cont.	Osc.Pt.
A1	39.5	A2	40.5	A3	42.0
B1	50.5	B2	51.5	B3	53.0
C1	51.0	C2	52.0	C3	51.0
D1	76.0	D2	69.0	D3	66.0

The points, as listed above, are standard reference points.

23. Test #2. The following data obtained after 600 revolutions in each direction at 20 r.p.m.

A1 - 39	A2 - 39	A3 - 41	Note the change in A2,
B1 - 51	B2 - 52	B3 - 54	A3, and C2 which have
C1 - 53	C2 - 50	C3 - 51	improved.
D1 - 76	D2 - 71	D3 - 66	

24. Test #3. After 2400 additional revolutions in each direction.

A1 - 40	A2 - 41.5	A3 - 42.5
B1 - 56	B2 - 52.5	B3 - 54
C1 - 53	C2 - 52	C3 - 54.5
D1 - 79	D2 - 71.5	D3 - 68

25. The switch now having had a total of 3600 revolutions, 1800 in each direction, was removed from the circuit and given a thorough mechanical inspection which disclosed the following defects:

(a) The ends of the double movable contacts of Group A were now very much flatter having lost considerable material. A very perceptible amount of ground metal was deposited upon the mounting base. The fixed contacts had the silver removed but there was no visible evidence of any of the base metal having been removed.

(b) All contacts of Groups B, C, D still appeared normal, although there was a black deposit on the fixed contacts of A, C, D.

(c) The spring washer over the clicker balls was caused to bind twice every revolution by the cotter pin which holds it in place.

26. The switch was then placed in a saline humidity bath. The temperature was maintained at 50° C while the humidity ranged around 90°. All contacts while in the bath were in the open position. After 44 hours in the bath the switch was removed, allowed to dry and then put into the test circuit again.

27. Test #4. The switch contacts were engaged successively by hand through the various positions with results as follows:

A1 - 40.5 (39.5)	A2 - 43 (40.5)	A3 - 44.0 (42)
B1 - 54.0 (50.5)	B2 - 64.0 (51.5)	B3 - 56.5 (53)
C1 - 54.5 (51.0)	C2 - 59.5 (52.0)*	C3 - 53.0 (51)
D1 - 82.5 (76)	D2 -112 (69.0)	D3 - 70.5 (66)

* means a howl, i.e. high res. cont.

The figures in the parenthesis are the reference figures of normal operating conditions, Test #1, and are given for ease of comparison.

28. Test #5. The switch was next revolved by power for a total of 2600 revolutions and the following measurements made.

A1 - 42.0 (39.5)	A2 - 43.0 (40.5)	A3 - 44.0 (42)
B1 - 54.5 (50.5)	B2 - 55.0 (51.5)	B3 - 56.5 (53)
C1 - 57.0 (51.0)	C2 - 53.0 (52.0)	C3 - 54.0 (51)
D1 - 82.5 (76.0)	D2 - 74.0 (69.0)	D3 - 69.0 (66)

29. Test #6. The switch was replaced in the humidity bath for 60 hours, removed and placed in the test circuit. The switch was rotated by hand for 10 revolutions, 5 each way, then measured.

A1 - 42.0 (39.5)	A2 - 43.0 (40.5)	A3 - 47.0 (42)
B1 - 56.5 (50.5)	B2 - 54.0 (51.5)	B3 - 56.0 (53)
C1 - 56.0 (51)	C2 - 52.5 (52)	C3 - 53.0 (51)
D1 - 84.0 (76)	D2 - 72.0 (69)	D3 - 68.0 (66)

Data taken after 4800 additional revolutions by power were made.

30. Test #7.

A1 - 40.5	A2 - 43.0	A3 - 43
B1 - 52.0	B2 - 51.5	B3 - 54.5
C1 - 54.0	C2 - 49.5	C3 - 50.5
D1 - 82.0	D2 - 68.5	D3 - 68.0

Photographs were then taken to show that the spring washer previously mentioned as binding on the cotter pin was broken in three places.

31. Test #8. The following data were taken after 8400 more revolutions by power.

A1 - 140	A2 - 20*	A3 - 19*
B1 - 19*	B2 - 20*	B3 - 19*
C1 - 203	C2 - 20*	C3 - 19*
D1 - 210	D2 - 20*	D3 - 19*

An investigation disclosed that the reason for the howl (*) was high resistance between the rotating contacts of the "A" section. This poor contact in the "A" section naturally affected all of the other readings due to the series method of test employed. The switch was replaced in the bath for 34 more days after which it was removed, placed in the test circuit under power again for 20 revolutions with the following results.

32. Test #9.

A1 - 43	A2 - 45	A3 - 21* Howl
B1 - 53	B2 - 51	B3 - 21*
C1 - 54	C2 - 68	C3 - 21*
D1 - 74	D2 - 68	D3 - 21*

33. Inspection was made after this test to determine the reason for the howl in No.3 contact positions. It was found that one of the double movable arms of the "A" group had worn down so that it did not make contact with the No. 3 fixed contact but did with fixed contacts No.1 and 2. No attempt was made to correct this trouble, but the test was continued to determine the effect on the other contacts.

34. Test #10. The switch was rotated for 760 rotations by power and the following notations made:

A1 - 42 (39.5)'	A2 - 45 (40.5)	A3 - 20 (42)*	Howl, caused
B1 - 52 (50.5)'	B2 - 51 (51.5)'	B3 - 20 (53)*	by poor con-
C1 - 55 (51)	C2 - 52 (52)'	C3 - 20 (54)*	tact of A
D1 - 78 (76)*	D2 - 68 (69)'	D3 - 20 (66)*	section
			rotating arm.

Note that the contacts marked (') are still practically perfect after the demonstration of poor contact shown in Test #8. The switch was removed from the circuit, all contacts except the ring contacts were thoroughly cleaned and the fixed contacts were sprung as necessary to assure reasonable contact pressure.

35. Test #11.

A1 - 42 (39.5)	A2 - 44 (40.5)	A3 - 44.5 (42)
B1 - 51.5 (50.5)	B2 - 52 (51.5)	B3 - 52 (53)
C1 - 52 (51)	C2 - 52 (52)	C3 - 52 (54)
D1 - 77 (76)	D2 - 69 (69)	D3 - 65 (66)

This shows very close agreement with the reference figures given above except for A2 which is not greatly different. 140 more revolutions under power failed to change the above figures and as inspection showed that the switch could be expected to continue to function similarly for a considerable period of time, the test was discontinued. The switch was removed from the circuit, washed in carbon tetrachloride and examined very carefully. The silver surfaces of rings "A" and "B" were worn completely through and rings "C" and "D" appeared to have retained the plating but in a polished condition. The clicker spring washer was badly broken in two places, while a third crack had already started. This washer was badly discolored from saline atmospheric exposure.

PROBABLE ERROR IN RESULTS

36. The errors involved in the test of this switch constitute primarily those due to the reading of the regeneration control dial "R". These readings can be considered accurate to $\pm$ 0.5°.

RESULTS OF TESTS

37. This test has demonstrated that the subject switch after having been through the equivalent of approximately ten years of service, shows very little sign of deterioration.

38. If, during the tests, the degree of rotation had been limited to that allowed by the stops provided, the clicker washer would not have been cracked. The principal defects are that of the silver plating wearing off the rotor contacts and the excessive wear of these contacts themselves.

39. Despite this excessive wear, it required only a slight springing of the fixed contacts (after washing the switch) to bring all contact resistances back to a normal condition.

SUMMARY OF DEFECTS

40. The breakage of the spring washer can not be considered as a defect as it was the result of rotation greater than the normal 90° rotation required for the three positions provided. It was caused by abnormal strain as the cotter pin head passed the clicker ball positions when 360° rotation was effected as in these tests. It is probable, however, that this would become a defect should this switch be employed for a greater number of steps requiring greater than 90° rotation unless the present cotter pin is replaced with some form of securing pin that does not contact the washer in rotation.

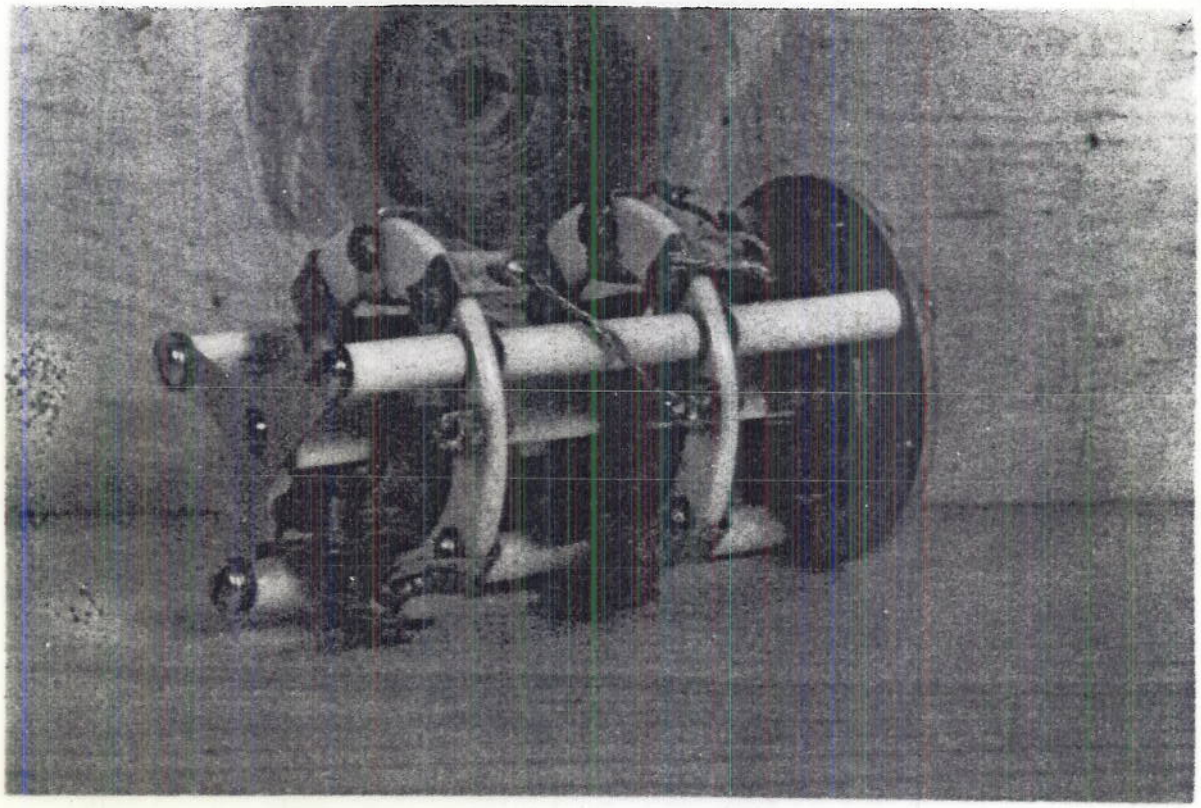
41. The silver plating on the spherical tips of the rotor contacts definitely wears off with relatively few switch operations.

CONCLUSIONS

42. This band switch is one of sturdy construction having excellent insulating properties, unusually great contact pressure, and a reliable clicker or positioning device. It has a positive limiting stop operating on an integral part of the control shaft which does not place any strain on the rotor contacts or their ceramic drive shaft. Although the switch was operated around 20,000 complete revolutions, the probable equivalent of ten years' service, there was no sign of loosening of any of the many parts required for its fabrication.

43. The fact that the contact area is plated, and does in the case of the brass rotor contacts wear off with relatively little use, constitutes its principal weakness. The silver plating was already worn off the ends of the rotating contact studs upon receipt of the switch at this Laboratory. This fact would in any band switch used in radio frequency circuits previously tested, prevent a recommendation for service use. In this case it was found that the silver plating on the beryllium copper contacts wore away at a surprisingly slow rate and that although the rotor or silver plated brass contacts did wear away very rapidly, the unusually great contact pressure was sufficient to clean the surfaces to permit satisfactory and normal operation continuously until the pressure was reduced by a wearing away of the brass. Although it is known that brass will corrode when exposed to saline

atmospheres, it is believed that the contact pressure is great enough to assure that the contacts will be self cleaned with a few operations of the switch. The switch could be improved if the rotor contacts were made of a non-corrosive material, provided that one can be found that will not wear away excessively with the relatively great contact pressure provided.



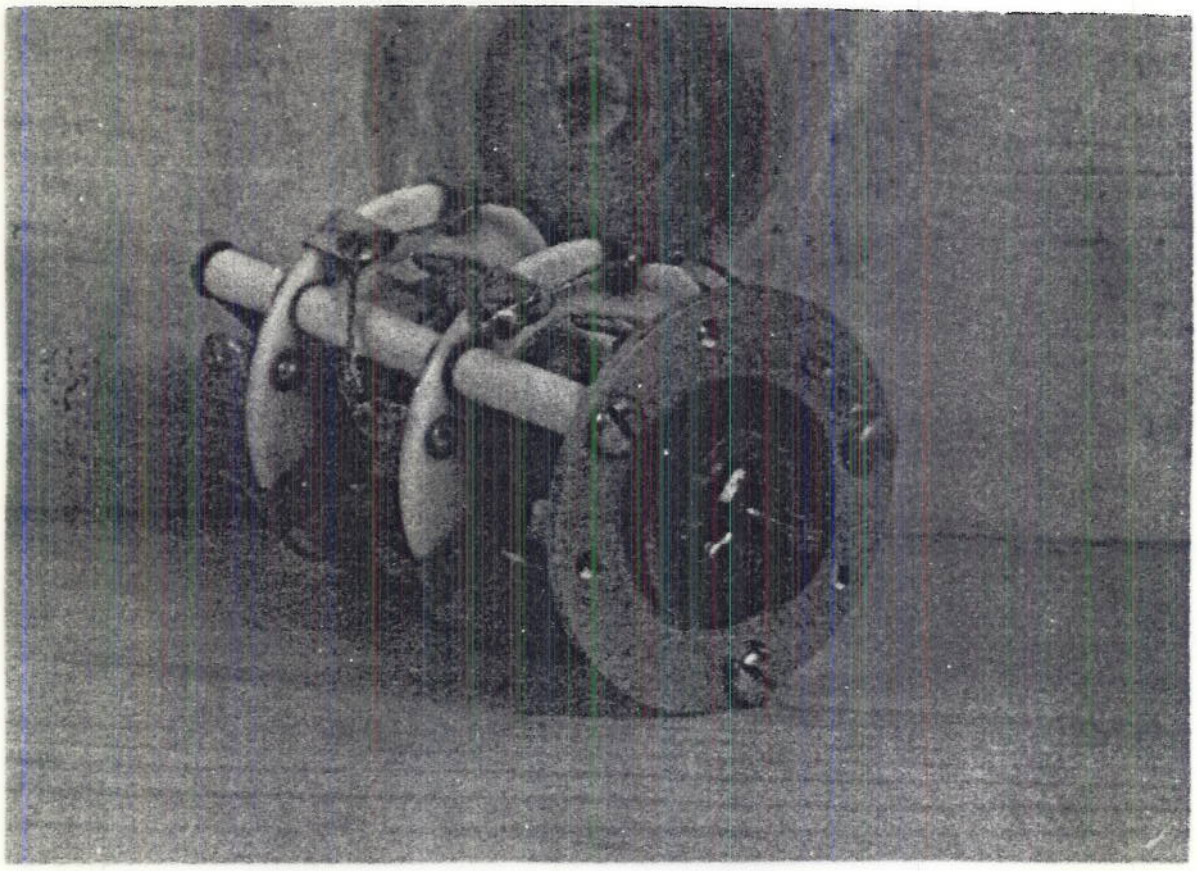
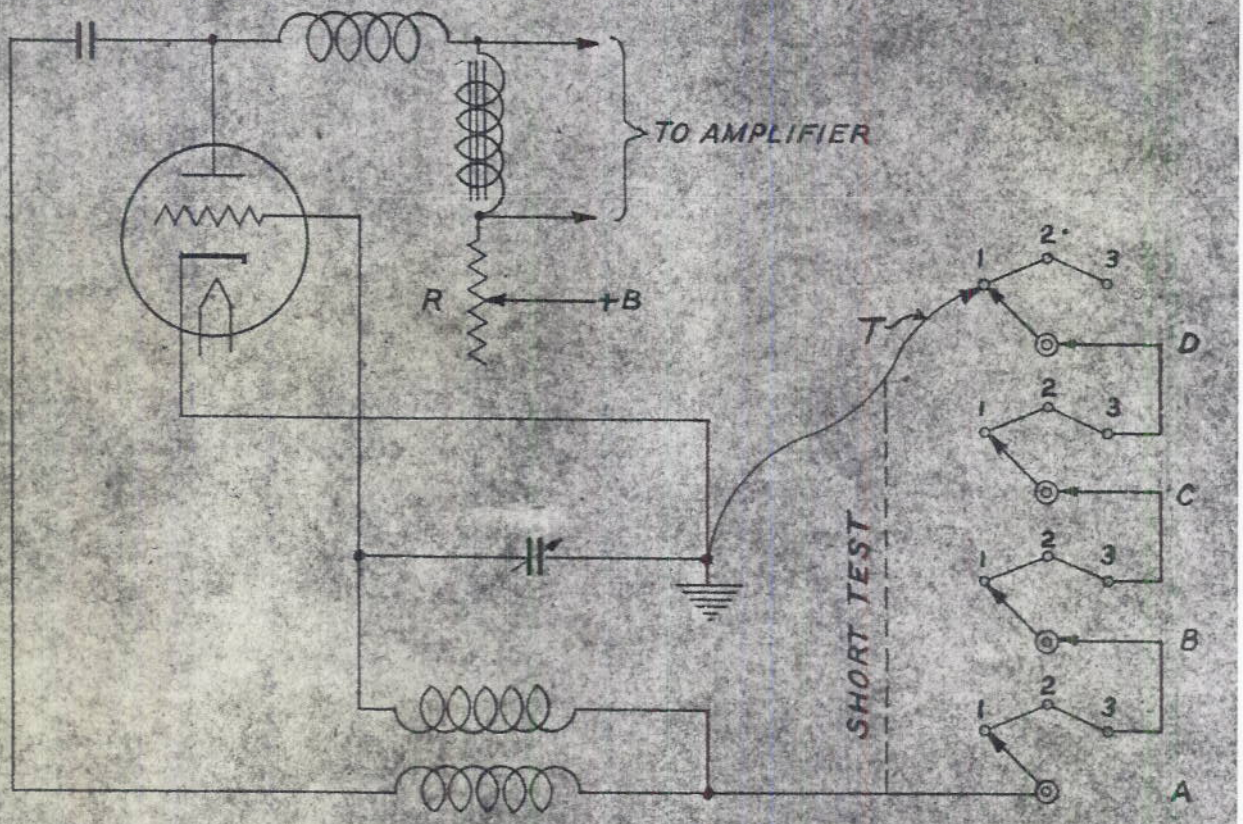


Plate 1



MODEL TBO-1 SWITCH ASSEMBLY

PLATE 2