CONFIDENTIAL

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H_2S MARK II EQUIPMENT
AND
A.S.V. MARKS IIIA & IIIB
CHAPTER 1

PREPARED BY DIRECTION OF THE MINISTER OF AIRCRAFT PRODUCTION

A. Rowlands

PROMULGATED BY ORDER OF THE AIR COUNCIL.

NOTE. This document is of a provisional character. It is issued in this form to ensure early promulgation of the information.

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Amendment List No.1
to
S.D.0296 (1), Chap.1
2nd Edition

H_2S Mark II and A.S.V. Mark III
ARI.5153

1. Make the following amendments in the book and when they have been incorporated, make an entry on the amendment Record Sheet.

2. Fig.67 amend marking of lead to repeater motor marked "black" to read "blue".

3. Fig.8 amend polarity marking of the D.C. input plug, red W-plug type 204 on power unit to read pin 1, negative pin 2, positive.

4. Reverse the 24V D.C. polarity in the explanation dealing with the operation of the relays as follows :

Para. 136 line 10 amend "24V -" to read "24V +"
Para. 137 line 2 amend "24V positive" to read "24V negative"
Para. 137 (iii) line 6 amend "+ 24V" to read "- 24V"
Para. 140 (iii) line 2 amend "+ 24V" to read "- 24V"
Para. 141 line 4 amend "24V negative" to read "24V positive"
Para. 141 (ii) line 1 amend "24V positive" to read "24V negative"
Para. 142 (iii) line 4 amend "24V negative" to read "24V positive"
Para. 143 line 2 amend "+ 24V" to read "- 24V".

SECRET

H_2S MK. II AND ASV MK. III

ARI 5153

Amendment Record Sheet

Incorporation of an Amendment List in this document should be recorded by inserting the amendment list number, signing the appropriate column, and inserting the date of making the amendment.

A. L. No.	Amendment made by	Date	A. L. No.	Amendment made by	Date

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A.R.I.5153

(H2S Mark II)

INTRODUCTION

FACILITIES PROVIDED BY THE EQUIPMENT

1. The equipment described in this document, which is known as H2S Mk.II or ASV Mk.III equipment is primarily a device to enable blind bombing to be carried out. It is also used for the purpose of aiding navigation of aircraft. The remarkable feature of the equipment is that it sets out to display on a screen a pictorial representation of the ground over which the aircraft is flying. This picture is produced with the aid of electrical rays so that it can be produced at night or in fog or cloud.

2. In addition to providing this somewhat rough picture of the surrounding country, the installation also gives the following important items of information:- These are the range and bearing of a selected target and the height of the aircraft above ground. This height is known as the terrain clearance, which is in general different from the height above sea level given by barometric altimeters. It is given to an accuracy of the order of ± 200 ft.

3. By means of switching arrangements, the area covered by the picture can be that within a radius of 10, 30 or 50 miles of the aircraft. Another range is also provided, known as 50 to 100 mile range; this gives a rather distorted picture of certain objects lying within a ring of country between 50 and 100 miles from the aircraft. This means that four alternative maps can be provided, three of which will have diameters of 20, 60 and 100 miles, and the fourth will have a diameter of 200 miles with the middle missing.

4. The orientation of the picture which is produced on the screen of the cathode ray tube can be controlled in two ways -

(i) The top of the picture can correspond to the direction in which the aircraft is flying, or

(ii) The top of the picture can always be true north.

These alternative facilities are obtained by either producing the picture directly on the screen or, as it were, uncoupling it from the aircraft and controlling it from the D.R. compass. In the case of Coastal Command aircraft, the direct method is used, but in the case of Bomber Command aircraft where it is desirable to know the relationship between the course of the aircraft and the true north and south, the second method is used, in which the D.R. compass controls the orientation of the map.

5. The D.R. compass is a gyroscopically-operated compass which is situated usually at some point in the tail of the aircraft well away from masses of metal, such as engines, which would be likely to affect the magnetic bearing. The position of the compass bearing relative to the course of the aircraft, can be displayed on dials situated in other parts of the aircraft, e.g. pilot's cockpit and navigator's table. For this reason the compass is called the distant reading or D.R. compass. Electrical currents are used to operate the distant reading dials of the D.R. compass, and by suitable interconnection of these circuits with the H2S equipment, the compass can be made to control the orientation of the H2S map.

6. Since the map will not now give any indication of the direction in which the aircraft itself is moving relative to the objects displayed on it, it is necessary to show on the map a line corresponding to the direction of flight of the aircraft. This line is known as the heading marker or course marker. The course marker appears as a bright line from the centre to the edge of the map.

NOTE: There is a point here which should be borne in mind by navigators. The heading marker shows the direction in which the nose of the aircraft is pointing, but if there is a side wind, the actual course followed by the machine will be the resultant direction obtained by combining aircraft speed and direction with the wind speed and direction by means of a vector diagram.

7. Other navigation considerations, such as, variation and deviation of compass bearings must also be allowed for by adjustment of the controls provided on the D.R. compass.*

8. The information given by the H2S equipment can, therefore, be summarised as follows:-

It gives -

(i) Blind bombing facilities by virture of giving a picture of terrain and built-up areas.

(ii) The most accurate available information on windspeed and direction.

(iii) The information required by the navigator or bomb aimer is obtained in terms of -

(a) an accurate range on the target,

(b) an accurate indication of height above ground,

(c) an accurate range on objects passed en route,

(d) the heading of the aircraft relative to compass north.

PRINCIPLES OF OPERATION

9. In order to understand how this equipment operates, it is perhaps desirable to examine the mechanism of ordinary vision. Imagine therefore an observer in an aircraft looking at the ground below him. In daylight when there is no cloud, light from the sun is reflected from objects on the earth. Owing to the different capacity for reflecting light possessed by different objects and also owing to the different angles that the surfaces of these objects make with the path of the light rays incident on them, these objects can be distinguished from one another. In the dark it would be necessary for the aircraft to provide its own illumination, e.g. in the form of a searchlight, before the observer could receive back reflections from objects on the ground. A normal searchlight has a focussed beam and consequently will only illuminate a small patch on the ground. To illuminate every object within a circular area of say 20 miles diameter beneath the aircraft, it would be necessary to move the searchlight about and illuminate successively each little patch on the ground.

The beam

10. In this equipment the ground beneath the aircraft is illuminated not by a searchlight but by a beam of radiation, also instead of illuminating just a small patch of the area, it is arranged that a wedge-shape slice of the area is illuminated. This is done by stretching out the beam in the vertical plane whilst keeping it narrow in the horizontal plane. The effect is illustrated in fig.1. In this illustration the aircraft is represented as positioned at A; B is a point immediately below the aircraft on the ground, and C and D are points on the ground showing the limit of the distance at which the ray strikes the ground. The area "illuminated" is thus the sector BCD of the whole circular area formed by rotating this sector about the point B. The angle CAD which is the angle of spread of the beam as it leaves the aircraft, is about 6 deg. All objects lying within the area DCB are more or less equally illuminated. The shape of the beam therefore somewhat resembles that of a slice of cake, with no height at the circumference. By rotating the beam through 360 deg. about the vertical axis AB, it is possible to illuminate the whole of the area enclosed by the dotted circle.

11. Consider now objects within this area; those nearest the point B will be nearer to the aircraft than those at the edge of the area, the actual distance from the aircraft being the slant distance from A to the object in question. This we will call the slant range. This difference-in-range feature of various objects is utilised in building up a map of the terrain in the H2S equipment.

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* Further information on this subject is available in A.P.1234. The D.R. compass itself is described in A.P.1767, later changed to A.P.1275B, Vol.I, Sect.3, Chap.7.

12. The picture which the equipment produces appears as stated above, on the screen of a cathode ray tube. The form of time base* employed is radial. This time base rotates and sweeps over the area of the screen just as the radiation beam covers the ground underneath the aircraft. The time base is arranged to rotate at exactly the same rate as the beam rotates.

13. Although the rotating time base is always present, it is not always illuminated. It is, in fact, arranged that the electron beam in the cathode ray tube which produces the spot on the screen, is intensity modulated by the reflections received from the ground. By careful setting of the critical level at which the time base becomes visible, it is possible to arrange that returns from objects illuminated by the beam (echoes) will brighten the trace sufficiently to produce a visible image on the screen. Since the time base is rotating at the same rate as the radiation beam any particular echo appears in the same position on the screen of the tube at each revolution. In order that a picture may be built up an after-glow screen is used, that is to say, one which continues to show a spot for a few seconds wherever one is produced on the tube face. By this method the tube retains a complete picture although each particular spot is only illuminated at the moment the rotating time base actually passes through it.

14. The picture on the screen which is so built up requires some experience in interpreting. In general, echoes are only obtained from abrupt changes of land or seascape. On land, buildings and other man-made structures and predominating relief features, such as coast lines (especially cliffs and islands) give good echoes. Minor topographical irregularities, such as small hills, valleys, rivers and woods, do not give rise to any noticeable response. Water except when rough gives an extremely small response, and thus ships (which give a good response) are distinguishable. It should further be noted that the part of the picture emanating from any particular feature or small group of features, is not constant in shape but tends to become a rough replica of the actual feature as the aircraft passes over it.

15. Whilst it has been stated that an electrical beam of transmission is sent the radiation is not continuous. Actually a series of pulses are sent out at intervals of approximately 1,500 microseconds, thus about 660 pulses are sent every second. The pulses are 1 microsecond long. As radio waves travel at the rate of 186,000 miles per second or one mile in 5.4 microseconds, there is time between the pulses for the wave to travel about 240 miles there and back to an object on the ground. Actually it is not possible to receive echoes, from objects other than large ones more than about 50 miles distant from the aircraft.

The plan position indicator

16. Since the plan view of the terrain beneath the aircraft is reproduced on the screen, this is called the plan position indicator. Let us now consider in greater detail, how the picture is built up on this plan position indicator or P.P.I. tube. We have said that the radiation beam scans the terrain, and that the rotating time base on the C.R.T. screen rotates at the same rate. Now the radiation beam consists of a series of pulses and the important point to grasp is that the moment of sending out each pulse is synchronized with the moment of starting off the radial time base from the centre. When the echo returns therefore, it brightens the trace at a distance from the centre of the tube corresponding to the slant range of the target.

17. Let us now analyse the echoes we shall receive from three different targets say at B, P and Q in fig.1(b). We find that at the point B immediately below the aircraft, the pulse has to travel to the ground and back to the aircraft, and its time of travel depends on the height of the aircraft. The echo therefore appears along the time base at a distance from the centre of the screen (which is, of course, at the beginning of the time base) corresponding to the height h of the aircraft.

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* The time base may be described as a line formed by a spot, visible or invisible, which moves at a uniform speed from the centre to the circumference of the screen. If visible for the whole distance, it will appear as a bright line like the spoke of a wheel.

Since the beam is rotating about the vertical axis AB, it follows that the point B always lies within the beam, and therefore the return will appear on every time base no matter in what direction the beam is sent. What appears on the tube is, therefore, a bright ring known as the "height ring" shown at (b) in fig.1(c). In the case of a target at P, the echo will brighten all the time bases sent out while point P remains in the beam as it rotates.

18. The beam rotates at the rate of approximately 1 rev. per second, and since it is approximately 6 deg. wide, it "illuminates" a point target for $\frac{6}{360} = \frac{1}{60}$ sec. in each revolution. Pulses are sent at the rate of 660 per second so that 11 pulses strike the target and return echoes which illuminate 11 time bases in succession, these form a small arc as shown at (p) in fig.1(c).

19. To facilitate the taking of bearings a Perspex scale which is fitted in front of the screen is used. This scale has lines engraved on it as shown in fig.52. It can be rotated so as to cover any desired echo, and the true bearing (given by the centre of the arc) can be read off the scale at the bottom of the screen. In the system described above, no returns can be produced from targets at ranges less than the height of the aircraft, other than from other aircraft or balloons; there is therefore an area in the centre of the screen with no picture on it.

20. The effect of the production of this "hole" is to distort the map. It may be operationally desirable to close up this hole and a method by which we can do this is to advance the firing of the transmitter so that the first return gets back at the moment that the spot forming the scan passes the centre of the tube. This means that the height ring has to be shrunk to a spot. The way in which it is electrically possible to shift the firing of the transmitter to produce this effect is dealt with later.

21. Another form of distortion is introduced into our maps because the radii measured on the screen to the arcs p and q in fig.1c will be proportional to the slant distances AP and AQ in fig.1a. On the 30 mile and 50 mile ranges this will not matter much as the slant ranges will not be very different from the ground ranges For bombing however when the 10 mile range is being used something more accurate is required and this is dealt with in paras. 26 et seq below.

The height tube

22. There is in addition to the plan position indicator a second cathode ray tube in the indicator unit known as the height tube. This tube has a fixed time base which is permanently illuminated, and echoes which appear on it take the form of sideways deflections or blips. The appearance of echoes on this tube, is very similar to that produced in the Mark II ASV. At the lower end of the trace there is an interval over which no echoes are produced, then follows the nearest return which comes from the ground immediately below the aircraft. Other echoes from objects further away from the aircraft appear at points higher up the scan. The first return to appear gives an indication of the actual height of the aircraft above the ground. For this reason, the tube is called the height tube.

HEIGHT AND MARKER RANGES

23. To obtain a direct measurement of height, it is arranged that another blip can be produced artifically, and its position can be adjusted by means of a manual control, to which is attached a height dial directly calibrated in feet of height. The control is turned until this blip disappears into the first ground return, and the height of the aircraft can then be read directly from the dial of the control.

24. In addition to this artificial marker blip, there is another marker which gives ground range. This marker appears on both tubes. On the P.P.I. it is produced as a bright ring, and on the height tube it appears as a second blip. Its position is adjusted by another control, known as the range marker control, which controls the radius of the ring on the P.P.I. tube, and the position of the blip along the time base on the height tube in the same way as the height marker is controlled. The control is adjusted so as to make the ring produced on the tube pass through the target spot. The range of the latter can then be read off from the scale on the control.

25. What is actually being read here is the slant range to the target. In cases where the height of the aircraft is low and the target is at a considerable distance, the slant range is actually very nearly equal to the range of the target measured along the ground from a point immediately below the aircraft. Referring back to fig.1, the range of an object say at D, will be measured as AD, whereas the actual distance the target is away will be BD. At targets closer to the aircraft, it is necessary to apply a correction to allow for the difference between ground distance and slant range. These corrections are worked out for a variety of heights and ranges and projected as a series of curved graphs on to a drum operated by the range marker knob. This forms a sort of ready reckoner enabling the operator to read the true range directly.

26. In the case of bombing, the range is less than 10 miles and slant range is no longer a sufficiently accurate approximation for ground range.

27. From Figure 2c it is clear that knowing the height AB of the aircraft and the slant range AC of the target, the ground range BC of the target could be calculated.

28. Ground range is not found in this manner, since for small values of BC, AC remains fairly constant and the method would not give a sufficiently accurate value of BC. The difficulty is overcome by altering the circuits of the equipment so that height AB and slant range minus height (that is, DC) are measured. It can be seen from the figure that DC decreases rapidly as C approaches B. Its measurement thus makes possible a very accurate calculation of BC even when BC is small. The method of setting the measuring controls is the same as for the longer ranges.

29. To avoid a delay in the calculation of the ground range from the height and slant range minus height, an automatic calculator is supplied. This provides a graphical result which can be read directly off a drum (See Fig.2d).

30. Graphs of a number of constant ground range curves are plotted on the cylindrical surface of the drum so that height appears along one axis and slant range minus height along the other. The pointer is moved vertically over the graph by the height control and the drum rotated beneath it by the range control; readings of the ground range are taken from the drum using the tip of the pointer as index.

31. The drum can be regarded as a whole series of dials, corresponding to all possible heights, joined together, with the pointer indicating which dial to use (See Fig.2d).

32. The accuracy in estimating ground range should be ± 200 yards on the 10 mile range and ± 2 per cent on the 30 mile or 100 mile range for an aircraft flying at 10,000 feet.

GENERAL DESCRIPTION

THE EQUIPMENT

33. Brief summary.- The equipment required comprises the units shown in fig.5. On the transmitting side, we start with a power supply produced from an engine driven generator regulated by the control panel. This is fed to modulator, type 64, in which 3.3 kV pulses of 1 microsecond duration are produced. These pulses are fed to the transmitter receiver unit, type T.R.3191 where they are converted to pulses of R.F. energy and supplied through a concentric line to the rotating scanner unit.

34. On the receiving side there is a receiver and indicator unit, in addition to the receiving section in the T.R.3191. The same aerial system is used for both reception and transmission.

35. As well as the units employed for transmitting and receiving, it is necessary to have some means of timing the whole equipment, and a waveform generator which acts as a sort of master clock is employed to synchronise the sending out of the pulses from the transmitter and the starting of the time base traces in the indicator.

36. The power required by these units is also obtained from the engine-driven generator controlled by control panel, type 5 or type 6 mentioned above, the conversion to the various voltages required being accomplished from the power unit, type 280.

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35. As well as the units employed for transmitting and receiving, it is necessary to have some means of timing the whole equipment, and a waveform generator which acts as a sort of master clock is employed to synchronise the sending out of the pulses from the transmitter and the starting of the time base traces in the indicator.

36. The power required by these units is also obtained from the engine-driven generator controlled by control panel, type 5 or type 6 mentioned above, the conversion to the various voltages required being accomplished from the power unit, type 280.

37. It is necessary to control the order of switching on the various supplies and to safeguard against the possibility of faults introducing a dangerously high load at any point. A system of safety circuits is included in the power unit.

38. To combine the D.R. compass position with the indicated map position, the heading control unit, type 218, is used.

39. These units, together with the junction box, type 83, complete the list of separate items of the equipment. The whole are interconnected by cables as shown in fig.5.

LIST OF UNITS

40. The ARI.5153 equipment comprises the following units:-

Unit	Ref.No.	Dimensions			Weights	
		Width	Length	Dept.	lbs	ozs
Power Unit Type 224 or	10KB/512	11.5"	18"	12"	30	0
Power Unit Type 280	10KB/747	11.5"	18"	12"	30	0
Switch Unit Type 207	10FB/6006	12"	6"	8"	14	0
Waveform Generator Type 27 or	10VB/6005	11.5"	10"	8"	15	0
Waveform Generator Type 26	10VB/6004	11.5"	10"	8"	15	0
Modulator Type 64	10DB/956	8.5"	21"	12"	47	0
Transmitter-Receiver Type TR3159 or	10DB/867	9.5"	15.75"	7"	42	0
Transmitter-Receiver Type TR3191	10DB/1003	9.5"	15.75"	7"	42	0
Receiver Type R3516 or	10DB/6061	11.5"	18"	8"	30	0
Receiver Type R3515	10DB/6060	11.5"	18"	8"	30	0
Indicating Unit Type 163 or	10QB/6011	8.5"	18"	12"	44	0
Indicating Unit Type 162	10QB/6010	8.5"	18"	12"	44	0
Control Unit Type 218	10LB/264	6.5"	3.5"	6"	2	8

41. The following equipment is part of the ARI.5153 installation but is usually permanently installed in the aircraft.

Unit	Ref.No.	Remarks
Junction Box Type 83 or	10AB/2212	Essential for aircraft fitted with TR3190 (Lucero Mark I) or TR3160 (Lucero Mark II).
Junction Box Type 206	10AB/6031	May be used for Lucero is not fitted.
Either Generator Type U	5U/349	AC Generator
and Generator Type KX	5U/	DC Generator
or Generator Type UKX	5U/421	AC/DC Generator used in Wellington XII aircraft to replace Generators, Types, U and KX.
Either Control Panel Type 5	5U/363	Used with Generator Type U
or Control Panel Type 6	5U/521	Used with Generator Type UKX
and Choke Box Type I	5U/2277	Used with Generator Type UKX
Scanning Unit Type 3	10AB/1369	For Bomber Command Halifax, Lancaster and Stirling Aircraft.
Aerial System Type 307 or	10BB/6035	Used with Scanning Unit Type 3 in Bomber Command Halifax and Lancaster aircraft.
Aerial System Type 178	10BB/3090	Used with Scanning Unit Type 3 in Bomber Command Stirling aircraft.
Connector Type 1341	10H/3561	Used with Scanning Unit Type 3 in Bomber Command Halifax, Lancaster and Stirling aircraft.
Scanning Unit Type 51	10AB/6022	For Coastal Command Halifax and Wellington XII aircraft.

Unit	Ref.No.	Remarks
Either Tubular Feeder Type 61	10AB/6134	For use with Scanning Unit Type 51
and Connector Type 1704	10H/6361	For use with Scanning Unit Type 51
or Tubular Feeder Type 62	10AB/6149)	Final models replacing Tubular
and Connector Type 1716	10H/6388)	Feeder Type 61 and Connector Type 1704.
Connector Type 1513	10H/3892	H.P. Connector for Bomber Command Halifax and Stirling aircraft and Coastal Command Halifax and Wellington XII aircraft.
Connector Type 1691	10H/6260	H.P. Connector for Bomber Command Lancaster aircraft.
Connector Set Type ARI. 5153/AU.	10H/6184	For Bomber Command Lancaster aircraft.
Connector Set Type ARI. 5153/AG.	10H/6185	For Bomber Command Stirling aircraft.
Connector Set Type ARI. 5153/AE. .	10H/6186	For Bomber Command Halifax aircraft.
Connector Set Type ARI. 5153/DL.	10H/6059	For Coastal Command Wellington XII aircraft.
Connector Set Type ARI. 5153/AE/2	10H/6360	For Coastal Command Halifax aircraft.

42. The following equipment is auxiliary to the main ARI.5153 equipment.

Transmitter-Receiver Type R3090	10DB/444	Mark III IFF Set.
Transmitter-Receiver Type TR3190	10DB/1002	Lucero Mark I
or Transmitter-Receiver Type TR3160	10DB/868	Lucero Mark II
Aerials Aircraft Type 301	10BB/6003	Aerials for Lucero Mark I

FUNCTIONS OF UNITS

43. Considering now in greater detail, the various functions performed by these units. These functions have been indicated in two block schematic diagrams, figs.3 and 4. Fig.3 is a simplified block schematic showing the important items while on fig.4 the complete course of all effects can be traced. In both fig.4 the power supplies have been omitted to reduce complexity. It will be seen that on the diagram the lines showing the passage of "effects" from one unit to another are marked with arrows showing the direction of the "effect".

44. To understand the sequence of operation, it will probably beeasiest to start with the master timing circuit or multivibrator, situated in the waveform generator. This produces a square wave and the zero on the time scales of the waveform diagrams are fixed by the negative-going edge of the multivibrator square wave.

45. Transmission and reception.- Let us first consider the production of the signal and its reception and subsequent wanderings. The negative going square of the multivibrator first controls a sawtooth generator situated in the waveform generator box. The sawtooth waveform is made available as both positive-going and negative-going slope reckoned again from the same time zero. At a given point on the slope, regulated by the transmitter timer, a timing pip, is sent through the the blue lead to the modulator. This locks the multivibrator in the modulator and ensures the exact timing of the modulator output. The multivibrator produces a 20 microsecond pulse which can probably best be described as a priming pulse. The end of the priming pulse times the firing of the high voltage pulse which is the actual modulator output.

46. The modulator output is stepped up by a pulse transformer and is converted to R.F. in the transmitter, from which it is fed through a concentric line to the scanner and radiated.

47. A portion of it is reflected back along practically the same path to re-enter the H2S system as the received pulse. During the time that the radio pulse is going to the target and back, the scanner which is rotating at the comparatively

low rate of 1 rev. per second has not moved appreciably, so that the scanner mirror is in the correct position for receiving. It is received on the same aerial and a soft rhumbatron electronic switch is used to change over the system from transmission to reception. The detailed manner in which this operates is given in para. 201. The received signal passes the soft rhumbatron and enters the crystal mixer chamber where it is mixed with the output of a local oscillator to produce an intermediate frequency signal. It is not amplified at signal frequencies because up to the present no method has been found of amplifying at this frequency.

48. The mixer, T.R. switch, and first stage of I.F. are all housed in the T.R.3191 unit. On leaving this, the signal passes along the green lead to the receiver where it is further amplified at I.F. then detected and passed on as a uni-directional pulse to a stage known as the receiver putput stage also situated in the receiver box (R.3515). Here it is mixed with two other pulses whose functions will be described later. The output from the receiver output stage leaves the receiver box via the grey Pye plug and goes back to the waveform generator box where it is mixed with another waveform known as the bright-up waveform. It leaves the waveform generator box and enters the indicator box through a black lead.

P.P.I. DISPLAY

49. After passing through a somewhat unusually arranged amplifying stage, it is applied to the grid or modulating electrode of the P.P.I. tube, where it brightens one or more of the radial scans at certain points along their lengths, and so forms the picture.

50. The generation of the radial time base on the P.P.I. and its synchronisation with the movement of the scanner is accomplished by inter-connection of a magslip attached to the scanner with the time base amplifier supplying the deflection plates of the P.P.I. tube. Details of this action are given in para. 161.

51. We mentioned above that the receiver output was mixed in the receiver output stage with two other pulses. These pulses are the course marker and range marker pulses. The course marker pulse is derived from contacts closed by a cam geared to the scanner mechanism. Closure of these contacts initiates a waveform which brightens at least one radial time base. The detail of this action is described in para.

52. The range marker is timed from the end of the priming pulse except when the equipment is set on the 10/10 mile range. Thus the application of the signal together with these pulses and the bright-up pulse to the grid of the P.P.I. tube, will produce a picture showing the course marker as a bright radial line, the range marker as a bright circular ring and the picture of the terrain beneath the aircraft as a pattern of bright spots.

HEIGHT TUBE DISPLAY

53. The sawtooth generator in the waveform generator unit also provides the necessary deflecting voltages of the height tube scan. Displayed on the height tube scan as sideways deflections or blips are also -

(i) the signal (to right)

(ii) the height marker (to left)

(iii) the range marker (to right)

54. The signal and range marker come in together from the branch output of the signal, range marker and course marker mixer stage. The height marker scan is timed from the modulator multivibrator because what the height marker in effect does, is to measure the time interval between the transmitter pulse and the first ground echo to get back to the scanner. This of course comes from the nearest point on the ground, which is the point immediately below the aircraft.

55. We have already stated in para. 16 above, that the timing of the radial scan on the P.P.I. tube is governed by the instant of sending out the transmitter pulse in the case of the 30 and 50 mile ranges. We therefore also time the range marker chain of stages from the priming pulse generator, as we do the height marker stages.

56. On the 10 mile range when we want to record the slant range less height or increment, we change over the timing of the range marker generating circuits from

the priming pulse to the height marker pulse. This changeover is shown on the block schematic diagram as a 2-way, single pole changeover switch.

SUPPRESSION

57. During the period of the transmitter pulse, it is necessary to render the receiver insensitive. To do this the priming pulse is taken from the modulator through the violet Pye plug to the receiver to be applied after suitable amplifying to the screen grids of the valves V_1 and V_3 in the receiver. It is applied to these screen grids as a negative pulse, and lowers their voltages sufficiently to render the receiver insensitive.

COURSE MARKER

58. This is required to show on the screen the line of flight or course, and is operated by a cam on the magslip rotor closing a pair of contacts when the scanner mirror is facing dead ahead. This is possible because the magslip is geared directly to the scanner driving shaft through a 1:1 gear. The leads from the course marker contacts on the scanner are taken through a 6-way cable to the waveform generator and from this unit through pins 10 and 12, of the plain W-plug, W.202, to the receiver unit. The closing of the scanner contact whilst it controls the brightening up of at least one of the radial scans, does not itself apply the brightening voltage to the grid of the P.P.I. tube. The sequence of operations is given in para. 239.

59. This completes our general survey of the functions of the various units of A.R.I.5153.

ANCILLARY EQUIPMENT

60. Mention must now be made of an important piece of subsidiary equipment which comes under the title of Lucero. This piece of apparatus enables aircraft fitted with H2S equipment to take advantage of certain ground and airborne installations operating on much longer wavelengths.

61. These are homing beacons, beam approach beacons and Mk.III I.F.F. sets fitted in friendly aircraft. Homing beacons are described in S.D.0245, Chapters 6, 10 and 11; Mk.III I.F.F. is described in S.D.0250, Chapters 1, 3 and 4.

62. There are two types of Lucero, Lucero Mk.I and Lucero Mk.II, the difference between them being that Lucero Mk.I operates on 176 and 173.5 megacycles, whilst Lucero Mk.II is made capable of receiving and transmitting on a number of channels in the range between 214 and 234 Mc/s. These channels are used by Eureka beacons described in S.D.0338, Chapters 1, 4 and 5. The Lucero equipment may be thought of as a kind of convertor.

63. To use the facilities provided by ground beacons, it is necessary for the aircraft to send out a series of pulses which are picked up by the ground beacon and returned by it. The beacon returns are coded so that one beacon may be distinguished from another. Details of these codes are circulated by the Commands. The function of the Lucero equipment is to generate the necessary signals and receive the coded returns. The receiving side of Lucero however only incorporates R.F. and mixer stages and one I.F. stage. Further amplification at I.F. is performed in the main I.F. receiver of the H2S equipment, and the subsequent display is presented on the height tube of the H2S indicator unit. The output of the Lucero unit TR.3190 which appears on the brown Pye plug on the unit is therefore taken straight to the receiver R.3515 input.

64. The Lucero unit itself is a fairly complicated piece of equipment and is described in a separate document S.D.0292A. The following is a brief description of how the Lucero equipment works in conjunction with H2S equipment. The Lucero equipment is timed from the H2S equipment, the timing pulse being obtained from the modulator. This pulse, which is the 20 microsecond priming pulse arrives via the violet lead from the modulator and is applied to the circuit in Lucero which divides by 3 or "counts down", so that only every third pulse is used.

65. Beacon returns.- The Lucero equipment employs two aerials one on either side of the aircraft, and owing to the difference in the strength of signals induced in these according to the direction from which they are coming, it is

possible to estimate the direction of the beacon with reference to the course of the aircraft. The display used is similar to that employed in previous marks of A.S.V. and A.I. and is as follows: The interrogating signal is sent out alternately from an aerial on the port side of the aircraft, and an aerial on the starboard side. This is done by using a motor-driven switch to switch the transmitter output alternately to each aerial; common T and R is used so that the returning echoes are received on the same aerials. Each aerial remains connected for about 0.025 second, thus allowing for about four or five pulses at the "counted down" repetition frequency of 220 or so per second. If the beacon is situated on the port side, the stronger return comes in on the port aerial than on the starboard aerial, and vice versa. To compare the strength of the returns of the two aerials, they are displayed on either side of the time base of the height tube. This is done by switching the output in synchronism with the aerial switch by operating a second pair of contacts on the switch motor. Thus, when the port aerial is connected, the receiver output deflects the trace to the left, whilst when the starboard aerial is connected, the deflection is to the right.

66. To arrange this, the receiver output appearing at the grey Pye plug on the receiver goes first to the waveform generator grey plug, thence through C_{540} in the waveform generator and the red Pye plug back to the Lucero unit for "splitting", and out of this unit through the yellow and orange output plugs to the indicator.

67. Beam approach.- When Lucero is used for beam approach (or BABS) a different technique is employed. Full details of the functioning of beam approach beacons is given in S.D.0245, Chapter 9. Briefly the system can be described as follows. The beam approach installation employs a system of Yagi aerials which are fitted on a rigid framework which is either fixed in the ground or attached to a vehicle. Three aerials are employed; one for receiving the aircraft signals and two for re-transmitting them. The two transmitting aerials have their lines-of-shoot inclined at an angle of about 25 deg. to the direction of the receiving aerial. Polar diagrams thus appear as shown in fig. 6. The receiving aerial picks up the Lucero signal, which after amplification, is used to trigger off the transmitter which energises the two inclined aerials alternately. It is arranged that the duration of the returns in the two transmitting aerials are of different lengths of time, viz. 0.2 and 1.2 secs. For this reason the transmitting aerials are known as the dot and dash aerials respectively. Thus an aircraft flying in the zone supplied by the dot aerial will receive a series of signals of 0.2 sec. duration with intervals between them of 1.2 seconds. If it is in the dash zone, it will receive signals of 1.2 seconds duration broken by intervals of 0.2 second.

68. These signals may appear on either side or both sides of the time base but this has no significance. D/F in beam approach is done entirely from the ground.

69. In actual practice, it will not be possible to fly exclusively in either the dot or dash zone, and normally a signal will be received consisting partly of dot signals of certain strength separated by intervals of dash signals either stronger or weaker. The signals seen will thus appear to move in and out in amplitude. A long period out and a short period in, indicates that the aircraft is in the zone where dash signals are stronger than dot signals; whilst a short period out and a long period in shows the aircraft to be in the dot zone. Typical ratios of amplitude of signals obtained where the aircraft is in different positions is shown in fig. 6.

70. To understand how the dot and dash zones enable the navigator of an aircraft to locate the aerodrome runway, it is necessary to examine closely what the polar diagrams really mean. To do this fig. 7 has been prepared. On this diagram there appear a number of polar curves which give the loci of points at which a signal of a certain given strength will be received from one of the transmitting aerials. The curves are theoretical but are closely related in shape to the actual curves. Arbitrary figures have been marked on the curves which may be taken as a measure of field strength at all points on the curve. Thus at all points on the curve marked 10 the field strength will be 10 units.

71. When we have drawn two families of polar diagrams, one for each transmitting aerial, we see that the points of intersection of each pair of curves in which the same strength signal is obtained from both aerials, all lie on a straight line. This line is known as the equi-signal path, sometimes abbreviated to E.S.P.

Thus, when the signals from the dot and dash aerials give responses of exactly equal amplitude, the aircraft must be at some point along the equi-signal path.

72. The beam approach aerials are so placed that this equi-signal path coincides with the centre line of the airfield runway. If the aircraft is flying towards the beam approach beacon along the line of the runway, the signals will move down the time base towards the zero end, as the range will be decreasing. This is the normal method of approach. In order that the pilot may know when he is over the approach end of the runway, which is the opposite end to that at which the beacon is situated, he must know roughly what is the length of the runway. He therefore uses his W/T set to communicate with the airfield, making a request to use BABS and asking for the runway length to be signalled to him. It is probable that certain delays will be introduced in beacon circuits to enable a standard approach range to be given for all runways to avoid the necessity for these enquiries having to be made.

73. In actual practice things are not quite so straightforward as the above explanation might lead one to expect, because the aerials produce side lobes in addition to the main lobe.

74. The Lucero equipment is brought into operation by means of a relay energised by the 24-volt D.C. supply. The supply to the relay comes via pins 8 and 9 of the 12-way connector to Lucero, and is controlled by switch S_{151} on the switch unit. The actual circuits may be followed on the wiring diagram fig.8.

SWITCHING AND POWER SUPPLIES

75. Power for the whole equipment is supplied from the power unit, type 280. This provides supplies at 80 volts A.C. plus 24 volts, D.C. plus 300 volts, D.C. plus 1,800 volts, D.C. minus 1,800 volts, D.C. minus 1,000 volts D.C. and minus 100 volts, D.C. The input to the power unit is obtained from the control panel, type 5, or type 6, which controls the engine-driven generator. The aircraft 24-volt D.C. supply is also fed into the power unit. These connections may be seen on the diagram, fig. 8. The unit contains a number of relays which are used to ensure that the H.T. supplies cannot be switched on before the equipment has had time to warm up. There is also a protective circuit which protects the supply in the event of certain faults developing. The transmitter H.T. supply is obtained from the modulator, type 64, and is the only supply which is not directly provided from the power unit.

CONTROLS

76. These may be divided into two sections -

(i) Those available to the navigator for use during flight.

(ii) Those which can be preset on the bench.

The ones used by the navigator are grouped together in the indicating unit and in the switch unit, and these units are placed close together. This is done to enable the navigator to observe the display tubes whilst operating the controls.

77. The main power supply to the equipment is switched on by the main switch on the control panel or on the navigator's table. Where two or more equipments are used from the same control panel a pair of ganged switches is used for each installation to control (i) the D.C. supply to the control panel and (ii) the A.C. supply to the installation.

78. A separate pair of switches is used for each installation but the D.C. sides of all the switches are connected in parallel so that the alternator field is excited whichever installation is switched on. It remains excited until all installations are switched off. These switches are mounted on a board fixed to some convenient part of the airframe. The leads to the switches must be screened and the screening braidings must be bonded together and earthed. The order of switching on is given in para.79 below under OPERATING INSTRUCTIONS. To safeguard the equipment from damage owing to incorrect operation, or due to short circuits or other faults developing in any part of the equipment, an elaborate system of relays has been evolved. This is dealt with in paras. 136 et seq.

OPERATING INSTRUCTIONS

SWITCHING ON

79. When switching on the equipment, the controls should be operated in the following order -

(i) Switch on the main master switch

(ii) Press the LT ON button; the green lamp should light.

(iii) After approximately 30 seconds, press the HT ON button.

The amber lamp should light.

If it does not light sufficient time has not elapsed and the HT ON button should be pressed again some seconds later. 45 seconds after the HT ON button has been pressed the red lamp will light, and the transmitter will then automatically switch on.

(iv) Set the scanner motor switch to the OFF position ready for tuning the system.

SWITCHING OFF

80. Switch off at the main A.R.I.5153 master switch.

SETTING UP BY THE OPERATOR

81. The position of controls can be seen on figs. 15 and 52.

(i) Set the range switch to position 1 and adjust the height tube BRILLIANCE.

(ii) Set the noise level (grass) to about one-third of full output by means of the gain knob.

(iii) Adjust the crystal current control to give a meter reading of 0.25 - 0.3 mA, and turn the tuning knob on the indicator unit until the signals are at a maximum. This should be tuned two or three times in the first 15 minutes and subsequently about every 30 minutes during flight.

(iv) Set the range switch to position 3.

(v) To set BRIGHTNESS, GAIN and CONTRAST controls (Bomber Command).

(a) Switch on the scanner motor and set gain and contrast controls fully anti-clockwise.

(b) Turn brightness control until a full diameter trace is just visible. Then turn it about three clicks anti-clockwise.

(c) Turn up the gain to required level (max. for long range use).

(d) Turn the contrast control clockwise until the grass is just visible as a speckling of the tube (with the scanner revolving).

(e) As the target is approached reduce gain. Contrast may be turned up slightly if desired.

(vi) Adjust the orientation of the P.P.I. map as follows:

(a) In Coastal Command aircraft, where no D.R. compass is available, set the map so that the upward direction on the tube face is the heading of the aircraft. This is effected by setting the track line from the perspex screen to zero, setting the switch on the control unit to manual, and turning the setting knob until the course marker lies under the track line.

(b) In Bomber Command aircraft, set the map so that the upward direction is true north. The procedure is the same except that the track line is set to the bearing on which the aircraft is flying, as given by D.R. compass. The switch on the control unit is finally returned to auto.

Reference should be made to A.P.1234 for information on navigation of aircraft, and corrections which have to be made for variation and deviation of compass bearings.

USE AS A HOMING DEVICE (BOMBER COMMAND)

Straight and level

82. (i) Set the range switch to position 3. A signal at approximately 30 miles will appear as a single thin arc. Odd echoes due to isolated buildings may appear momentarily but these should be ignored. Only signals which persist say for 30 seconds should be relied on. This rule, is, of course, not infallible.

(ii) Determine the range of the required signal by setting the marker ring on the signal and reading off the range on the 30 mile scale.

(iii) Turn the perspex screen in front of the P.P.I. until the double arrow track line lies across the signal.

(iv) Read off the bearing at the bottom of the scale. This gives the track to make good to the target. In the absence of drift this is the course to give to the pilot. If the course set is correct, the target should move in to the centre of the P.P.I. along the track line.

(v) Set the marker ring so that it lies just inside the required signal. This helps identification of the required signals should the operator's attention be distracted.

(vi) When the signal is approximately one-third way from the centre, put the range switch to position 2. The signal will move out to the edge of the P.P.I. but, as the marker will also move, it can be picked up again.

(vii) (a) As soon as the picture has settled down and the signal is identified, switch to position 1, and reset the marker.

(b) If required, the range is read off on the 10 mile scale by use of the pointer ganged to the height control.

(c) On this range, it should be possible to determine whether the target is a town or, for example, an airfield. At extreme ranges all types of targets will give a single return as only the front edge of a town can be seen. However, as the range decreases, more of the town will be seen and the echo will increase in depth. The rough shape of the town can be made out on this range and, if necessary, a course correction made to take the aircraft over any desired area of it.

(viii) When the target is about half way out from the centre, set the pointer to the release line corresponding to the ground speed by moving the marker knob. It is preferable to set the pointer to the "30 sec." (dotted line) as the marker ring will appear too close to the "height ring" when the other lines are used.

(ix) 30 seconds after the required area of the target crosses the marker ring release the bombs.

Drift

83. If there is a side wind, the correction must be made for drift. The following procedure should be adopted after sub-para. (iv) of para.82 above.

(i) If the wind is known, calculate the required course. A rough estimate of the drift is normally sufficient and the corrected course should be given to the pilot. If the estimate was correct, the signal will move in along the track line.

(ii) If the signal drifts off to one side of the track line, the estimated course was wrong. Give a course to bring the signal back on to the track line. When the signal is again on the track line, give the pilot a new course, corrected from the original one. Repeat this procedure until the signal does not deviate from the track line.

(iii) Follow the procedure of sub-paras (vi) to (ix) of para. 82 above.

Evasive action

84. The drill outlined above of keeping the marker ring just inside the signal may seem unnecessary while flying straight and level, but will be found very helpful if evasive action is being taken. If the aircraft has to turn off course, the course marker will move round but the signal will not move, as the picture always has true north at the top. (This does not apply in Coastal Command aircraft when the display is not locked to the DR compass). Should the signal disappear completely when violent evasive action is being taken, it will reappear on levelling out at the intersection of the track line and the marker ring. There may of course be a slight movement of the signal owing to the change in position of the aircraft relative to the ground.

85. As the course marker always shows the course, the turn necessary to bring the aircraft back to the correct course is seen at once.

86. It will be noted that if the nose of the aircraft is down, a bright area will appear ahead, if up, astern. In a bank the bright area appears to one side.

USE AS A NAVIGATION AID (BOMBER COMMAND)

87. The equipment can be used as a fairly accurate method of determining track and ground speed.

(i) Choose a steady echo with the range switch in either position 1 or position 3 and note its range and bearing. Take the time.

(ii) Plot the position on the calculator.

(iii) Repeat the above at intervals of 3 minutes.

(iv) From the calculator determine the distance travelled and, knowing the time, calculate the ground speed.

(v) To determine the track, line up the plotted points with the vertical lines on the calculator

The use of the beam approach and beacon facilities provided by Lucero are described in some detail in S.D.0245, Chaps. 6, 9 and 11, and in A.P.1751 and its supplement.

USE FOR TARGET LOCATION OVER SEA (COASTAL COMMAND)

88. Summary of operation.- Controls set on the ground, which may be re-set by operator if equipment is faulty.

(i) Mixer current adjustment on Indicator, set to give maximum stability.

(ii) Mixer coupling adjustment on Indicator, set to give 0.5 mA current. (This may be between 0.2 and 0.6 mA. before the equipment is considered faulty, however).

(iii) PPI Focus on Indicator, set to focus noise scintillations and trace.

(iv) PPI Brightness on Indicator, set with minimum gain, but contrast set to give brightest Markers, so that Markers are clearly visible but not defocussed.

(v) PPI Contrast, on Indicator, set so that with gain set to give half maximum noise on height tube and brightness set as at (4), noise scintillations are clearly visible on PPI, but not blurred.

(vi) Height Tube Brightness on Indicator, set for clear picture.

(vii) Line of flight setting on H.C.U. set so that marker lies vertical on PPI

89. Controls used by operator during operations.

(i) Gain control, on Switch Unit, varied continuously during search between level to give bright noise scintillations on PPI and level at which sea returns extend only to 1 - 2 miles, and kept as low as possible once a contact is obtained.

(ii) 10-mile zero Control on Switch Unit, used to keep a contact as near the edge of the PPI as possible on the 10 m. range.

(iii) Tuning Control on Indicator, checked every ½ hour or so and set to give greatest sea return or echo box response.

(iv) Switches on Switch Unit, used as required. In general, the 30 m. range is used for searching, except for convoys and coast line, for which the 50 m. range is better; while the 10 m. is used for homing.

BENCH SETTING UP PROCEDURE

APPARATUS REQUIRED

90. (a) A complete set of units comprising the ARI.5153 installations as listed in para. 40 et seq. The scanner should be mounted on a tripod and otherwise made suitable for bench working.

(b) The following items of test gear:-

(1) Signal Generator Type 47 (A.M.Ref.10SB/143) together with its associated equipment, comprising Aerial System and Mounting, Adaptor and Connectors. This is an R.F. Signal Generator.
(2) Signal Generator Type 52 (A.M.Ref.10SB/165) together with its appropriate connectors. This is an IF Signal Generator.
(3) Modulator Unit Type 67 (A.M.Ref.10DB/1032) together with its appropriate connectors. This unit is used with Signal Generator Type 52.
(4) Monitor Type 28 (A.M.Ref.10T/500) together with its appropriate connectors.
(5) Test Set Type 202 (A.M.Ref.10SB/6002) - a crystal controlled calibrator for use with Monitor Type 28.
(6) Test Set Type 85 (A.M.Ref.10SB/145) - a field strength meter comprising thermocouple, meter and lead.
(7) Testmeter Type D (A.M.Ref.10S/10610)
(8) Testmeter Type H (A.M.Ref.10S/46)
(9) Detector Unit Type 3 (A.M.Ref.10SB/179), used to check local oscillator output.
(10) Insulation Resistance Tester Type A (A.M.Ref.5G/1621) - Megger
(11) Electrostatic Voltmeter (A.M.Ref.10A/12248) - 0-3.5kV.
(12) Thermocouple Voltmeter (A.M.Ref.42Y/200) - 0-100V.
(13) Milliammeter (A.M.Ref.10A/7207) 0-2ma., fitted with one telephone jack plug (A.M.Ref.10H/488)
(14) Transformer Unit Type 74 (A.M.Ref.10KB/1040) - 80-230V transformer.
(15) Resistance Unit Type 228 (A.M.Ref.10C/11984) - Dummy load to replace the T^2R
(16) Resistance Unit Type 230 (A.M.Ref.10C/10986) - Dummy load to replace the CV64
(17) Resistance Unit Type 231 (A.M.Ref.10C/11987) - Dummy load to replace the whole equipment in lining up the Control Panel.
(18) Petrol Electric Set with trolley (A.M.Ref.42Y/800)
(19) Testers, Generator, Bench Type (A.M.Ref.5G/2029), comprising AC and DC Generators for appropriate aircraft and Control Panel Type 5 or 6 for regulating AC output.
(20) Connector Set Type ARI.5153 (A.M.Ref.10H/6004) Bench Test Connectors.

NOTE:- Information on the final setting up of ARI.5153 controls for Coastal Command is given in Para. 127.

LIST OF PRINCIPAL CONTROLS

91. Switch Unit Type 207

3 'ON-OFF' press buttons:- 'L.T. OFF', 'L.T. ON', 'H.T. ON'
Lucero Control Switch
Range and Marker Switch
Scanner Motor Switch
Line of Flight Marker Switch
Gain Control
10-mile Zero Control
30-mile Zero Preset
Range Marker Control
Height Marker Control
Height Zero Preset
Range Zero Preset
PPI Radial Adjustment (preset)
Dimmer Switch

92. Indicating Unit Type 162

PPI Brightness Control
PPI Vertical Shift (preset)
PPI Horizontal Shift (preset)
PPI Focus Control
PPI Contrast Control
Height Tube Brightness Control
Height Tube Vertical Shift (preset)
Height Tube Focus (preset)
Main Tuning Control
Mixer Current Control
Mixer Coupling Adjustment
Local Oscillator Coarse Frequency Control (inside the unit)

93. Waveform Generator Type 26

PPI Radial Adjustment Preset

94. Receiver Type R3515

Suppression Delay Preset

95. Transmitter-Receiver Type TR.3191

CV43 (Soft Rhumbatron) Tuning Control
Coarse Tuning Control of the CV43 (internal)
Matching Stub for Aerial System (internal)
Mixer Coupling Adjustment (internal)

96. Control Unit Type 218

'Manual-Auto' Control
Line of Flight Setting Control

97. Modulator Type 64

'On-Off' Switch
Recurrence frequency adjustment (internal)

TEST POINTS EXTERNAL TO THE UNITS

98. Power Unit Type 280

Main H.T. jacks +1800V and -1800V D.C.
Grid Bias jack -100V D.C.
300V H.T. jack
300V Feed jack

99. Modulator Type 64

Current Test Pye Plug
Voltage Test Pye Plug

100. Transmitter-Receiver Type TR.3191

Mixer Test jack

101. Indicating Unit Type 162

Mixer Current Meter

SWITCHING-ON AND PRELIMINARY TEST

102. (i) Connect up the units as shown in fig.49, using the special set of bench connectors and disposing the longer leads behind the units to leave the front panels as clear as possible..

NOTE:-

(a) Confusion of lead number 29 (12-way, violet) with lead number 28 (12-way, blue) will damage the T2R and Indicator Units.

(b) Confusion of the 12-way, orange, and 12-way plain plugs on the waveform generator will give normal displays, except that the scan range will remain at 30 miles for all positions of the range and marker switch, and there will be no bright-up on the PPI.

(c) The 18-way lead from the indicator unit to the junction box (number 23) is not interchangeable with any of the other 18-way leads.

(d) Hollows in the H.F. plugs at each end of the high power connector should be filled in by the use of sticky washers.

Power is supplied to the equipment from the workshop power supply, which will normally be obtained from a motor generator set. The power required is 24 V. D.C. at 5 amps., and between 75 and 80 V. A.C. at 1500-2500 cycles per second. The A.C. supply must be regulated for variations in speed and load and a type 5 or a type 6 control panel is used for this purpose, according to the type of the generators available.

(ii) Put the modulator 'ON-OFF' switch in the OFF position and switch on the control panel. Press the L.T. ON button on the switch unit. Check that the green pilot lamp lights and that blower motors start. Watch for any indications of over-heating and sparking.

(iii) The next step is to see that the supply voltages are correct. Owing to the fact that the waveform of the generator output varies widely according to the load connected, it is difficult to lay down a hard and fast rule as to what voltage A.C. should be supplied. Adjustment of supply is therefore made so that the correct rectified voltages are obtained from the power unit, since these voltages are in fact the ones which it is most necessary to keep within specified limits. Accordingly jack points are provided, and all tests can be made by means of a 0-5 mA. which can be plugged in at various points. In the Mark II equipment the shunts are arranged so that a reading of 1 mA. is obtained; except in the case of units having a prefix 'R' to their serial numbers, in which case the 300V. test point gives a reading of 0.3 mA. The limits are ± 10 per cent. If the 300 V. or -100 V readings in the power unit are outside these limits, the regulator in the control panel must be adjusted.

The adjustment of control panels varies according to the type of regulator fitted, and it it is available, A.P.1766 JA should be consulted, as it gives particulars of all the various voltage regulators type E in service up to the time of publication. Relevant information referring to the regulators used with the A.R.I.5153 equipment is given below in case this publication is not available.

When making adjustments first of all determine the type of regulator in the control panel. This is given on a name-plate on the end of the regulator. Adjustment of the carbon pile should always be avoided if possible, as it is unlikely to have varied from the previous setting.

The meter used for measuring should be checked against another if available, as meters do not retain their accuracy indefinitely. To avoid the necessity for adjustments to the core, a number of voltage regulators are now provided with a trimmer resistance, which is located on the base of the regulator between the terminal block and the regulator. This gives a range of ± 6 V. and should normally be sufficient to correct for any normal variations.

Certain voltage regulators known as type EU are fitted with a stabilizing circuit the object of which is to prevent 'hunting'.

The regulators which may be met with are types E1, E3 and EU. They have a 'core' adjustment situated at the front end of the regulator i.e. the end nearest the terminal block, and a compression screw at the rear end.

If a type EU regulator is fitted special care must be taken to ensure that the connections from the field of the alternator to the two-way terminal block on the regulator are correctly connected i.e. alternator positive (white) to red on terminal block and alternator negative (black) to green on terminal block.

The method of adjustment of these types if they have been correctly set up by the makers is as follows:-

Adjust voltage
(a) By means of trimmer if fitted.
(b) If insufficient variation is provided by trimmer adjust core.
(c) If no trimmer is fitted, adjust core.

DO NOT TOUCH COMPRESSION SCREW

If a control panel shows a tendency to 'hunt' it should be replaced by a correctly set up panel. The procedure for setting up a voltage regulator which 'hunts' or will not regulate is given in A.P.1766 JA.

(iv) After the equipment has warmed up press the 'H.T. ON' button and check that the amber lamp lights. Check that the aerial system rotates and that clockwise rotation of the PPI and Height Tube Brightness controls will give a trace on both tubes. Check that 45 secs. after pressing the 'H.T. ON' button the red pilot lamp lights and that a small spark is visible in the CV85 in the Modulator. Measure that D.C. supplies at the +1800V and -1800V test points on the Power Unit by means of the milliammeter. If the readings obtained do not lie within the limits 1 ma. ± 10 per cent (or 1.9 and 2.1 ma. if the units have a prefix 'R' to their serial numbers) adjust the Control Panel until they do.

(v) Measure the forward resistance of the crystal by means of an avometer plugged into the jack socket on the T^{2}R unit. If this exceeds 200 ohms replace the crystal. Check that the mixer current does not exceed 0.5 ma. If it does exceed 0.5 ma. attempt to reduce it by use of the mixer control knob on the Indicator Unit. If this is unsuccessful, loosen the coupling at the Indicator until less than 0.5 ma. is obtained. Watch for signs of over-heating or sparking and for violent jitter on the tubes (due to supply voltage oscillation or insulation failure).

(vi) If there are no signs of distress in the equipment put the switch on the Modulator in the 'ON' position. Check that the main H.T. voltage is still steady and correct, and that brilliant sparking occurs in the CV85. Examine the Transmitter and R.F. system for sparking and, by means of a neon tube, that power is being radiated. (Do NOT leave the Modulator switched on if sparking is taking place or if power is not observed). Tune the local oscillator for local signals using the height tube.

(vii) Check that the Modulator does not go out of synchronisation when the range and marker switch is shifted fairly quickly through the different settings. If this does occur, readjust the 'Recurrence frequency adjustment' which is inside and at the rear of the Modulator chassis. Set this so that the audible note from the spark gap is slightly lower when the synchronising pulse from the Waveform Generator is removed by disconnecting the cable from the blue Pye Plug.

(viii) Check as an overall functional test, that height tube and PPI now show traces, noise, suppression, bright-up, markers and local signals. If this is not so, locate the fault before proceeding with the adjustment of the controls.

(ix) To switch the equipment off, it is preferable to cut the 80 volt work-supply, as this avoids leaving it open circuit.

ADJUSTMENT OF CONTROLS

103. (i) Switch the set on but with the scanner motor and Modulator off. Set the range and marker switch to 10:30.

Adjust the height tube brightness and focus to give a clear trace.

Turn the gain, contrast and suppression preset fully anti-clockwise. Turn the PPI brightness clockwise until the trace is just visible. Adjust the PPI focus.

(ii) Turn PPI brightness control three 'clicks' anti-clockwise. Turn the contrast control clockwise until the brightened-up part of the trace is again just visible. Turn the PPI radial adjustment on the Switch Unit fully anti-clockwise. Switch the scanner motor on, and adjust the PPI shift controls until the trace is rotating about the centre point of the perspex screen.

(iii) Turn the PPI radial adjustment on the Switch Unit fully clockwise. Adjust the PPI radial preset on the Waveform Generator until the dark hole at the centre of the tube is the same size for all positions of the range and marker Switch. Now adjust the preset on the Switch Unit until the hole just disappears.

(iv) Adjust the Gain Control to give about 3/4 maximum noise amplitude. Turn contrast control anti-clockwise until this noise just shows as scintillations on the PPI. Adjust the 10 and 30 mile Zero controls, with the range switch in the appropriate position in each case, until there is a dark hole of about 1/8 in. diameter at the centre of the PPI free from scintillations. (This hole is caused by the receiver suppression).

(v) Now adjust the height tube vertical shift until the suppression 'flat' is only just visible at the bottom of the tube.

(vi) (a) Adjust the Height Zero Preset by one of the following methods:-

<u>Method 1.</u> Switch the Modulator on. Set the Monitor 26 time-base switch to the 10 microsecond position. Connect the test point (Pye plug F) on the Modulator to the Monitor Y-plates. Set the X-shift at 10 microseconds and bring the leading edge of the pulse on to the centre line of the tube by means of the time base start control.

Switch the Modulator off to prevent interference due to pick up in the lead. Now put the height marker on the monitor by disconnecting the lead from the yellow Pye plug on the Indicator and connecting the lead to the monitor. Set the gain on the monitor to x20 and the Height Control to 3000 ft. Turn the X-shift on the monitor to 2.5 microseconds, but do NOT alter the time base start control. Now set the height marker on the centre line by means of the Height Zero Preset.

<u>NOTE</u>:- If the time base does not reach the centre line of the tube with the X-shift at 2.5 microseconds, undo the grub screw and move the knob with respect to the spindle until it does. This will not affect the accuracy of the readings on the X-shift, as they are purely relative.

<u>Method 2.</u> Set up a Corner Reflector (TRE drawing E100/9312 as in Information Pamphlet WT/TRE/31) at an accurately known distance of between 2000 ft. and 5000 ft. Identify the new echo appearing on the height tube. Set the Height Control to the known distance. Bring the height marker opposite the echo (partial cancellation occurring) by means of the Height Zero Preset.

Method 3. Leave the Height Zero Preset in its present position. Adjust it later during a flight test as follows:-

Fly at a height of from 2000 ft. to 5000 ft. Set the Height Control to the reading given by the altimeter. Bring the height marker opposite the leading edge of the ground returns by means of the Height Zero Preset.

(b) Adjust the Range Zero Preset as follows:-

Set the range and marker switch to the 10:10 position. Set the Height Control to 2000 ft. and the Range Control to zero. Adjust the Range Zero Preset so that the range marker is opposite the Height marker, partial cancellation occurring.

(vii) Switch the Modulator on and turn the suppression preset until the suppression just removes the transmitter pulse break-through. Tune the local oscillator for optimum signals on the height tube. Set the mixer current control knob so that the current is maximum and then turn it two clicks anti-clockwise. Remove the coupling loop from the Indicator and check that it is in the same plane as the dot on the collar. Replace the loop and set the coupling so that the plane of the loop is at 30 degrees to the horizontal: this provides half maximum coupling. Check that the coupling probe at the Transmitter is pushed fully in and now adjust the plane of the coupling loop in the Indicator so that the current is between .25 and .3 ma. there being no instability. (Instability, if present, will show itself by a fluctuating mixer current meter reading or as intermittent fluctuations in noise level). Check that, if the equipment is switched off, the mixer current will settle down to between .25 and .3 ma. on switching on again. Recheck the tuning and then reset the coupling loop to give .25 to .3 ma. mixer current.

Set up the Test Set 85 some 20 ft. from the scanner which should be pointing directly towards it. Adjust the matching control in the Transmitter for maximum output power as indicated by the field strength meter.

Adjust the CV43 tuning control for maximum signals on the height tube. Readjust the main tuning control, Indicator coupling loop and PPI brightness as required.

(viii) If the local signals are now weaker than usual try replacing the crystal by a new one. If an improvement results reject the old crystal and repeat the procedure in paragraph (vii) above.

(ix) Adjust the Contrast Control as follows:-

Turn Gain and Contrast fully anti-clockwise. Adjust the Brightness Control so that a full diameter trace is just visible and then turn it anti-clockwise two clicks beyond the position where it just disappears. Turn the Gain up to about 3/4 maximum noise amplitude on the height tube. Now turn the Contrast clockwise until the noise just appears as faint scintillations on the PPI.

NOTE:- No adjustment should be made to the Contrast during operations. The picture should be varied by means of the Gain Control.

(x) Run the equipment on the bench for one hour and at the end of that time recheck the readings at the various test points. The values obtained should be within the following limits:-

Mixer Current	0.2 - 0.4 ma.
Main H.T. Jack	1 ma. ± 10 per cent (or 1.9 to 2.1 ma.)
300V. H.T. Jack	1 ma. ± 10 per cent (or .27 to .33 ma.)
-100V. Grid bias Jack	1 ma. ± 10 per cent (or .9 to 1.1 ma.)
300V. Feed Jack	1.2 to 1.6 ma. (or 250 ma. approx)

Recheck all controls

INSTALLATION AND GROUND TESTING

INSTALLATION PROCEDURE

104. Before installing the units in an aircraft the complete Setting Up Procedure detailed in para.90 et seq should be carried out. The Installation Procedure given below is that to be undertaken when first fitting an aircraft with ARI.5153. The procedure can be somewhat modified when re-installing units.

(i) Check that all cables are fitted and that they are run correctly.

(ii) Check and colour code the cabling to the Control Panel.

(a) D.C. Input lead. Ensure that the ARI.5153 Master switch controls the 24V. D.C. supply to the equipment correctly.

(b) D.C. Output lead to the field of the alternator. If this lead is coupled correctly, a reading of 6 or 7 ohms should be obtained when testing for continuity. (Does not apply to Generator Type UKX).

(c) A.C. Input lead from the alternator. When tested for continuity this lead should show practically no resistance. Colour code the plug GREEN.

(d) Colour code both ends of the A.C. output cable BLACK, and of the D.C. output cable, RED. (The other ends of these cables are attached to the Power Unit).

(iii) Check all keyways and see that the locking rings are tight. It is important that this should be done before testing the cables for continuity.

(iv) Check that the colour coding of the cables is correct. Colour code the 24V. D.C. plug on the Junction Box and the corresponding socket on the cable from the Heading Control Unit, RED. This is necessary in order to avoid confusion with the two-pin plug on the Waveform Generator.

(v) Check the continuity of all the cables with an avometer using the 1000 ohms scale. Megger the inners of all cables to earth and check that the leakage is in all cases greater than 15 megohms. See that the grub screws in all Pye sockets are tightened up and that the sockets are secure. Frequent trouble with Uniradio Cables has been due to a dry joint between the inner conductor and its terminating sleeve.

(vi) Instal the scanner using 5/16 in. high tensile steel nuts and bolts ensuring that the fixing lug marked 'AFT' is towards the rear of the aircraft. Bomber Command only:- Check that the shelf on the mirror assembly of the scanner is set correctly. Fig.67 gives details of the scanner and shelf settings in each type of aircraft.

(vii) Instal the ARI.5153 units and connect up cabling by reference to the appropriate Cable Connector Schedule for the aircraft and the Connector Diagram (Fig.5).

GROUND TESTING

105. (i) Connect up the petrol electric set to the aircraft's Control Panel. If no T^2R is available connect the Modulator to its dummy load.

It should be noted that Wellington XII aircraft employ a Control Panel Type 6 fitted with Regulator Type E, while all other aircraft use a Control Panel Type 5 fitted with Regulator Type EU.

(ii) Switch on the Control Panel and press the 'L.T.ON' button on the Switch Unit.

(iii) Using a 0-5 milliammeter connected to a jack plug, measure the supplies at the 300V and -100V test points on the Power Unit. The readings obtained should be within the limits 1 ma. ± 10 per cent (or .27 - .33 ma. and .9 - 1.1 ma respectively). If necessary adjust the Control Panel until the readings lie within the above limits. Check that blower motors start and watch for any indications of overheating or sparking.

(iv) Press the 'H.T. ON' button checking that the scanner motor switch is OFF. When the H.T. circuit is complete and the red lamp lights recheck the voltages at the test points. The ± 1800 V. D.C. test points should now give a reading of 1 ma. ± 10 per cent (or 1.9 - 2.1 ma) on the meter.

(v) Check that the time bases and markers are present on the tubes and that the controls function correctly. This will ensure that the cabling is in order.

(vi) Switch on the scanner motor and the line of flight marker. Check that the scanner revolves reasonably quietly at approximately 60 r.p.m. Check also that the line of flight marker appears on the PPI when the scanner is pointing directly ahead, and that PPI trace rotates in the same direction as the scanner.

(vii) (a) <u>In Bomber Command aircraft</u> Switch the D.R. Compass on and check that movement of the D.R. Compass causes correct movement of the line of flight marker on the PPI. This can be done by turning the aircraft, or, more conveniently by means of the Variation Setting Corrector.

NOTE:- If the Variation Setting Corrector is used, the variation MUST BE RETURNED TO ITS ORIGINAL SETTING when the check has been made. To ensure that no mistake is made the co-operation of an instrument mechanic should be sought.

An increase in the compass reading should result in a clockwise rotation of the line of flight marker, and vice versa. If the marker moves in the reverse direction to the compass reading, the changing over of two of the connecting leads from the D.R. Compass junction box to the Heading Control Unit will correct this. Check that the line of flight marker can be moved through 360 degrees by use of the manual control on the Heading Control Unit.

NOTE:- A satisfactory test of the Heading Marker can only be obtained in a test flight.

(vii) (b) <u>In Coastal Command aircraft</u> Check that the switch on the Heading Control Unit is in the 'Manual' position. By use of the 'Setting' control adjust the position of the line of flight marker on the PPI until it corresponds to the zero drift line on the perspex screen with the bearing set at zero. (i.e. the line of flight marker points to the top of the tube face).

(viii) Switch off the equipment. Install the T2R if it is not already fitted. Use rubber packing washers to ensure that the R.F. connector from the T2R to the scanner fits well with no air gaps, but ensure at the same time that the outer conductors of the cable are still in contact.

(ix) Switch on the equipment and check that signals are received. Adjust the crystal current as described in para. 103 (vii) and tune for maximum signals.

NOTE:- The signal to noise ratio obtained on the ground will vary with different local conditions and the satisfactory ratio can only be determined by experience.

(xi) Switch off the equipment, disconnect the Petrol Electric Set and connect the Control Panel to aircraft's generators.

MAINTENANCE SCHEDULE

DAILY INSPECTION

106. (i) Connect up the Petrol Electric Set to the aircraft's Control Panel and start up the driving motor. Switch on the Control Panel and after sufficient time has been allowed for it to warm up press the 'L.T. ON' button on the Switch Unit. Check that the green pilot lamp lights and that blower motors start and watch for any indications of over-heating or sparking.

(ii) Using a 0-5 milliammeter connected to a jack plug measure the D.C. supplies at the 300V. amd -100V. test points on the Power Unit. The readings obtained should be within the limits 1 ma. ± 10 per cent (or .27 -.33 ma. and .9 - 1.1 ma. respectively). If not the Regulator in the Control Panel should be adjusted as in para. 102 (iii) above.

(iii) Press the 'H.T. ON' button and check that the amber lamp, and after 45 seconds, the red lamp, light. Check the main H.T. supply by plugging the milliammeter into the test points on the Power Unit. A reading of 1 ma. ± 10 per cent (or 1.9 - 2.1 ma) should be obtained at both the jack sockets, and the Control Panel adjusted if necessary Switch Modulator on and off by means of the switch on its front panel and check that the readings show no signs of jitter nor vary beyond the limits given.

Switch to each position of the Range and Marker Switch in turn and again check that no jitter is present in the supply. If fluctuation does occur in the supply voltage, adjust the Control Panel and if unsuccessful, replace it. If any further trouble is experienced reject the units for a major inspection.

(iv) Check all Pye plugs, W plugs and sockets. This is best done by observations on the Indicator Unit while an assistant is examining the plugs, etc.

(v) Check focus and shift on Indicator Unit and adjust if necessary. Check that Contrast, PPI Radial, Zero and Suppression controls are correctly set and that operation of the 10-mile zero control gives the desired result.

If a fault occurs during this procedure and minor adjustments do not give the desired result, reject the units for a major inspection.

(vi) Switch Scanner Motor and Line of Flight Marker 'ON'. Check that the scanner rotates smoothly and without undue noise. Check that the line of Flight Marker is vertical in Coastal Command Aircraft and adjust if necessary; leave the switch in the 'Manual' position. In Bomber Command Aircraft check that the line of flight marker can be moved through 360 degrees by use of the 'Setting' control on the Heading Control Unit; return the marker to its original position and the switch to 'Auto'.

(vii) Check that the crystal current is between 0.25 and 0.3 ma. If it is not, adjust the crystal current as outlined in para. 103 (vii).

(viii) Switch the Modulator on and check that signals are received. Tune the local oscillator for maximum signals and attempt to estimate the sensitivity by means of local signals or aircraft in the vicinity.

If poor sensitivity is suspected try replacing the crystal by a known good one.

Listen at the aerial system for the sound of R.F. sparking.

(ix) Check that display and markers are satisfactory on all ranges.

(x) Switch off the Equipment and the Petrol Electric Set and reconnect the Control Panel to the aircraft's generators.

MAJOR INSPECTION

107. This should take place each time the aircraft has a major mechanical and electrical inspection, or in the event of persistent faults.

108. Procedure.

(i) Remove all the units from the aircraft and check trays for security of mounting and earthing.

(ii) Check the run of all cables; megger to earth. Inspect all plugs and sockets for tightness of clamping rings and grub screws. Remove lid of the Junction Box and inspect for worn or frayed leads.

(iii) Remove, overhaul and replace blower motors.
Carry out the normal bench setting up procedure as outlined in Chapter 4.

(iv) Re-instal units in aircraft as in Chapter 5.

(v) Inspect and overhaul the aircraft alternator and cabling to the Control Panel.

(vi) Inspect the aerial system for rigidity and shelf settings (Bomber Command).

(vii) Before operational use carry out the Daily Inspection as outlined in para. 106 above.

MISCELLANEOUS SERVICING DATA

REMOVAL OF SPECIAL VALVES

109. Removal of CV64 from the Transmitter Unit

(i) Remove filament leads carefully to avoid breaking the glass seals.

(ii) Unscrew the collar holding the output line to the CV64.

(iii) Undo the bolts holding the airduct to the frame of the Transmitter.

(iv) Undo the bolts holding the other side of the airduct to the magnet support (insert a long screwdriver between the blower and its suppressor).

(v) Withdraw the CV64, airduct and anti-corona plates (Note:- The inner of the output line is flexible).

In replacing it is advisable to leave the 3 bolts between the halves of the airduct loose until the bolts through the magnet support have been located and at least partly tightened.

110. Removal of CV43 from the Transmitter Unit

(i) Remove the tuning plunger through the front panel.

(ii) Disconnect the -100V. D.C. supply.

(iii) Free the mixer chamber, i.e. loosen the two clamping rings on the input line to the mixer and withdraw the input line through the front panel.

(iv) Unscrew the collar on the line from the T-junction to the CV43 input.

(v) Undo the four screws in the vertical plate supporting the CV43.

(vi) Disconnect the Pye plug connection between the mixer and first IF stage.

(vii) Withdraw the CV43, support plate and mixer past the blower motor.

111. Removal of CV67 from the Indicator

(i) Remove valve base and disconnect the reflector supply.

(ii) Undo the three screws clamping the output line to the front panel.

MAJOR INSPECTION

107. This should take place each time the aircraft has a major mechanical and electrical inspection, or in the event of persistent faults.

108. Procedure.

(i) Remove all the units from the aircraft and check trays for security of mounting and earthing.

(ii) Check the run of all cables; megger to earth. Inspect all plugs and sockets for tightness of clamping rings and grub screws. Remove lid of the Junction Box and inspect for worn or frayed leads.

(iii) Remove, overhaul and replace blower motors.
Carry out the normal bench setting up procedure as outlined in Chapter 4.

(iv) Re-instal units in aircraft as in Chapter 5.

(v) Inspect and overhaul the aircraft alternator and cabling to the Control Panel.

(vi) Inspect the aerial system for rigidity and shelf settings (Bomber Command).

(vii) Before operational use carry out the Daily Inspection as outlined in para. 106 above.

MISCELLANEOUS SERVICING DATA

REMOVAL OF SPECIAL VALVES

109. Removal of CV64 from the Transmitter Unit

(i) Remove filament leads carefully to avoid breaking the glass seals.

(ii) Unscrew the collar holding the output line to the CV64.

(iii) Undo the bolts holding the airduct to the frame of the Transmitter.

(iv) Undo the bolts holding the other side of the airduct to the magnet support (insert a long screwdriver between the blower and its suppressor).

(v) Withdraw the CV64, airduct and anti-corona plates (Note:- The inner of the output line is flexible).

In replacing it is advisable to leave the 3 bolts between the halves of the airduct loose until the bolts through the magnet support have been located and at least partly tightened.

110. Removal of CV43 from the Transmitter Unit

(i) Remove the tuning plunger through the front panel.

(ii) Disconnect the -100V. D.C. supply.

(iii) Free the mixer chamber, i.e. loosen the two clamping rings on the input line to the mixer and withdraw the input line through the front panel.

(iv) Unscrew the collar on the line from the T-junction to the CV43 input.

(v) Undo the four screws in the vertical plate supporting the CV43.

(vi) Disconnect the Pye plug connection between the mixer and first IF stage.

(vii) Withdraw the CV43, support plate and mixer past the blower motor.

111. Removal of CV67 from the Indicator

(i) Remove valve base and disconnect the reflector supply.

(ii) Undo the three screws clamping the output line to the front panel.

(iii) Withdraw the output line through the front panel.

(iv) Loosen clamp across the normal tuning plunger.

(v) Force back the driving part of the clutch in the tuning drive against its spring and remove the CV67 and the driven part of the clutch from the unit.

SCANNING UNITS TYPE 3 AND 51: MAINTENANCE NOTES

112. General

If at any time the running speed of the scanner (60 r.p.m) is found to have changed, adjustment can be made by rotating the brushes of the driving motor. This is done by:-

(i) Removing the circlip and cover from the upper end of the motor and band covering the brushes, and

(ii) Slackening the clamping screws of the brush carrier, accessible through the holes in the cooling fan.

NOTE:- The brush carrier must be held in position until the scanner has stopped, and then the clamping screws should be re-tightened and the cover and band replaced. The gears are designed to run dry except for the oildag treatment described below. NO ORDINARY OIL OR GREASE should be applied to them

113(a) Routine Maintenance (Every 120 hours)

(i) Grease main bearing through grease nipple near top of main casting, using anti-freezing grease (DTD.143C).

(ii) Remove the small screws adjacent to the bearings of the main drive gear train and fill the oil holes with anti-freezing oil (DTD.44D).

113(b) Rountine Maintenance (Every 240 hours)

(i) Remove the scanner from the aircraft, dismantle and examine thoroughly. Clean all parts and re-assemble, replacing any parts which are seriously worn.
Paint all the teeth of all non-metallic gears with oildag.

(ii) Examine the motor brushes and replace if worn to 1/4 in. or less. Thoroughly clean the motor commutator with a clean soft cloth slightly moistened with petrol.

(iii) Examine also the magslip brushes and replace if less than 7/32 in. long when measured from the shoulder which locates the spring.

(iv) Clean the six magslip slip rings with a soft cloth slightly moistened with petrol. Do not, under any circumstances, use an abrasive for cleaning the slip rings. Replace the slip ring brushes when worn to less than 1/4 in.

114. Dismantling and Assembly Instructions

(i) To remove Reflector. Remove aerial and detach aerial feeder from reflector base casting. Undo the three nuts on the studs holding reflector casting to adaptor plate. The reflector can then be drawn clear.

(ii) To remove aerial feeder. Remove aerial and detach the aerial feeder from the reflector base casting. Remove top cover casting complete with fixed member of capacity sleeve taking care not to lose or damage the shim between the top cover and main casting. The fixed member can then be withdrawn from the top cover after slackening the clamping bolt. To remove the rotating member, remove collet nut from the end of the shaft and remove collet jaws. The feeder can then be withdrawn downwards.

When re-assembling proceed in the reverse order except for the following points. In replacing the rotating feeder, insert feeder through the shaft and fasten lower end to the reflector base casting. Then replace collet jaws and replace and tighten collet nut. Replace the fixed member of capacity joint in the top cover, pushing it up as far as is possible, but leaving the clamping bolt slack. Replace cover on main casting without the shim, push fixed member down into contact with the rotating member and tighten the clamping bolt. Remove top cover again, replace shim and replace top cover finally.

(iii) To remove main motor. Disconnect breeze plug on side of motor and undo fixing screws. The motor can now be lifted clear, but care must be taken not to lose the centre piece of the Oldham coupling. In replacing the motor care must be taken to see that the Oldham coupling is properly engaged before the fixing screws are tightened.

(iv) To remove main shaft. Remove reflector and aerial feeder. Undo the nuts on the studs holding the adaptor plate to the main shaft and remove the adaptor plate. Remove bottom cover of main casting. Undo ring nut at the top of shaft, and mark the teeth of the magslip gear and the main gear so that they can be remeshed in the same relationship on assembly. The main shaft can now be withdrawn downwards.

(v) To remove magslip. Remove reflector adaptor plate and bottom cover. Remove magslip driving gear, marking the teeth as described above and remove gear on magslip body. Remove terminal cover and disconnect wiring, noting to which terminal each wire is connected, and remove magslip cover. Remove the screws holding the outer race of the upper bearing to the main casting. The unit can now be withdrawn upwards (care must be taken not to lose or damage any shims between the outer race of the upper bearing and the main casting). When re-fitting it is important to see that all shims are replaced; but if any new parts have been fitted, it may be necessary to alter these so as to take all play out of the bearings, whilst ensuring that no permanent load is placed on the bearing.

No timing is needed between the magslip body and the compass repeater motor or between the magslip rotor and the mainshaft, but it is necessary to ensure that the blade brushes make contact with the contact segment when the timing mark on the bottom cover is in line with the timing mark on the main shaft with the reflector facing forward, and that they break contact with the reflector facing aft.

(vi) To dismantle the magslip. After removing the unit from the scanner, undo the screws holding the ring retaining the outer race of the lower bearing to the inner race, taking care not to lose any of the 54 balls in bearing. Remove the slip ring brushes and brush holder. Disconnect the wires joining the slip rings to the magslip terminals; undo the screws holding the slip ring pot to the inner race of the upper bearing; remove the slip ring pot and remove outer race of the upper bearing. Again take care not to lose any of the 54 balls. Undo the screws holding the two inner races together and remove inner race of upper bearing. Remove locating screw from inner race of lower bearing and remove the race.

In reassembly proceed in the opposite order, taking care of the following points. The clamping screw of the inner race of the lower bearing must engage a space between two of the teeth cut in the driving end cover of the magslip. In reassembling the bearings, fix balls to inner race with liberal coating of anti-freezing grease DTD.143C, wiping off any surplus after the outer races are refitted, and making sure that all 54 balls have been replaced in each case.

WELLINGTON XII - ELECTRIC POWER SUPPLIES AND THEIR ADJUSTMENTS

115. The power supply comprises three generators:

Type UKX - Driven by Port Engine.
This gives 1200 volt-amps at 80V. A.C., and 60 amp. 29V. D.C.
A type W Suppressor is fitted.

Type KX - Driven by Starboard Engine.
A D.C. Generator giving 60 amp. at 29V. D.C.

Type KZ - Driven by Starboard Engine, and used for the searchlight
A.D.C. Generator giving 7 amp. at 100V. D.C.

116. The A.C. ARI.5153 is supplied by the UKX generator - See Figures 61 to 63. The D.C. is taken from the general aircraft D.C. supply which is maintained by the KX generator and the D.C. part of the UKX generator running in parallel.

117. The voltage regulators and cut outs are situated on the main distribution panel, on the starboard side of the aircraft, opposite the wireless operator's compartment.

D.C. Control

118. This is effected (on each generator) by two carbon piles; one of which regulates the voltage and the other limits the output current. Their mode of operation is as follows:-

(i) Voltage Control
The activating coil of an electro-magnet is connected across the generator output. Variations of current through the coil (caused by variation in voltage from the generator) cause relaxation or compression of a carbon pile, which is in series with the field winding of the generator. Thus, an increase in voltage causes the carbon pile to relax. The resistance is thereby increased so that the current through the field winding diminishes and the output voltage falls. In the case of decrease in voltage, the opposite effect takes place.

The carbon pile and electro-magnet associated with this action, are generally referred to as the 'voltage pile'.

(ii) Current Control
The purpose of this is to limit the total output current to some pre-determined value (the usual value is 10 per cent) in excess of the total current required. This limitation is brought about by connecting the activating coil of an electro-magnet in series with the load.

When the current reaches its pre-determined value, the pull of the electro-magnet causes relaxation of the carbon pile and reduction of the current through the field winding of the generator.

This arrangement is referred to as the 'current pile'.

119. Figure 63 shows the method of connecting two regulated D.C. generators in parallel. Such a system will only function properly provided that the generators are balanced - i.e. regulated to give the same voltage.

120. If they are not balanced, the generator giving the higher voltage discharges through the other and opens its cut-out. The opened cut-out is then closed by its own generator and the process is repeated. The practical result of this is that the cut-out 'chatters'.

N.B. This is the most probable cause of instability in the 80V. A.C. supply to the ARI.5153 equipment.

A.C. Control - See Figure 62

121. An iron cored choke, on which is wound a second coil which can be supplied with D.C. is connected across the output terminals of the A.C. generator. The impedance of the choke depends on the value of the current flowing through the D.C. coil: for example, if the current flowing through the D.C. coil is sufficient to saturate the iron core of the choke, the choke presents a low impedance to the generator; or on the other hand, if there is no current flowing through the D.C. coil, the impedance of the choke to the generator is maximum.

122. The current flowing through the D.C. coil is controlled by means of a carbon pile connected in one limb of a resistance bridge. The regulation is effected as follows:-

123. Suppose the A.C. voltage from the generator increases; an increase in current occurs through the electro-magnet winding; the carbon pile relaxes and its resistance increases. There is an increase in current through the D.C. coil; the impedance of the choke decreases and the voltage output across AB is restored to its former value.

124. The reverse effect would take place if the voltage developed across the terminals of the A.C. generator decreased.

125. The arrangement of the rectifiers in the bridge circuit is such that the current through the D.C. coil remains uni-directional even if one of the resistances (3 ohms, 19 ohms, 19 ohms) of the resistance bridge goes open circuit. Thus, provided the carbon pile unit remains intact some measure of regulation is still operative.

Setting Up Procedure and Adjustments

126. (i) Balancing of D.C. Generators

This is the responsibility of the Station Electrical Officer. The apparatus necessary for the operation consists of a UKX generator (for use with the type J regulator) and the KX generator (for use with the type F24 regulator).

The procedure is as follows:-

The D.C. regulator is connected to the D.C. output terminals of the appropriate generator and run up, on open circuit, for twenty minutes A voltmeter connected across the output (G+, G-) will probably show a slight decrease over this period. The generator is now switched off and then on again - this ensures that the value of the magnetic inducation of the iron core of the electro-magnet is given by a point on the lower curve of a hysteresis loop. (It is at such a point that it will be working).

The voltage should now be set to 29 volts. In the case of the F type voltage regulator the voltage is set by adjusting the core of the voltage pile. In the case of the J type voltage regulator the adjustment is effected by means of a separate rheostat which is in series with the electro-magnet coil of the voltage pile.

In the event of a regulator showing instability, the setting of the back stop of the voltage pile should be checked. The standard setting is obtained by screwing in the back stop until the pile is fully compressed (the front stop being set flush) and then unscrewing three quarters of a turn. Only slight variation from this setting should be necessary; if this is not the case, the carbon pile (48 discs) should be examined to see if any of the discs are damaged or jamming.

NOTE:- If the regulators are tested by using the aeroplane generators and running the engine, they should be tested with the ACCUMULATORS DISCONNECTED. For, if they will regulate without the steadying influence of the accumulators, they will certainly regulate with this influence.

(ii) Setting of A.C.

For this purpose a UKX generator - with the D.C. output controlled by a type J regulator - must be wired so that its D.C. and A.C. outputs can be plugged in to the Control Panel Type 6 - See Figure 62.

A voltmeter of the rectifier type, which has previously been calibrated against an accurate thermal voltmeter, should be plugged in to the top left hand 4 pin plug of the V.C.P. and the voltage determined under a load. Adjustment to 80V. is effected by means of the trimmer resistance which is in series with the ballast resistor and electro-magnet winding of the carbon pile element; 1 the control for this is situated between the terminal block and the magnet pot of the carbon pile element. It should be noted that the ultimate criterion for the A.C. voltage setting is that the D.C. voltages (1800V, 300V, 100V) of the Power Unit are correct.

It is claimed that no further regulation is necessary and that there will be no tendency for the 80V. supply to jitter (provided, of course, that the D.C. has been properly regulated and that the bridge circuit D.C. and A.C. coils are in good condition). If, however, jittering does occur it can be overcome by slight adjustment of the compression screw (i.e. the back-stop) of the carbon pile. 2 It should be noted that increased compression of the carbon pile does not necessarily produce an increase in voltage (as it does in the case of the Control Panel Type 5); it depends on whether the original setting of the compression of the pile is such that increased compression takes the bridge further away from a balance or nearer to a balance. When the jittering has been over-come, the voltage is brought back to 80V. by means of the rheostat. Finally, compress the spider spring between the first two fingers and thumb and make sure that the carbon pile is not too tight to regulate.

1 In the first few models, there is no such adjustment and the core adjustment (front) must be used.

2 In later models this will be locked in position.

(iii) Additional Note
It is highly important that the polarity of the D.C. input be as follows:- Pin 1 negative. Pin 2 positive. If this is not the case the V.C.P. will not regulate.

If a new V.C.P. will not regulate when the input polarity is correct, it is probable that the polarity has been reversed in the internal wiring. Check this by finding out if the junction of the two 19 ohm resistors is connected to Pin 1; if it is connected to Pin 2, reverse the leads from the suppressor to the bridge.

SUMMARY OF SETTING OF CONTROLS ON ARI 5153

Controls not used on Squadrons

127. (i) I.F. Tuning in T^2R and Receiver.

(ii) Marker Timing in Receiver Timing Unit.

Controls used by Maintenance Personnel only

128. (i) Suppression delay on Receiver; set fully anti-clockwise.

(ii) PPI Radial on wave-form Generator; set, with gain fully anti-clockwise, so that the brighten-up leaves about 1/16" dark hole in the centre of the PPI on the 10m. range. This control interacts with (vii).

(iii) Recurrence Frequency in Modulator; set to give free frequency just lower than locked frequency. i.e. red dot on control opposite spring.

(iv) Mixer coupling on T^2R; set right 'in'. It should be checked that this does not entail loss of sensitivity (using Sig. gen.47 on bench). If so, set as far as possible in without losing sensitivity.

(v) CV 43 Tuning on T^2R; set on signals or echo-box response for maximum.

(vi) CV 64 Matching Slug in T^2R; set so that frequency change is less than 4 M/c for ± ¼" movement, with minimum loss of power. Procedure as follows:-

(a) Determine range of slug movement for which power is not more than 15% down on max.

(b) Set slug ¼" inside end of this range further from CV64.

(c) Tune CU43 and CU67.

(d) Move slug ¼" either way and see whether echoes on indicator drop 75%. If not, slug is set satisfactorily.

(e) If not, move slug ¼" nearer CU64 and tune CV43 and CV67 and try again, etc. until position where echoes do not drop is found.

(vii) PPI Radial on Switch Unit; set as (ii) on 30m. range.

(viii) Range Zero on Switch Unit; set so that when Range Dial is set to zero, the range marker just touches the trigger pulse. This is visible when the suppression is removed by setting it between two clicks with the modulator switched off.

(ix) Height Zero on Switch Unit; set in Mk.IIIB so that the range and height markers coincide at 1 m. and 6000' respectively.

(x) 30 mile zero on Switch Unit; set so that the suppression gives about $\frac{1}{8}$" dia. dark hole in the centre of the PPI when noise scintillations illuminate the rest of it.

(xi) PPI shifts on Switch Unit, set to centralize picture.

(xii) Height Tube shift; used to bring the suppression flat to the bottom of the tube when the zero controls are correctly set.

(xiii) Taps on CRT input transformers, set to give circular scan, 11 - 12 cms. according to PPI tube in use.

(xiv) Taps on cathode resistance of second stage in PPI input amplifier in indicator; set to maximum with present type of PPI.

DETAILED DESCRIPTION OF UNITS

129. In the earlier sections of this document we have described the purpose of the H2S equipment and given a general description of the functioning of the various units which go to make up the equipment. In the following section we shall consider each unit in detail and show how the various functions performed by it are produced.

THE POWER UNIT

130. To study the action of the power unit the diagram given in figs. 8 and 10 should be used. Fig.8 is an interconnection wiring diagram which shows the complete circuit associated with the power unit. It will be seen that the buttons for operating the switching sequence are situated in the switch unit type 207. The location of components and controls may be seen in figs. 11, 12 and 13.

131. The equipment in the power unit is concerned with the conversion of the 80-volt A.C. input to the various D.C. output voltages required. These are as follows:-

(i) +300V.

(ii) +1800V.

(iii) -1800V.

(iv) -1000V.

(v) -100V.

132. The means by which these supplies are obtained can be seen by referring to fig.10. The transformer T303 which is connected to the 80-volt supply when relay B operates, furnishes through the full wave rectifying valve V304 the +300V supply and also through W303, the negative 100-volt supply. These supplies therefore come on when the L.T. ON button is pressed to energise relay B.

133. The smoothing circuit consists of a "choke first" arrangement employing CH302 and C302. This arrangement minimises the peak load on the rectifying valve during the condenser charging period which would otherwise be very great. Adequate smoothing is obtained because the frequency (1000-2000 c/s) is fairly high. Further tappings on the secondary winding of T303 supply the rectifiers W302 and W303. These are arranged to furnish the negative 100V. bias supply. The voltage of the 300V. supply is measured by inserting a milliammeter in the jack J304 which is itself connected across part of the

(vii) PPI Radial on Switch Unit; set as (ii) on 30m. range.

(viii) Range Zero on Switch Unit; set so that when Range Dial is set to zero, the range marker just touches the trigger pulse. This is visible when the suppression is removed by setting it between two clicks with the modulator switched off.

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(ii) +1800V.
(iii) -1800V.
(iv) -1000V.
(v) -100V.

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potentiometer formed by R_{319} and R_{318}. The values of R_{318} and R_{319} are chosen so that a reading of 1 mA. is obtained when the supply is 300V. The tolerance permitted is ± 10%. Similarly the resistances R_{316} and R_{317} form a potentiometer by which the -100V. supply can be checked by inserting the milliammeter into J_{303}. Again a reading of 1 milliamp. ± 10% should be obtained. The total current supplied by V_{304} can be measured by inserting a milliammeter in J_{302}. For this reading, the resistances R_{337} and R_{340} give a multiplying ratio of about 220:1, so that if the correct feed current of about 250 mA. is being supplied the reading on the milliammeter should be approximately 1.1 to 1.2.

134. The +1800V. and -1800V. and -1000V. supplies are all obtained from the transformer T_{302}. This transformer is energised when the 'H.T. ON' button is pressed to operate relay C. It supplies the four valves V_{300}, V_{301}, V_{302} and V_{303} which are arranged in a bridge circuit. V_{300} and V_{302} are arranged to supply -1800V. through choke CH.301 and V_{301} and V_{303} supply +1800V. through the choke CH.300. The potentiometer R_{334}, R_{339}, R_{338}, R_{333} divides off the -1000V. supply and two other potentiometer chains feed the jacks J_{301} and J_{300} by which the positive and negative voltages may be measured. The series resistances are chosen to give a reading of 1 mA. when the voltage is 1800 in both cases.

135. The Modulator operates when the 300V supply is switched through to it by the closing of contacts operated by relay E. The operation of relays D, E and F is given in full in para. 139 et seq. below.

136. Switching on sequence.- As has been stated above, the switching on sequence is performed by means of relays. These relays are situated in the power unit. In the diagram, the relay operating coil is shown as a square with a letter giving the reference of the relay and a number which is the number of contacts operated by the relay. When the main switch, which may be at the navigator's table or on the voltage control panel, or on a block grouped with other switches, is switched on, 80V. A.C. is applied to the two-pin black W plug W.204. The rectifier W 300 immediately furnishes the necessary current to operate relay A. Relay A contact 5/6 closes and prepares the following circuits:

> W.204 two pin red 24V $\overset{+}{-}$ into relay contact A 5/6 pin 3 of 18-pin plug to junction box type 83, pin 6, W.201, closed contacts of L.T. OFF button, the green signal lamp SL.150, to L.T. ON contact.

137. When the L.T.ON button is pressed, this circuit is completed through pin 2 of W.199, the operating coil of relay B to 24V. pos~~itive~~. Relay B now operates and its four switches close with the following results: negative

(i) Contact 7/8 closes and holds the relay energised independently of the L.T. ON button so that when the button is released the relay continues to hold.

(ii) Contact 5/6 closes and completes the 80V. supply to the junction box via contact 6/7 and 8/9 of the 18-pin plain W plug number W.203. The other side of the 80V. supply is already connected.

(iii) Contact 9/10 closes and prepares the circuit of the operating winding of relay C. This is the first stage of the preparation of this circuit, and relay C does not actually operate until the second stage, given in para.140 below, has been completed, and the H.T.ON button is pressed. The function of contact B 9/10 is to apply - +24V. to one side of relay C. This contact also supplies D.C. to pin 2 of W.203 and thence via the junction box to the blower motors in the T^2R and indicator.

(iii) Contact B 11/12 closes and completes the 80V. supply through T_{300} and T_{303}. The metal rectifiers of the W.302 and W.303 (see fig.10) now become operative and develop the negative 100V. power supply. V_{304}, the H.T. rectifier, also operates and develops the +300V. H.T. supply. A further winding on T_{303} heats the filament of the valve V_{305}. This valve is known as the protective valve because its function is to prevent the switching on of the H.T. supply before the L.T. supply has been on for a certain time.

138. The further actions in the switching on sequence now depend on this valve. It will be seen on examining the circuit diagram that the contact 5/6 of relay C in the grid circuit of the valve is closed and relay C is not energised. Consider now the potentials on the various electrodes of the valve before it commences to pass current; that is, before the cathode has warmed up sufficiently:

The anode will be at +300V.
The screen at +280V.
The grid at +15V. and the suppressor and cathode will be at zero volts.

139. As soon as the valve conducts, there is a fall in potential at the anode which is fed back to the grid through the condenser C304 and the contact 1/2 of relay E. This contact, is closed when the relay is not energised. The feed back effect from anode to grid immediately reduces the grid voltage, and this in turn stops the flow of anode current. This type of circuit is known as the Miller feed back circuit, and the special feature of it is that the grid potential only rises extremely slowly. With the values of the circuit constants used it actually takes 30 to 40 seconds before the grid voltage rises sufficiently to allow anode current to flow and so operate relay D. The anode current in the valve divides at the anode between the operating coil of relay D and the shunt resistance R323 (fig.10).

140. When the current has become sufficiently great to energise relay D the following circuit changes occur:

(i) Contact 6 breaks from 5 and closes to 7 to remove the shunt resistance R323 and also to short-out the series resistance R322. The current through the relay winding therefore increases and holds the relay well energised.

(ii) Contact D 1/2 closes to connect the operating coil of relay C through pin 4 of W.199 to the H.T. ON push button. This is the second stage in the preparation of the circuit to this push button mentioned at para. 137 above.

(iii) Contact D 3/4 which is closed when the relay is not energised, now opens and breaks the 24V. supply to relay E.

141. If the H.T. ON button is now pressed the 24V. D.C. circuit through relay C is completed through the amber lamp SL.151, the L.T. ON button contacts, the L.T. OFF contacts pin 6 of W.201, junction box type 83, pin 3 of W.203 and through contacts A 5/6 which are closed to 24V. negative positive. Relay C therefore operates and its four contacts produce the following circuit changes:

(i) Contact C 3/4 closes the completes the 24V. D.C. circuit independently of the H.T. ON push button so that the relay holds when the button is released.

(ii) Contact C 1/2 closes and applies 24V. negative positive to the operating coil of relay F and also to contact 3 of relay D.

(iii) Contact C 7/8 closes and completes the 80V. A.C. supply circuit to the primaries of transformers T301 and T302. This makes the E.H.T. circuits operative, and the +1800 and -1000 volt supplies are developed.

(iv) Contact C 5/6 now opens and removes the positive voltage from V305 grid and leaves the valve with a negative bias of about -20V. due to the negative feed to the junction of R28, R29 obtained from the -100V. bias supply through R330. The anode current now commences to fall, but the feed back coupling prevents the fall from occurring rapidly, so that it takes about 20 seconds before the fall of current is sufficient to de-energise relay D.

142. When relay D becomes de-energised the following actions take place:

(i) Contact D 1/2 opens to break the D.C. circuit between relay C and pin 4 of W.199. This has no effect as relay C is still being held through contact C 3/4 and pin 5 of W.199.

(ii) Contact 6 of relay D now breaks from contact 7 and closes with contact 5 to put R322 again into V305 anode load and shunt R323 across the winding of relay D. V_{305} is now back to the condition which existed when its filament was first heated, with the exception that the bias of +15V. on grid now becomes -20V.

(iii) Contact D 3/4 now closes and completes the 24V. D.C. circuit through the winding of relay E which now becomes energised, the circuit from the relay winding being completed through A 5/6 to 24V. negative.
positive

When relay E is energised, the following changes occur:

(i) Contact E 9/10 closes to connect +300V. to the modulator to W.203 pin 17 and the junction box.

(ii) Contact E 1/2 breaks and E 5/6 closes, and the feed back condenser C_{304} is disconnected from V_{305} grid leaving V_{305} cut off on the grid.

(iii) Contact E 7/8 closes to complete the 24V. D.C. circuit through the red pilot lamp SL.152 and pin 6 of W.199. This is the indication to the navigator that the equipment is fully on.

143. As has already been stated, when relay C is energised, the contact C 1/2 connects the +24V. D.C. line to one side of the winding of relay F. The other side of the winding is connected via pin 1 of the W.199 plug to the motor switch in the switch unit. When this motor switch is put to the ON position, therefore, relay F is energised. Contact F 1/2, parallelled to 5/6 because of the high current loading, closes to feed the 24V. supply via W.200 to the scanner motor.

Switching-off sequence

144. When the L.T. OFF button is depressed the D.C. supply to relays B and C is broken. This cuts off the entire power unit and hence all the other units. All relays therefore return to their initial conditions.

145. If the L.T. ON button is depressed when the equipment is running, the H.T. and E.H.T. supplies are switched off, but the L.T. is left on. The actual sequence of events is as follows:

(i) The -24V. D.C. is disconnected from pin 5 of W.199 in the switch unit so that the supply through the operating coil of relay C is broken and the relay is de-energised.

(ii) The contact C 7/8 opens and cuts off the 80V. A.C. supply from the transformers T_{302} and T_{303}, so that there are no further E.H.T. supplies.

(iii) Contact C 1/2 breaks the 24V. D.C. supply to relays E and F.

(iv) Relay E is de-energised so that contact E 9/10 opens and cuts off the +300V. supply from pin 17 of W.203 thus breaking the supply to the modulator.

(v) Relay F is de-energised and breaks the scanner motor supply.

(vi) The contact C 5/6 closes to connect the positive bias from R_{125} to the grid; further, contact E 5/6 opens and E 1/2 closes to connect C_{304} between the anode and grid of V_{305}. This restores the situation where we have +300V and -100V. developed and it is necessary to wait for the delay action of V_{305} to take place before relay D becomes energised again, and connects relay C to the H.T. ON push button. Once this has occurred the H.T. ON button can be pressed at any time, putting the equipment into operation again as outlined in para.

146. Cutting off the 80V. A.C. supply to the power unit by switching off the main switch at the switch block, voltage control panel, or navigator's table will also cut off everything since the A relay is energised by rectified A.C., and contact A 5/6 must be closed to obtain any 24V. D.C. supply for the other relays.

Safety circuits

147. The following points should be noted in case of certain failures:

(i) If the 24V. supply fails, relays B,C,D,E and F are de-energised, thus switching off the equipment.

(ii) If the 80V. A.C. supply fails, relay A is de-energised and breaks the 24V. D.C. supply thus switching off the equipment.

(iii) If some fault develops which results in excessive load on any of the rectifiers and hence on the 80V. A.C. supply, the current through the primary of the transformer T_{300} in the power unit will increase. Hence the rectified output developed by the rectifier W.301 will increase. This is applied to relay A in such a sense as to oppose the output of W.300. Relay A then becomes de-energised and so opens and cuts off the D.C. supply to the power unit. All the relays are then de-energised and the equipment is switched off.

(iv) For details of the safety circuits in the modulator type 64 (see para. 193).

148. This completes the review of the operation of the relays in the power unit.

SWITCH UNIT TYPE 207

149. The function of the various adjustments in this unit has been or will be covered mainly in the description of the other units in conjunction with the effects which they control. The circuit diagram of the switch unit given in fig.14 is actually repeated in full in the wiring diagram fig.8 and this figure should be used to see the way in which the various controls fit in with the circuit details of the other units.

WAVEFORM GENERATOR

150. The waveform generator acts as the master clock of the equipment. It is supplied with A.C. at 80V. and with D.C. at +300V. and -100V. A self-running multivibrator in the waveform generator provides the timing for the system and further stages provide the waveforms which are required. The following are the outputs of the unit:

(i) A sawtooth waveform which is supplied to the magslip rotor whence, as previously stated, it supplies the time base scans on the P.P.I. tube in the indicator.

(ii) The transmitter timing pulse to the modulator taken through the blue lead.

(iii) The waveform for brightening up the trace on the P.P.I. tube to transform what is originally a diametril scan to a radial scan. The reasons for this will be apparent when the generation of the P.P.I. scans is dealt with in para. 161 below.

(iv) A mixer stage in which this bright-up waveform is combined with the output from the receiver is also included in the waveform generator.

MASTER MULTIVIBRATOR

151. The circuit diagram of the waveform generator is given in fig.17 and figs. 19 and 20 give the layout of components.

152. Considering first of all the master clock itself, this comprises the valves V_{500} and V_{501} and their associated components. The circuit used is a cathode coupled multivibrator. Since great stability of operation is required the H.T. supply is not obtained directly from the 300V. supply, but from a stabilising valve V_{511}. At the cathode of this valve a steady H.T. supply of approximately 200V. is available. A square waveform is produced at the anode of V_{500} which is used to synchronise the bright-up waveform generator V_{506} and V_{507}. Waveforms are given in figs. 21 to 27(vii) and that at V_{500} anode is given in fig. 21. The waveform produced at the anode of V_{501} is used to time the sawtooth generator comprising the valves V_{502} and V_{503}.

153. The repetition frequency of the square wave produced and the proportions of negative and positive square are determined by the constants of the two

cathode circuits and to a lesser extent by the anode loads. When the equipment is changed over from one range scale to another, the repetition frequency is unaltered but the relative length of positive and negative portions of the square wave must be changed. The times during which the grid of V_{501} is at a high potential and at a low potential are given in the table below:

Scan Range	Time for V_{501} grid high	Repetition period
10 mile	240 µS. ± 10%	1500µS.± 10%
30 mile	720 " ± 10%	1500 " ± 10%
50 mile	1200 " ± 10%	1500 " ± 10%

Relays are used to switch the circuits, and these are controlled from the switch unit. The relays employed are lettered M and N in fig.17.

154. It will be seen on examination of the diagram that the cathodes of V_{500} and V_{501} are coupled by three condensers permanently connected in parallel and there are three resistances in each cathode circuit to earth. The relative width of positive and negative scans are determined by the ratios of these cathode resistances. They can be changed by the closing of the shorting contacts shown in fig.17, thus contact N 7/8 shorts-out R_{510} leaving R_{518}, R_{509} in circuit with the cathode of V_{500}. Also contact M 3/4 shorts-out R_{509} and R_{510} leaving only R_{508} in circuit. In the cathode circuit of V_{501}, R_{518} may be shorted-out by the contact M 8/7 and R_{517} and R_{518} are both shorted-out by the contact N 3/4. Thus when relay N is energised on the 50 mile range the small resistance R_{516} of only 15 K. is inserted in V_{501} cathode, whilst all three resistances are in circuit with V_{500} cathode. This causes the grid of V_{501} to have its long period high for the timing of the 50 mile scan. On the 10 mile range relay M is operated, and only R_{508} of 20 K. is in circuit with V_{500} cathode, whilst contact 7/8 opens to place all three resistances in series with V_{501} cathode. This has the effect of making the time for V_{501} grid to be high, only 240 microseconds. When neither relay is operated R_{508}, R_{509} are in circuit with V_{500}, and R_{516}, R_{517} are in circuit with V_{501}. This is the position for the 30 mile scan.

155. <u>Saw-tooth forming stage</u>.- The next stage which we will examine is the sawtooth waveform stage formed by the valves V_{502} and V_{503}. These have to produce a voltage which is either rising or falling linearly with time. The type of circuit used is a form of Miller feed-back circuit, because it has been found that this circuit gives an output with a particularly straight characteristic. The function of the valve V_{503} is to produce at its anode this sawtooth waveform. The function of the valve V_{502} is to determine the steepness of each slope, so as to fit the sawtooth in with the times allocated by the multivibrator V_{500}, V_{501} - on each range.

156. A steady current flows through the chain of resistances formed by R_{530}, R_{531}, R_{532}. When V_{502} is conducting, this continues through the valve and through as many of the cathode resistors as are in circuit. The number of these resistances inserted is changed for each position of the range switch.

157. Leaving V_{502} for a moment let us consider the valve V_{503}. This is really the sawtooth forming valve. Suppose first of all that no changes of voltage are being applied to the junction of C_{514} and C_{513}, and that the electrodes of the valve are allowed to take up steady D.C. potential levels. The grid will be at earth potential due to the resistance R_{538}; current will flow through the valve and the cathode will acquire a positive voltage due to R_{539} thus biasing the valve. As a result of this there will be no grid current. If now small changes of potential are applied to the grid through C_{514}, these will not cause grid current whether they are positive or negative, provided that the largest positive excursion does not exceed the bias voltage. Since no grid current can flow, there will be no flow of current into the plate of the condenser C_{514}, which is connected to V_{503} grid. We may therefore be sure that any waveform present at V_{502} anode will also be applied to V_{503} grid.

158. The grid of the triode section of V502 is held at a steady potential and the square waveform from V501 anode is applied to the diodes of V502. During the positive period the diode anodes and therefore the cathodes are carried positive to the grid thus cutting the triode section off. During negative periods the triode section is conducting. We will now examine what happens when the valve V502 is switched on and off by the square waveform from the master multivibrator which is applied to the diode anodes of V502. As the multivibrator is operating continuously we must choose some point in the cycle and consider what happens during the rest of the cycle. Let us therefore choose the moment when V502 ceases to conduct in its triode section. Since it has been previously conducting, the voltage drop in the anode resistances will have caused V502 anode to be at the lowest point in the potential cycle. The anode of the valve will therefore tend to rise in potential. We have said that this point in the cycle represents the lowest voltage value for V502 anode and V503 grid. Furthermore the potential at the upper end of R532 is applying a positive voltage which will tend to raise V502 anode. As soon as V503 grid rises in potential V503 anode falls and thus opposes the rise of grid potential through the coupling action of C513. The net result is that V502 anode is only allowed to rise very slowly whilst V503 anode falls M times as fast, where M (about 120) is the voltage factor of the valve V503.

159. Slope of sawtooth.- The rate at which the change of potentials takes place, that is, the volts change per second, or per microsecond, is determined by the rate at which current is supplied by R532 to the side of C513 connected to V502 anode. This rate actually depends upon two factors, (i) the relevant time constant associated with R532, C513 and the valve V503, and (ii) the voltage applied to the upper end of R532. The relevant time constant is the complex one, R532 multiplied by C513 multiplied by (1 + M) where M is the amplification factor of V503. Since we do not alter these values when changing from one range to another it follows that if we wish to change the slope of the sawtooth (that is, rate of change of voltage of V502 anode with time), we shall have to change the voltage of the upper end of R532 as we switch from range to range. This is taken care of by a suitable choice of the values of R530, R531 and the cathode resistances R533, R534, and R535, one or more of which is switched into circuit as the range change switch is moved, thus providing a different D.C. level of the junction of R531 and R532 for each range.

160. It will be noticed that we have not made any mention of the function of C512 connected to the upper end of R532. This condenser feeds back the cathode voltage of V503 to the junction of R531 and R532 and it has the effect of applying feed back to the grid circuit of V503, thus still further ensuring the linearity of the sawtooth.

161. The sawtooth waveform produced across R541 is fed to the grid of V504 where it is amplified and supplies the winding 3/4 of the transformer T501. A secondary winding of this transformer, which is centre-tapped to earth, supplies two waveforms in opposite phase to the scanner magslip rotor over the connections, pins 2 and 6 of the 6 pin plain W plug, W.199. As has been already pointed out, the output from the stator windings of the magslip is supplied to the four deflector plates of the P.P.I. indicator to produce the rotating diametral scan. The same timebase is also taken off from the secondary of T501 through a parallel connection to the indicator unit to supply the height tube with its time base.

162. The winding 1/2 of T501 acts as a feed-back. The sense of the feed-back winding is such that the potential of terminal 2 moves in step with the voltage of the anode of V504. The anode load of V504 is large, so that the gain of the stage, neglecting the feed back, is high. The resultant gain is therefore determined almost entirely by the feed-back ratio. The net gain is about 4, and since the amplitude of the sawtooth on V503 anode is a little less than 80V. the amplitude on V504 anode is therefore a little over 300V. This is the required value. The resistance R544 can be chosen when the unit is manufactured to make the output amplitude correct in spite of the variation of the components from their nominal values. To compensate for the loss at low frequencies introduced by the circuits which carry the scanning waveforms to the P.P.I. subsequent to the waveform generator, the blocking condenser C518, C539 in the feed-back resistance chain is made of such a value that the feed-back is reduced at low frequencies. This means, in effect, that the valve boosts the low frequency to compensate for these losses. C537 is a bypass for any stray H.F. voltages which may be picked up.

Transmitter timing valve

163. We have now to consider another function performed in the waveform generator, namely the production of the timing pip, controlling the operation of the timing multivibrator in the modulator described in para. 189 below, and hence the moment of firing the transmitter. We have already shown that the output of the sawtooth generator when applied to the P.P.I. tube in the indicator produces a diametral scan. What we have to do is to fire the transmitter at the exact moment that this diametral scan passes the centre of the tube. The valve which does this is V505, and it is supplied from a further winding of the transformer T501 mentioned above. This winding, the winding 8/10 of the transformer has terminal 10 earthed and terminal 8 connected to the grid of V505 through C520 and C550. The winding is so arranged that the potential of 8 rises during the working stroke. The timing pip which we require to produce at a point approximating to the middle of the scan is produced at the anode of V505 and led out of the waveform generator box via the blue Pye plug.

164. The way in which the valve V505 produces this pip is as follows: first of all, to understand its action, consider the voltages on the various electrodes of the valves, and assume that no potential is being applied at C520. The cathode is directly connected to earth. The grid is connected through the 1 megohm resistance R550 and a smaller resistance R556 to the range zero control in the switch unit through pin 8 of the 12-way range plug. This merely produces a point of variable positive potential. The grid itself is held slightly more positive than the value determined by the setting of this control, because a further leak R588 is taken to a high voltage point. Anode current to the valve is supplied from the junction of R553 and R555, the effective anode load being about 90,000 ohms. Owing to the potentiometer method of connection, the anode voltage is about 18V. A further potentiometer R551 and R552 provides the screen with an effective supply of about 70V. and a screen load of 70,000 ohms. Both anode and screen supplies are taken from the 200V. stabilised line.

165. The screen is lightly de-coupled by C521, the time constant being 70 µS The suppressor is coupled to the screen by C522. R554 is a leak resistance between suppressor and earth. Furthermore the suppressor is prevented from going positive to earth by the first half of the diode V509. The valve V505 is thus a form of transitron. When the scanning voltage is being continuously applied to C520, the control grid of V505, when it is positive to the cathode, will cause C520 to become negatively charged through R550. The level of grid voltage will be "restored" about the zero volts line, and its excursion of voltage will be to about 35 or 40 volts negative. In normal working, therefore, there will exist a difference of D.C. potential level across C520, after the application of a few cycles of sawtooth. We therefore have the condition that the commencement of the rising stroke V505 grid is at an extreme negative potential of the order of 40 to 45 volts negative to earth, the waveform being as shown in fig. 26.

166. If the grid potential rises, following the working stroke of the sawtooth, it will eventually reach the point of cut off, namely about -2V. Anode current will commence to flow thus reducing the potential of the anode from its previous value of 18V. Screen current will also flow and reduce the potential of the screen. This will in turn reduce the potential of the suppressor through the coupling action of C522. The effect of this is to cut the flow of anode current off at the suppressor grid, thus diverting the whole flow of cathode current to the screen. This still further reduces screen and suppressor potential thus confirming the cut-off of anode current. As a result of this, the anode voltage rises first of all by a few volts and then when completely cut off, it returns to its original potential of 18V.

167. There is a certain amount of capacity between anode and earth, due to the capacity of the cable connecting it to the modulator, so that the rate at which it returns to its original potential is determined by the time constant formed by this capacity, and the resistance R555. This somewhat long time constant waveform is differentiated in the modulator itself by the condenser C7, and resistance R19 in the modulator unit, thus producing the required short-duration pip for triggering the modulator multivibrator.

168. Range zero adjustment.- The point on the sawtooth at which is this pip occurs and therefore the point on the scan at which the transmitter fires can be

advanced or retarded by means of the range zero control. This closes or opens up the "hole" in the P.P.I. picture see para. 20.

Bright-up multivibrator

169. The purpose of this stage is to brighten the diametral scan during the second half of its travel across the P.P.I. tube, so as to turn it from a diametral scan into a radial scan. Whilst this stage goes by the name of the bright-up stage, and we talk about brightening half of the scan, we do not actually raise the potential of the "brightened" half of the scan to produce a continuous, bright trace. What we do is to bring up the potential of the P.P.I. tube during this half of the scan to the critical level above which any further positive voltage applied to it, will result in a visible trace. During the first part of the diametral scan, the P.P.I. tube grid (modulating electrode) is kept so well negative that no signals, or other voltages applied to it, can produce a visible spot or mark. The type of waveform required to perform this function is therefore a square wave having the positive square equal in duration to a radius of the P.P.I. This positive portion must have a very flat top. This type of wave is produced in the multivibrator stage employing the valves V_{506} and V_{507}. The output from the bright-up generator is not applied directly to the indicator, but is first of all mixed with the output from the receiver in the mixer stage comprising the valve V_{508}.

170 Let us consider now the form of multivibrator used in the bright-up generator. This comprises the valves V_{506} and V_{507}. The connections make this stage a flip-flop type of multivibrator. That is, one which has a stable state in which one of the valves is cut off and the other is fully conducting. In this case the valve V_{507} is conducting and V_{506} is cut off in the stable state. The cathode resistance R_{568} is common to both valves. The DC potential of the grid of V_{507} is determined by the setting of the radial P.P.I. adjustment in the control unit. This adjustment is merely a potentiometer connected between earth and point of positive potential. This sets the level of the grid of V_{507} and, therefore, the level of the cathode of V_{507} in the stable state. The cathode of V_{506} is connected to the cathode of V_{507}, and thus the bias on V_{506} is determined.

171. The kind of square wave which we have to produce is one which has its positive portion commencing at exactly the centre of the rising sawtooth. This positive portion must be sustained until the end of the sawtooth and the negative portion must immediately commence at this point so as to black out the fly-back stroke. The negative portion must continue for the first half of the next rising sawtooth. The relative times can be seen in the diagram, fig.19. The way in which this timing is carried out is somewhat involved but essentially it is done as follows:-

172. The positive going edge of the master multivibrator produced at the anode of V_{500} and the sawtooth rising stroke produced at terminal 8 of the transformer T501 are both applied through condensers and a network to the grid of V_{506}. To show the way in which these waveforms are added together in the network comprising the double diode valves V_{509} and V510 and their associated resistances and condensers the diagram fig.18 has been prepared the sawtooth waveform is applied through C_{524} to the point A i.e. junction of C_{524} and R_{559} giving the waveform labelled A in fig.19. The square waveform from V_{500} anode is applied through C523 to the point B resulting in waveform B fig.19.

173. The cathode potentials of the 2nd half of V509 and both diodes of V510 and the grid potential of V507 are all set by the potentiometer chain R557, R558 and VR_{151} in the switch unit. This point we have labelled C in fig.18 and the waveform diagram shows the waveform of C as a horizontal line.

174. The waveform diagram has been split up into periods by the vertical lines labelled 1, 2, 3, 4 and 5.

175. The object of the network mentioned in para.172 above is to control the potential of the point E which is the grid of V506, because what we are trying to do is to limit the period during which this point is above that of the point C to the second half of the working stroke of the sawtooth. The potential of the point E, as can be seen from the curve d fig.19 follows first of all the potential of A during the period 1/2.

176. At the point 2 it reaches the potential of C and consequently fires the flip-flop circuit. V506 becomes conducting and V507 is cut-off. During the period 2/3 the points D and E are held by the first half of V510 to a potential only slightly above that of C.

177. At the point 3, the sudden negative excursion of the square wave at B carries the potential of E down below that of C and thus allows the multivibrator V506, V507 to swing back to the stable state with V507 conducting. During the period 3/4 this state is maintained because the potential of E is now governed by that of B through R561. During the period 4/5 the potential of E follows that of D, that is, it follows the second half of the fly-back portion of the sawtooth and the grid of V506 is, therefore, carried down well below cut-off, so far, in fact, that at point 5 when the rising positive square wave is applied to (B) this height is insufficient to bring it up to the required level at which the flip-flop circuit will again strike. We are now back at the same point in the cycle at which we begin to consider the operation of the circuit.

178. It will, therefore, be evident by considering curve (d) that the only time during which V506 is conducting is that between the time points 2 and 3. That is, the second half of the working stroke of the sawtooth.

179. Control of start up of bright-up.- It will be profitable at this stage to examine the effect of varying the P.P.I. adjustment on the switch unit. Operation of this control changes the number of volts through which the sawtooth must raise the grid of the V506 before the bright-up pulse can begin since the number of microseconds taken on a sawtooth to raise V506 grid through a given number of volts will vary inverseley as the velocity of the sawtooth. Adjustment of this control will, therefore, delay the beginning of the bright-up pulse by the largest amount on the 50 mile scan, less on the 30 mile and least on the 10 mile.

180. There is also a radial P.P.I. adjustment control on the wave form generator. This is a screw-driver control and is a variable resister VR500 tied to earth through a condenser C525. The other end of the variable resister connects point A. The effect of this resistance and condenser arrangement is to delay the rise in voltage of the point D whilst a condenser C525 charges up. The rate at which it charges up is determined by the setting of VR500. This delay will not vary with the velocity of the sawtooth and so will delay the start of the bright-up pulse an equal number of microseconds on each scan.

181. Whilst, therefore, these two similarly labelled adjustments do the same thing their effectiveness on the various ranges are opposite to one another. By manipulation of these two controls it is, therefore, possible to start the three scans at approximately the same point on the tube. A series of adjustments on the trial and error principle may be necessary before the correct combination is found.

182. Bright-Up Mixture Stage.- We have seen how the bright-up wave form is produced at the anode of V507 and our problem now is to combine this wave form with the output from the receiver. The lead carrying this output is, therefore, brought to the wave form generator box via the grey Pye plug. The actual process of mixing these two wave forms together is complicated by the requirement that for the P.P.I. display the receiver output must be mixed with the bright-up wave form, whereas on the height tube display the bright-up pulse is not required. In fact, if it were present it would cause a step to appear on the height tube trace. We, therefore, have to employ an isolating stage (V512) so that we can take off the output to the height tube through a separate lead before it has become tangled up with the bright-up wave form. Accordingly, we apply the output through C540 to the red Pye plug and this is the height tube supply.

183. A lead is also taken from the grey Pye plug to the grid of V512. This valve is wired as a cathode follower and can be regarded as the last stage of the receiver circuit. Its cathode load is formed by the resistances R575, R576, R577. The signal frequencies are, therefore, fed from the upper end of R575, through a condenser and resistance network of a special form, the reason for which will be discussed later, to the grid of V508. The resistance R581 is inserted in the cathode of V508 which is also wired as a cathode follower and the final output wave form to the P.P.I. tube is taken from the black Pye plug connected to the cathode of V508. The bright-up wave form is mixed in with the receiver output on the grid of V508.

184. It is desired that a definite potential relative to ground should correspond to the "no signal" condition. To obtain this definite DC level of potential at the grid of V_{508} the potentiometer chain R_{571}, R_{572}, R_{578} and R_{582} is employed between the H.T. positive line and the negative 100 volt bias line which enters the unit via pin 13 of the 18-way N-Plug. R_{571} is the anode load of V_{507}.

185. In order to pass high frequencies to the grid of V_{508}, R_{572} is shunted by the condenser C_{532} and this combination then has a time constant 0.1 μF x 1.5 Megohms = .15 seconds. In order to avoid distortion of the wave form between V_{507} anode and V_{508} grid a similar resistance in series with a resistance and condenser in parallel is employed in the grid circuit. These are R_{573}, R_{574} and C_{533}. It will be seen that the same time constant is obtained although the values are changed, viz. R_{574} .15 meg. x 1.0 μF = .15 seconds.

186. The grid circuit of V_{508} is completed through the cathode load of V_{512} so that the grid potential of V_{508} actually follows both the wave form fed in from the cathode of V_{512} and the bright up wave form fed to it from the anode of V_{507}.

MODULATOR UNIT TYPE 64

187. What the modulator sets out to do is to produce a pulse of 3.3 kV. to apply to the transmitter. The pulse has a duration of approximately one microsecond and the peak power during this period is considerable, of the order of 120 kW. The immediate source of this power is the artificial line shown as AL.1 in fig.29. This is charged up from a high tension supply in the modulator during the intervals between pulses and is discharged very rapidly during the pulse itself. The function of the circuits in the modulator is to provide the high voltage necessary for the charging process, to time the discharge, and to provide the link by means of which this discharge is conveyed to the transmitter box.

188. Consider now how these various functions are performed. First of all, the charging process is performed by the high voltage rectifier comprising the valves V1 and V2. This is fed directly from the 80V. supply through a suitable filter circuit. This rectifier builds up a negative potential of about 3.5 kV across the condenser C2. Current commences to flow through L_1 into the artificial line and the condensers of the artificial line charge up one by one until the voltage of the line is equal to the voltage of the condenser C2. During the time that this is taking place, the current through L1 has been increasing, and there is, therefore, some energy stored in the inductance equal in fact to half LI^2, where L is the self-inductance of the coil and I is the current. This energy maintains the charging current into the line and actually charges the line to a voltage of almost double that of condenser C_2, viz. 7 kV. Current ceases to flow into the line when the current in L1 is reduced to zero. In the absence of any action from some other circuit the energy in the line would flow out again through L_1, since the voltage across the line is now higher than the voltage feeding into L_1 from C2. It is, however, arranged that at the moment that the artificial line reaches its peak voltage, it is discharged through the gas discharge tube V_3 into the 80 ohm line which feeds the transmitter. To obtain maximum transference of energy the capacitances and inductances forming the artificial line are chosen so that its characteristic impedance matches into this 80 ohm line. The circuits used for timing the discharge for "firing" of V_3 comprise the valves V_5, V_6 and V_7.

189. The valves V_5 and V_6 are connected as a multivibrator which would normally free-run. Its natural repetition period is however chosen so that it is slightly longer than the interval between the driving pulses from the wave form generator. Its frequency is thus speeded up slightly and locked to these pulses. Since it is necessary in the equipment to synchronise the timing of a number of the circuits with the "firing" of the transmitter pulse, it is obviously logical to time these circuits from the same source as that used for timing the transmitter pulse. Accordingly the plugs which supply these pulses labelled J, K, M and N are connected to the cathode of V6. The constants of the multivibrator circuit are so chosen that this cathode produces a positive 20 microsecond square wave at this point. The period during which V6 is off and V_5 is on may be adjusted by the setting of the potentiometer R_{24} which controls the grid voltage of V6. As stated above, this repetition time must be set so that it is slightly longer than the interval between the timing pulses.

190. The current pulse in V6 produces a 20 microsecond negative pulse at the anode which is phase reversed in the transformer T_4 and is applied as a positive

pulse to the grid of the valve V_7. This is the valve which is used to "fire" the discharge tube V_3. This discharge tube has two main electrodes and one auxiliary electrode. The auxiliary electrode takes the form of a small rod which is inserted in a hole drilled in one of the main electrodes. There is a small gap between the auxiliary electrode and this main electrode. This gap can be broken down by the application of a potential of 3kV. The main electrode which is perforated is connected to earth through the resistance chain R_{10}, R_{11} and R_{12} and the artificial line which is connected to the other main electrode is at a negative potential of about 7000V. To produce ionisation of the gas in the gas discharge tube, a potential is required on the trigger electrode and it is a function of the valve V_7 to furnish this suitable positive voltage.

191. To see how it does this, we must return to consider what happens when the 20 microsecond positive pulse is applied to its grid from the transformer T_4. V_7 is normally biased beyond cut-off by the metal rectifier W_1 fed through R_{28} and the secondary of the transformer T_4. The pulse on the V_7 grid runs the valve to grid current and switches it hard on. The screen circuit comprises the parallel resonance circuit L_3, C_{11}, R_{31}. This has a resonance frequency of about 25 kC, or a time for 1 cycle of 40 microsecond. The flow of screen current through this circuit.produces an initial fall in screen potential, but by the end of the 20 microsecond grid pulse, equivalent to half a cycle of the natural period of the circuit the screen potential rises again to the 300V. supply potential. In the anode circuit of V_7 is connected an inductance L_4. During the grid pulse, current reaching about .5 amps. is built up in this inductance. At the end of the grid pulse valve V_7 is sharply cut off. The energy stored in L_4 causes a very high positive voltage to build up at the anode of V_7, which is conveyed through C_{13} to the trigger electrode of V_3. This positive voltage pulse fires the tube, and discharges the artificial line as stated above.

192. It has been stated that the artificial line and the cable to the transmitter both have the same characteristic impedance of 80 ohms. If we consider the line therefore as a sort of battery having an e.m.f. of 7 kV. and an internal resistance of 80 ohms, feeding into a load also possessing a resistance of 80 ohms, it will be seen that the voltage must be reduced to half by this load, and the actual voltage applied to the line is therefore theorectically 3.5 kV. Actually, on account of losses in the gap and elsewhere the output voltage is about 3.3 kV. To enable the output to be monitored, the potentiometer R_{10}, R_{11}, and R_{12} is connected across the output, monitoring point being plug F.

193. Safety circuits.- Owing to the considerable voltages present in this unit and in the transmitter, a system of safety circuits is needed to safeguard the unit in case of short circuits developing. These safety circuits comprise the safety valve V_4, and the relays A, B and C. These faults will normally result in too much current being drawn through the rectifier. When this happens, relay A in the E.H.T. circuit of the rectifier will operate with the following results:

(i) Contact A/1 opens and removes the negative bias from the grid of the valve V_4 which is a protective valve.

(ii) This valve now conducts and relay B in its anode circuit is energised.

(iii) Contact B/1 opens and cuts off the H.T. supply from the trigger valve V_7.

(iv) Contact B/2 connects C_5 which has previously been discharged by R_{14} between the anode and grid of V_4.

194. As a result of the removal of the H.T. from V_7, the operating coil of relay C in its anode circuit is disconnected, the relay is de-energised and so the contact C/1 opens and cuts off the 80V. A.C. supply from the primary of T_3. Hence we get no E.H.T. to charge the artificial line. Since the H.T. is cut off, relay A is de-energised and the negative bias is again applied to V_4. Due to the presence of condenser C_5 the anode current falls gradually, but after a certain delay (about 20 seconds) this fall is sufficient to cause the relay to be de-energised. The contacts of this relay therefore revert to their original positions, viz. the contact B/2 then switches out C_5 and discharges it and contact B/1 switches the H.T. to V_7. Relay C is now energised and C/1 closes to feed the 80V. supply again

to the H.T. transformer T_3. The E.H.T. supply is thus restored to the artificial line.

195. If the fault which caused relay A to operate initially is still present, the same cycle of operation is repeated at about 20 second intervals until the fault clears itslef or the power is switched off.

196. The contact C/2 is for use when a modulator type 64 is used with another R.D.F. installation.

197. The location of individual components may be seen in the diagrams figs. 30 to 32. Wave forms are given in figs. 33 to 35.

T^2R UNIT, TYPE TR.3191

198. A circuit diagram of the T^2R unit is given in fig. 36 and figs. 37 and 38 show the layout of the principal components. The unit comprises the magnetron transmitter valve V_{101} which is supplied with its high voltage pulse from the modulator, the aerial feeder, the soft rhumbatron common T and R switch, the crystal mixer stage and one stage of I.F. amplification. Considering first the production of the R.F. pulse, this is produced by the magnetron when a voltage of about 10 to 15 kV. is applied between its anode and cathode. Since we wish to draw off the R.F. supply through a concentric feeder which is integrally connected to the anode, it is convenient to have this electrode at earth potential and we therefore arrange that we supply the cathode with a high voltage burst of negative potential. The cathode is heated by the transformer T_{300} which must, therefore, have its secondary winding insulated to withstand this voltage.

199. Referring to fig. 36, the 3.3 kV. pulse arrives via the 80 ohm lead marked 3/W and is applied to the pulse transformer T_{102}. The high voltage line of this is connected directly to the cathode of V_{101}. The valve V_{102} is a diode which has its anode connected through a 4 k. resistance to this high voltage point. During the negative pulse no current will flow in this diode, but owing to the unavoidable oscillatory nature of the discharge a positive overswing is produced after the initial negative swing, and this can be conveniently damped out by the conductivity of this diode. Any further negative swing which might produce a second "ghost" pulse is thus prevented from occurring.

200. The output from the magnetron is fed to the wave guide orifice in the scanner through a concentric cable and it is necessary to match the impedance of this cable to that of the resonant cavity of the magnetron. For this purpose a matching slug* is used.

201. Since the same aerial is used for both transmission and reception it is necessary to have some means by which the high voltage pulse from the transmitter can be prevented from reaching the easily damaged crystal mixer which is used on the receiving side. This is done by the use of the soft rhumbatron valve V_{100} illustrated in fig.39. The method is an extension of the "quarter-wave switching" which has been already employed in other circuits and it depends for its operation on the fact that if a short circuit is placed across one end of a quarter wave line the other end "looks like" a high impedance and vice versa.

202. The function of the V_{100} switching valve is to effect this changeover immediately after the transmitted pulse has been sent. The required short circuit is produced by the ionisation of the gas inside the tube. The construction of this valve is shown in fig.39. It is essentially similar to the reflector klystron which is described fully in S.D.0169 and in S.D.0419 with the exception that it has no gun assembly. The electrode, which in the klystron is used as the reflector electrode in the case of the rhumbatron serves as a probe. This is held at a pressure of -1000V. and therefore provides a D.C. field between its extremity and the earthed rhumbatron. The valve is filled with water vapour at about 6 mm. pressure. A coupling loop in the rhumbatron terminates the quarter wave concentric line which connects by means of a T joint to the feeder between the magnetron and the aerial. During the transmitter pulse a powerful burst of R.F. energy is supplied to this loop and produces an R.F. field in the cavity of the frequency at which the cavity is resonant. A

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* Note. The theory of matching of concentric lines is dealt with more fully than is possible in this manual in S.D.0169 para. 5. 3. 2. 3.

large oscillating current therefore builds up on the internal surface of the cavity producing a high H.F. voltage across the "neck"; this ionises the gas in the valve which has already been strained almost to break down point by the D.C. field due to the probe. The effect of the break down of the gas at the neck is to damp down very heavily the oscillation in the cavity. The cavity will then present a very low impedance to the R.F. frequency at the rhumbatron end of the quarter wave coupling line. The upper end of the coupling line therefore "looks like" a high impedance to the R.F. pulses and these latter pass through to the aerial without sensible loss.

203. Going back now to the cavity in the soft rhumbatron; this is provided with a second loop feeding into another concentric feeder which in its turn feeds into the crystal mixer chamber. During the transmitter pulse we have only a heavily damped oscillation in the cavity, and therefore only a small amount of power is drawn off to the mixer circuit. Even this is inconveniently large for the receiver to handle and therefore steps are taken to suppress the receiver during this period. It is not, however, great enough to cause damage to the crystal.

204. As soon as the transmitter pulse is over, the gas in the soft rhumbatron becomes de-ionised and there is then no low resistance path across the neck. The rhumbatron therefore is in a condition to respond to any received pulse which may be picked up in the aerial and fed to it. If and when such a pulse arrives it is not powerful enough to cause ionisation, and oscillations therefore build up in the rhumbatron proportional to the intensity of the received pulse and these induce currents in the second loop coupling the feeder to the crystal mixer chamber.

205. The theory of the crystal mixer has already been dealt with in S.D.0169 and S.D.0419, and therefore only a brief reference will be made to its functioning here. Since the navigator will require to observe the screen of the indicator whilst tuning his R.F. circuits, it is convenient to have the local oscillator situated in the indicator unit. The local oscillator can be made powerful enough to generate an oscillation which, although attenuated in the fairly long connector cable, will still be sufficiently large when it arrives in the crystal mixer box, to furnish a strong signal.

206. The crystal has been found up to the present to be the most generally satisfactory method of rectifying signals of the order of 3000 Mc/s. frequency, and it has the advantage that its efficiency can be tested by taking simple D.C. measurements of its forward and backward resistance. As a general rule the forward resistance should not exceed 200 ohms, although crystals having a forward resistance as high as 400 ohms have been found to give a satisfactory performance. The back to front ratios, that is, the ratios of the back resistance to the forward resistance should normally exceed 8:1 although in some cases crystals having a back to front ratio of 5:1 have been found quite satisfactory. The back to front to back check is not a complete test, but is a useful indication. The crystal capsule can easily be changed and the final decision will be to compare signals actually obtained with those obtained with a crystal which is known to be efficient.

207. The intermediate-frequency output is obtained by tapping off across a capacity connected between the crystal and the outer of the mixer chamber. This capacity acts as a short circuit to the 3000 Mc/s. frequency of the R.F. and local oscillator signals, but presents a comparatively high impedance at the intermediate-frequency of 13.5 Mc/s. The output of the crystal is transformer coupled to V_{125} which forms the first stage of the I.F. chain. This gives approximately 4:1 voltage step up and feeds to the green concentric cable to the receiver.

208. Due to the rectification of the R.F. currents by the crystal, a certain amount of D.C. is produced. This causes a D.C. current to flow through the primary of the first intermediate frequency transformer L_{126}, the choke L_5, the jack J_{125}, the terminal marked 2, pin 7 of the 12-way plug on the T^2R unit, through the junction box to pin 12 of the yellow 18-way plug to a meter connected in the indicator unit between pins 11 and 12 of the corresponding 18-way plug in this unit. This records the D.C. current through the crystal except when a portable meter is inserted in the jack J 125 in the T^2R unit.

209. To maintain the water vapour in the soft rhumbatron in a gaseous condition so that ionisation will always take place at the same applied pressure, the heating coils R_{105}, R_{107} connected across the 24V. D.C. supply, are provided. There is also

a blower motor for cooling the magnetron, fed through an interference suppressor unit of conventional design.

RECEIVER UNIT

210. This unit contains a normal I.F. amplifier of conventional design, diode detector, output valve, and also a series of circuits each performing different functions and grouped together on one chassis under the general title of the Receiver timing unit. A complete circuit diagram is given in fig.40 and the positions of the principal components in the unit are shown in figs.41 to 44. Waveforms at numerous points in the receiver unit are given in figs.45 to 50.

211. The output from the T^2R unit enters the receiver unit through a concentric cable and a green Pye plug, to feed directly into the intermediate frequency transformer tuned to 13.5 Mc/s. in the grid circuit of the valve V_1. Five stages of intermediate frequency amplification follow this valve making six stages in all. An intermediate frequency transformer is connected to the anode circuit of the last stage and the secondary of this transformer is connected directly between earth and the cathode of the diode valve. The diode load is connected between anode and earth and across this a signal potential is developed as a negative pulse. This is applied through L_5 and C_{49} to the grid of V_8 and results in a positive pulse output at the anode of V_8. This is taken to tag 7 on the tag strip through which connections pass to the timing unit located on the other chassis. At this point we have only the signal present in the receiver output.

212. As has been stated in the general description, para. 51 this output has to be mixed with a course marker pulse, and the range marker pulse. The bright-up mixer pulse which has also to be added is formed in the waveform generator box and the output of the receiver is therefore taken through the slate Pye plug and the coaxial lead to the waveform generator box for this purpose.

213. Height marker pulse formation.- The valves used for producing the height marker pulse are also housed in this unit. They are: V_{400}, V_{401}, V_{402}, V_{403}. Since the height marker is used on the 10-mile range for timing the range marker pulse, we will first consider how the height marker pulse is produced.

214. The 20 microsecond priming pulse from the modulator enters the receiver timing unit through the violet Pye plug, and is connected to one side of the pulse transformer T_{400}. The waveform at this point is shown in fig.51, and can be seen to consist of a 20 microsecond positive pulse followed by an interval of the order of 1500 microseconds. What the height marker pulse forming circuits have to do is to produce a short pulse of about one microsecond duration which can be applied as a 'Blip' to the trace of the height tube. It is necessary for this pulse to be produced at some time after the end of the modukator priming pulse, which time can be exactly controlled. The most convenient way of producing a pulse having a nice symmetrical shape is to employ a delay network.

215. V_{401} and V_{402} form a "flip-flop" circuit. This circuit can be stable with either V_{402} conducting and V_{401} cut off or vice versa. Considering first the state in which V_{402} is conducting and V_{401} is cut off the "flip-flop" effect is brought into operation by the application of a positive voltage to V_{401} grid. The output of the "flip-flop" circuit is taken from V_{401} anode, so that what we have to do is to time the arrival of a positive impulse at V_{401} grid. This has to be delayed by a variable amount after the negative priming pulse has been applied from T_{400}. The double diode valve V_{400} performs this relaying action and is fed with the priming pulse on its cathode.

216. Consider now the voltages present on the various electrodes of V_{400}. During the interval between pulses, the grid is driven down negative to the cathode and the valve is cut off. The reason for this is as follows; when the pulse occurs, the cathode is driven negative and current flows in the grid circuit charging the grid condenser C_{402}. At the end of the pulse the cathode rises to a potential positive with respect to the grid, the grid cathode path then becomes non-conducting and the charge remains on the grid, holding it negative until the next pulse arrives. In the absence of pulses, it would in fact leak away relatively slowly through R_{401}. When the 20 microsecond negative pulse which has an amplitude of about 16V. drives the cathode of V_{400} down in potential, the diode anodes, which are coupled together and

connected to the lower plates of the condensers VC400, C461 and C403(which are all connected in parallel) are lowered in potential by about 14V.

217. The resistance R400 in the anode circuit of V400 has its upper end connected to the 300V. stabilised line, and when current in the triode section of V400 is cut off at the grid, the timing condensers will commence to charge exponentially. The voltage of the grid of V401 connected to the V400 anode through R405 will rise until the cut off value of V401 is reached, and the "flip-flop" circuit will then be fired. This firing will occur earlier or later according to the potential level of the lower plates of the timing condensers, which are directly connected through pin 4 of the 6-way plain W-plug to the height control potentiometer in the switch unit.

218. The grid of the valve V.402 is supplied with a variable potential adjustable by means of the height zero adjustment in the switch unit. This voltage reaches the grid of V.402 through Pin 6 of the 6-pin plain W plug. Current flowing in the valve causes the cathode to sit at a voltage approximating to the grid voltage owing to the drop in the cathode resistance R.406 of 15,000 ohms. The cathode of V.401 is directly connected to the cathode of V.402, and V.401 is therefore cut off. The "flip-flop" circuit will fire when the grid of V.401 reaches a potential within about 10 volts or so of that of the cathode. This will occur as explained in para. 217 above when the timing condensers connected between V.400 triode anode and the diode anodes have charged up sufficiently.

219. During the interval between the firing of the "flip-flop" circuit and the end of the next priming pulse, the valve V401 is conducting. When it is conducting its grid potential is about +150 volts and its cathode current will therefore be about 10 mA. The anode current will be about 75% or 7.5 mA. The delay network L.400, C.405 etc., connected in the anode circuit has an impedance of approximately 2,000 ohms terminated by R409 of 2000 ohms and this forms the anode load. Anode potential governed by the drop in R409 will be about 15 volts below that of the supply (+ 300 volts stabilised).

220. The anode potential will rise as soon as the valve switches off and fall again as soon as it switches on. The delay network has a time period of 1 micro-second so that anode current will continue to flow in the terminating resistance R409 whilst the condensers C405, C406 to C409 discharge in succession through it for a period of 1 micro-second after it has stopped flowing in the valve. This same delay will take place when the valve again conducts, that is to say, current will not flow in R409 until 1 micro-second after the anode current has started again. The waveform obtained at the cathode of V401 is as shown in fig. 45 as will be seen in para. 223 below we are not interested in the pulse formed by the switching off of the valve V401 but we will consider exactly what occurs when we switch on the valve.

221. When we do this the anode potential drops and causes a drop in potential of the point 1 of T301 through the coupling action of C409. This is stroke 1 of the waveform shown in fig.51 curve f; simultaneously the junction of L400 and L401 falls in potential because of the coupling action of C405 and so do all the other junctions between the inductances L401, L402, L403, L404. After a period equal to the delay per section C405 charges up, then after equal intervals C406, C407, C408 and C409 become charged when C409 is charged to H.T. potential; (stroke 2 of fig.51 curve f)this is the end of the pulse.

222. Consider now the effect on applying these pulses to the transformer T401; the terminals 1 and 2 of this transformer are connected across the delay network, and the pulses which appear on the secondary of this transformer are the positive and negative 1 micro-second pulses. The direction of winding of T401 is arranged to phase-reverse the pulses and these are applied to the grid of V403.

223. This valve is connected as a cathode follower, its cathode load consists of a delay network and its grid is permanently biased sufficiently far to cut the valve off. When the negative pulse is applied to the grid, this has no effect since the valve is already non-conducting. The positive 1 micro-second pulse corresponding to the switching on of V401 however, raises the grid of V403 sufficiently to switch the valve on, and the pulse appears at the cathode. After an interval of approximately 2 micro-seconds it reaches the last but one section of the delay, at the

junction of L414 and L415, to which is connected the white Pye plug. From this plug it is supplied to the indicating unit.

224. Thus we see that the shape and duration of the height marker pulse is determined by the constants of the delay network L400, L405 etc. in the anode circuit of V401, and that it is delayed 2 pulses in the cathode of V403 before being passed on to the indicator. This delay network is terminated by R414 equal to its own characteristic impedance to avoid reflections.

225. The potential changes of the more important points in this chain of operations are given in fig. 51 curves these curves have been simplified and the pulses drawn to a distorted time scale to show the smaller intervals.

226. To appreciate the reason for the delay in the cathode circuit of V403 we have to consider exactly what happens when we time the range marker pulse from the height marker for the purpose of displaying slant range minus height or increment on the 10-mile range (see para. 28 above) and we will refer back to this after we have considered the production of the range marker pulse.

227. The Range Marker.- The range marker adjustment operates in a similar manner to the height marker but a rather more elaborate circuit arrangement is required because of the three alternative ranges. What the range marker circuits set out to do is to produce a pulse which can be applied to the grid of the P.P.I. tube at some specific radial distance from the centre of the tube on each scan so that the range marker appears as a brightened circle on the scan. The function of the valve V406 is to time the moment on the scan that this brightening takes place and the function of V407 and V408 is to fashion the actual pulse so that it is of suitable shape and duration.

228. As this is not the only voltage which is going to be applied to the grid of the P.P.I. tube, arrangements have to be made to mix in this pulse with the output of the receiver proper.

229. Having now stated in general terms what we are going to do, we will consider in detail the circuit arrangements used. First, the valve V406, the timing valve, has to time the triggering of the multi-vibrator V407 and V408. This multi-vibrator operates with V407 conducting for most of the interval between the priming pulses on the modulator. During the period from the commencement of the initiating pulse which may be either the priming pulse from the modulator or a pulse from the height marker circuits, the valve V407 is in the non-conducting state. The interval which must elapse until it reverts to the conducting state is determined by the rate at which the condensers VC401, C462 and C431 can charge up exponentially through the resistances R464 etc. in the anode circuit of V406. Reference should be made to fig.48 for waveforms at these points.

230. The movement in anode potential of V406 during this timing period is as follows. Firstly, its maximum level is set by one of the diode anodes of V405 at a little over 150 volts. When relay A is in the unenergised condition, the positive pulse from the modulator after phase reversal in T400 becomes negative and is applied through C428 to the cathode of V406. The valve, which is biased by grid current between pulses in the same manner as V401, conducts and lowers the potential of the anode. The lower plates of the timing condensers are connected to the diode and it will be seen from the circuit that the potential of these can never exceed that of the cathode decouple point to which they are connected through R438 nor can they ever be much higher than the cathode potential. The diode anodes potential therefore follows that of the cathode during the negative pulse but when this finishes and the cathode potential rises above that of the point to which it is decoupled, the diodes stay at the decoupling potential. By this means the overswing and bass loss effects on the cathode are removed from the diode anodes and so from the lower plates of the timing condensers for a considerable period following the pulse. When the cathode potential falls the triode portion of the valve conducts and the anode potential is reduced to within a few volts of that of the cathode. The potential of the anode does not fall as rapidly as that of the cathode as the timing condenser has to be discharged to the difference in anode and diode potentials. i.e. from 150 volts or so down to a few volts.

231. At the end of the 20 microsecond pulse, the triode is cut off and the diode potential rises to the cathode decoupling potential. The anode follows this sudden

rise very closely and then the timing condensers begin to charge through the anode resistances. As stated above, the anode potential then rises exponentially towards the 300 volt stabilized supply line. Only the early part of the charging curve is used so that the rise is fairly linear.

232. The level at which V407 grid fires the multivibrator is determined by the potential applied to the grid of V408 from a range zero adjustment in the switch unit supplied through pin 5 of the 6-pin W-plug and R444.

233. As with the height marker pulse, a delay network is used for shaping the pulse; this is connected in the anode circuit of V408. The pulse output is taken to a cathode follower which is biased beyond cut-off so that only a positive pulse is passed on to subsequent circuits. V407 is switched off from the start of the priming pulse until the time at which the potential of V406 anode reaches the critical potential for V407 grid. V408 is on during this latter period and otherwise off. The pulse shaping network is in the anode circuit of V408 and consists of six sections each having a delay of .092 microseconds. The delay is terminated by a resistance of 4,000 ohms equal to its characteristic impedance and it is short circuited at the far end. When the valve V408 is switched on at the beginning of the pulse, the anode potential drops. The impedance in the anode circuit looking towards the terminated end of the delay is 4,000 ohms and it is across this impedance that the potential drop is built up. The fall in anode potential creates a potential difference between the two ends of L417 which starts to build up current drawing it from the shunt capacity at the junction of L417 and L418.*

234. As this capacity charges a voltage is built up across L418 which in turn starts to draw current from the next condenser in the series C435. This process goes on until the last inductance L422 starts to take current from the supply. As soon as L422 has reached its full current the potential across it drops to zero and C438 becomes discharged and the remaining condensers are discharged sequentially as the current reaches its final value in each coil in turn. The final steady state is with all the condensers discharged and V408 steady anode current flowing through the inductive chain. The voltage drop in these is negligible. Thus we have produced at V408 anode a square negative pulse.

235. There are six sections between the anode and the shorted end of the network; the negative pulse on the anode therefore lasts for 2 x 6 x .092 = 1.1 microseconds because it has to travel to the end of the delay and back. Only five sections are between the input point for V409 and the shorted end and the negative pulse applied to V409 grid therefore lasts for 2 x 5 x .092 = .92 microseconds and is delayed by the delay of one section, i.e. .092 microseconds after the anode pulse. When V408 is cut off, the reverse process occurs and a positive pulse lasting .92 microseconds is passed to V409. This is the actual operating pulse. The positive pulse appearing at the cathode of V409 has an amplitude of about +8 volts and is mixed with the signal output from the IF amplifier on the grid of V411.

Range Marker Calibration

236. To enable the operation of the range marker control to move the range marker over the full length of the scan on each of the three ranges, it is necessary to have three alternative time constants in the anode of V406. These are selected by means of relays which are energised from the range switch through pins 4 and 5 of the 12-way W-plug and pin 2 of the 18-way W-plug. Relays are labelled A and B in the diagram. When A is energised on the 10 mile range, only R464 is in circuit; on the 30 mile range B is energised and A is unenergised placing R464, R437 and R436 totalling 1.525 megohms in circuit and on the 50 mile ranges all the resistances totalling 5.325 megohms are in circuit.

237. On the 30 and 50 mile ranges the timing is taken from the modulator pulse as explained above; on the 10 mile range the range marker timing is taken from the circuits which produce the height marker pulse. The actual point of connection being the anode of V402. Accordingly, the condenser C428 which feeds the initiating pulse to the cathode of V406 is connected to V402 anode on the 10 mile range. When the

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* Note: This particular capacity is omitted as a condenser forming part of the delay and exists only as the input capacity of V409.

height marker pulse is being produced by the sudden fall in the potential of V401 anode when it swings over to the conducting condition, the anode of V402 rises. This rise in potential corresponds to the rising stroke at the end of the negative modulator pulse which it normally gets from T400 in the 30 mile and 50 mile positions. The grid bias of V406 is maintained in the same manner by the current charging it during the period that V402 is low.

238. The range marker is accordingly timed from the moment at which the height marker is formed at V401 anode. The actual moment at which the height marker appears on the height tube trace is delayed two microseconds in the cathode circuit of V403. This means in effect that it appears a little further up the trace than it otherwise would, depending on the speed of the scan. No such delay is introduced in the production of the range marker pulse and therefore when this is moved down towards the zero end by operation of the range control, it can be brought down into coincidence with the height marker pulse even though it is triggered from the same circuit as the height marker. This is the reason for the inclusion of the delay in the height marker pulse output.

Course Marker

239. As we have previously stated, the orientation of the picture on the P.P.I. tube is controlled from the DR compass. To show the pilot the actual direction of flight in relation to the map which is locked by the DR compass to the true North position, we produce on the map a bright line. The way this is done is to brighten at least one of the traces when the scanner is pointing dead ahead. A rather elaborate circuit arrangement is used to achieve this result and it comprises the condensers C422 and C423 and the resistances R465, R418 and R416, together with the first half of the diode V410.

240. In order to brighten one trace on the P.P.I. tube, we have to apply a positive voltage to the grid of the P.P.I. tube. We can do this by mixing in to the receiver output a positive impulse of the required duration. One way in which this can be produced is to cut off the valve V8 at the suppressor grid by the application of a negative voltage exceeding about 25 volts for the required time. On all the scans the duration of the stroke and flyback is about 1500 microseconds and if we apply a pulse lasting somewhat longer than this we should be sure to brighten at least one scan.

241. The timing is obtained from a cam-operated switch in the scanner. The shape of the cam is a semi-circle see fig.65 and it is arranged so that the contacts are made at the moment that the scanner is pointing dead ahead. The contacts remain closed for about 30 seconds and then open for the remaining half of the revolution. These contacts are connected through to pins 10 and 12 on the 12-way plug; pin 12 is earthed.

242. In the switch unit there is a two-pole single-way switch with "ON" and "OFF" positions. This is connected to pin 7 of the 12-way W-plug which connects to the switch unit. When the course marker facilities are required, this switch is in the "ON" position and pin 7 is connected to +300 volts in the switch unit; in the "OFF" position this pin is earthed.

243. The suppressor grid of V8 is connected to the diode anode of the first half of V410, the corresponding cathode being earthed. This diode anode is connected through R416 to +300 volts. It therefore prevents the suppressor grid of V8 rising appreciably above earth potential but it can, of course, fall to any potential below earth. Consider the system when the course marker contacts have just opened, i.e. that pin 10 of the 12-way plug connected to R465 has just been disconnected from earth. Current will flow from the 300 volt supply through R418, charging C422 and C423. The time constant is 1 x 0.1035 = 0.1 seconds approximately. During the period therefore that the contact in the scanner is open, these condensers will charge up to approximately 300 volts because the opposite sides of the condensers are connected to earth. C423 is connected directly and C422 through the diode V410.

244. When the contacts close C423 discharges through R465, the time constant is 1,000 x .1 microseconds = 100 microseconds so that within about 300 microseconds the junction of C422 and C423 will be reduced to very nearly zero potential. This drop of nearly 300 volts will be applied to the other plate of C422 which was previously

at earth potential, driving it down to the full extend of the voltage change that is to nearly -300V. As soon as the fall of voltage ceases, this side of C422 will commence to charge up from nearly -300 volts towards +300 volts through R416, the time constant in this case being 1 x .0035 = 0035 seconds = 3500 microseconds. The time taken therefore for the diode anode to reach zero potential will therefore be of the order of 2500 microseconds, i.e. .7 time constant.

245. The suppressor grid of V8 is also connected to this point and it will therefore be held down below a potential of -25 volts for a period comfortably exceeding the repetition period necessary for the establishment of the course marker.

Signal and Marker Mixer

246. We have seen in the preceding paragraph how the course marker signal is added to the output of the IF amplifier in the valve V8. The output of the IF amplifier is a negative signal applied to the grid of this valve and we have just seen that the course marker is also a negative signal applied to the suppressor grid of the same valve. The output from the valve which is taken from the anode is therefore positive. The cathode is earthed. Our problem now is to introduce the range marker signal present on the cathode of V409, and it is done as follows.

247. Included in the anode circuit if V8 are the resistances R452 and R451, together with a HF stopper L6. During the intervals between range marker pulses, V409 is cut off. The effective anode load of V8 is then R451 +R449 = 1500 ohms. When the range marker pulse occurs, the cathode impedance of V409 is reduced to about 100 ohms so that the effective anode load of V8 then becomes only about 1100 ohms. At the same time the cathode potential of V409 and therefore the anode potential of V8 is raised by about 8 volts for the duration of the marker pulse. By comparison with the signals present, this is about two-thirds of the peak signal, viz. 12 volts. V8 anode is coupled by C441 and C442 to the grid of V411. V411 grid is connected to the cathode of the second half of the double diode V410 and the corresponding anode is maintained by the potentiometer R461, R462.

248. This potentiometer sets the minimum level of the potential of V411 grid at +1.4 volts with respect to earth. This level will therefore correspond to the lowest potential reached by V8 anode. This will occur during the time that V8 is most conducting, i.e. when it is not receiving rectified signals from V7. This period in practice corresponds to the period during each repetition cycle when the receiver is suppressed during the transmitter pulse. The potential levels of V11 grid therefore will be as follows:-

(i)	During suppression interval	+ 1.4 volts
(ii)	Range marker	+ 10 volts
(iii)	Peak signals	+ about 16 volts

The valve V11 is connected as a cathode follower and the output appears at the grey Pye plug which is connected to the cathode. The cathode resistance of V411 is R467.

249. The actual function of the various resistances in the anode circuit of V8 may be a little confusing at first sight. The supply of 300 volts is first of all reduced in R415, decoupled by C421. This point may be regarded as the source of HT supply. The resistance R452 of 10,000 ohms should also be regarded mainly as a dropping resistance because its lower end is connected through the one mfd. condenser C440 and the cathode resistance of V409, i.e. R449 to earth. The real effective anode load, therefore, is R449 plus the 1 k. resistance R451. The voltage movements of the various points in the circuit have already been dealt with in para. 248 above.

Suppression Generator

250. It has already been stated that it is necessary to suppress the receiver during the period of sending the transmitter pulse. This is effected by reducing the amplification of the valves V1 and V3 in the receiver to zero for the required period. To do this we connect the screens of V1 and V3 to the anode of the valve V412.

During the suppression period this anode is reduced to approximately zero potential. A lead is taken from the violet Pye plug which brings in the pulse from the modulator to the delay network L_{423} etc. This delay network is terminated at both ends by resistances R_{457}, R_{456}.

251. The modulator pulse develops a voltage of about 16 volts across R_{456} to which it is applied; the pulse can be delayed in one microsecond steps up to 8 microseconds in the delay before being dissipated in the terminating resistance R_{457}. Between pulses the valve V_{412} is biased by grid current beyond cut-off. When the pulse arrives, the valve is switched hard on and the anode potential is reduced to very nearly zero volts to effect the suppression as outlined above.

252. The transmitter pulse takes place immediately after the end of the priming pulse from the modulator and the disturbance created by the transmitter pulse is all over within about two microseconds of this time. What we have to do therefore, is to ensure that the receiver is suppressed over this critical period. If therefore we set the control on the delay network so as to delay the pulse by say 4 microseconds, we shall actually be suppressing the receiver by means of this 20 microsecond priming pulse from about 16 microseconds before the transmitter has fired until about 2 microseconds after its firing. The delay is adjusted in service so that there is just not any break through from the transmitter into the receiver.

Voltage Stabilizer

253. The only remaining valve which has not been considered in the receiver unit is the valve V_{404}. This is a voltage stabiliser to remove any low cycle fluctuations in the HT supply which are not smoothed out by the normal smoothing condensers. The principle on which it operates is that the 300 volt supply is applied to the anode of the valve through R_{421} and to the grid of the valve through C_{424}. Considering the effect of applying the supply voltage to the grid we may say that any fluctuations of voltage will affect the current drawn through R_{421} and produce a voltage at the lower end of R_{421} 180 degrees out of phase with the input to the grid and will oppose at the lower end of R_{421} the fluctuations applied directly through it. If the value of R_{421} is correctly chosen having regard to the voltage factor of the valve, (the value demanded by theory is $\frac{1}{g}$ ohms where g is the mutual conductance of the valve). These fluctuations can be made to cancel out.

Indicating Unit Type 162

254. The circuit diagram of this unit is given in fig.52 and details of component layouts in figs. 53 to 55.

255. In the indicator unit there are 2 tubes, the P.P.I. tube and the height tube. There is also an amplifier for the signals to be applied to the grid of the P.P.I. tube, the time base forming-stage for the height tube and also the local oscillator which is included in the indicating unit box for convenience of tuning. Let us consider first the way in which the output from the magslip stators produces the rotating time base on the P.P.I. tube. The necessary voltages enter the indicating unit through the 4-pin W-plug, W_{198}, and are applied to 2 transformers, T_{651} and T_{652}. The secondary windings of these are split and have their inners supplied through a resistance network with the shift voltages; the outers, which will be 180 degrees out of phase with each other, feed the actual saw tooth voltages to the deflecting plates. To compensate for varying sensitivites in different tubes alternative tappings are provided by which the voltage applied to the plates may be adjusted.

256. The shift voltage which is really the mean DC level, is applied to the horizontal deflection plates from the variable potentiometer VR656 and to the vertical deflection plates from the variable potentiometer VR657. These potentiometers in parallel form part of a chain connected between +1800 volts and -1800 volts. The horizontal shift chain comprise shift adjuster VR656, R701, R702, R694, R695, R696, R697, VR655, R698, R699, VR654, R673 and R674 to -1800 volt line. When VR656 is adjusted the potentials of the two halves of the secondary windings of T_{651} are shifted in potential, one up and one down.

257. A similar chain is employed to operate the vertical shift adjustment. This feeds through VR_{657}, R_{708}, R_{709} and then on through the same chain to 1800

volt negative as for the horizontal shift. The magnitude of the sawtooth applied to each pair of plates has already been resolved into sine and cosine components in the magslip geared to the scanner, and since these two voltages are being applied in the correct phase to both pairs of deflection plates, the result must be to reproduce a rotating diametral scan.

Signal Amplifier

258. The signal with its course marker, range marker and bright-up pulse added arrives via the black Pye plug and is applied to the cathode of the valve V653. The signals take the form of positive pulses which are amplified without change of phase in the valve V653 and are applied to the grid of V652. This latter valve is connected as a cathode follower with its cathode load formed by R733, R716 and R717. The signals are taken off from the junction of R733 and R716 and applied through the condenser C674 to the grid of the P.P.I. tube.

259. The valve V652 is DC coupled to V653 by R719 and the condenser C671 is connected across this to ensure transference of higher frequencies. The grid is maintained at a suitable level by a connection to the negative 100 volt line through R718. This gives us a coupling network comprising a condenser and resistance in parallel, in series with a resistance. A similarly constituted network is therefore arranged in the anode of V653 comprising R726 in series with R724 and C673 in parallel. When the values of components are correctly chosen, this arrangement ensures equal transference of all frequencies from V653 anode to V652 grid.

Height Tube

260. The time base on the height tube consists of a single vertical line and is produced by the application of a suitable sawtoothed voltage to two opposite deflection plates of the tube. These are supplied from two secondary windings of the transformer T650, the primary of which is fed directly from the 2-pin plain W-plug which brings in the sawtooth scanning waveform from the waveform generator box. Tappings are provided to adjust the length of the scan according to tube sensitivity.

261. Vertical shift is provided by the potentiometer VR658 in a similar manner to that employed on the P.P.I. tube.

262. Brightness control is obtained from VR652 and the diode restorer V658 prevents the grid of the P.P.I. tube rising above the level set by this control. During the flyback period the grid of height tube is reduced in potential by a circuit arrangement comprising C682, C683 and R730 the theory of its operation may be explained as follows.

Control of height tube black-out

263. In order to black out the tube during the flyback stroke, it is necessary to apply to the grid of the tube a square wave form. We have no convenient source of such a waveform in the indicator unit and so we obtain one by differentiating the sawtooth waveform which provides the scanning stroke.

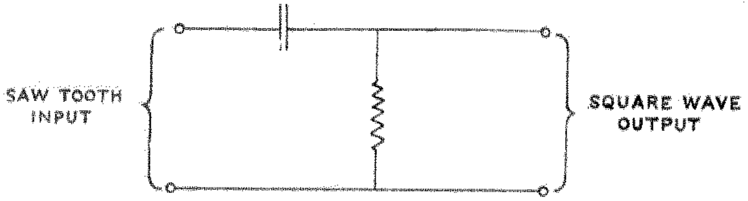

Fig. 59 Generation of height tube brightening

264. Looking at the transformer T650 the terminal 11 provides a convenient source of sawtooth voltage. This is applied to the condenser C683 paralleled by C682 in series with the resistance R730. This resistance has a value of one megohm and the other end of it is connected to the cathode of the tube. During the rising stroke of the sawtooth the junction of C683 and R730 will be at a steady potential corresponding to the positive portion of the square wave (see fig.59) and when this sawtooth reverses its direction this point will drop in potential and remain at the value of the negative part of the square wave during the whole of the falling stroke. Connected to this junction point through the condenser C679 and the comparatively low resistance R729 is the grid of the height tube. This grid accordingly follows the square wave potential, thus allowing the trace to be brightened during the rising stroke but blacked-out during the falling stroke of the sawtooth.

Note:

265. The exact process by which a sawtooth waveform is converted to a square waveform by a condenser and resistance network may present a little difficulty in following at first sight. Let us however, consider the reverse process, i.e. the charging of a condenser by arranging for a steady charging current to flow into it; the voltage across it will rise at a steady rate, i.e. the waveform of the voltage between the plates of the condenser will form part of a sawtooth. If we now reverse the direction of flow so as to discharge the condenser the voltage between the plates will commence to fall at a uniform rate. This is the negative slope of the sawtooth. A sawtooth voltage across a condenser may therefore be derived from a positive and negative steady voltage applied alternately to the condenser with a resistance in series with it. Conversely the application of a sawtooth waveform to a condenser and resistance in series results in the production of a square waveform across the resistance.

266. Signals are applied to the two horizontal deflection plates of the height tube from the paraphase amplifier V650, V651, the receiver output combined with the range marker and course marker pulses comes from the red Pye plug in the generator box and enters the indicator unit through the orange Pye plug and is applied after amplification through V650 to one of the horizontal deflection plates. Owing to the coupling between the cathode circuits of V650 and V651 the same plates may also be supplied through V651 with the height marker pulse which enters the indicator unit through the yellow Pye plug. This plug is connected by a co-axial cable to the white Pye plug on the receiver unit.

267. Diode restorers V656 and V657 are employed to prevent lateral displacement of the scan by the signals or by the marker pulses.

Local Oscillator

268. The remaining two valves in the indicating unit, V654 and V655 are merely housed in the indicating unit for convenience in operating the equipment and do not form part of the indicator as such. They are put in this box because it is desirable for the operator to be able to view his screens while tuning the local oscillator. Furthermore, there is a convenient source of -1800 volts which is used to supply the high tension for the Klystron valve.

269. The action of this valve has already been described in SP.0169, Chapter 9 and also in SD.0419. The cathode is supplied with a negative potential approaching 1500 volts and the reflector electrode is supplied with a variable potential having a negative value in the region of 1500 volts from the potentiometer VR650. The output is taken by means of a concentric cable from the rhumbatron. The frequency is adjusted by varying the volume of the rhumbatron cavity.

270. As may be seen from the circuit diagram, the rhumbatron valve V654 is connected in series with the resistance R662, R661, the valve V655 and the resistance R659. The purpose of the valve V655 is to stabilise the current through the Klystron. The grid of the valve V655 is fed from a potentiometer R654, R655, R656, R657 and R658 across the -1800 volt supply. This potentiometer draws about .5 mA. The ratio of these resistance is such that the grid potential is approximately 50 volts above the HT negative potential and is decoupled to the -1800 volt line by C650. The cathode resistance R659 is 8000 ohms. Due to the current flowing through

the valve, the voltage developed across this resistance is about 52 volts; and the cathode therefore sits at 52 volts above the -1800 volt line. The valve is accordingly biased about 2 volts. The cathode current is of the order of 6.5 mA.

271. The height tube and the P.P.I. tube have their various electrodes fed from two potentiometer chains connected between +300 volts and -1800 volts, and +1800 volts and -1800 volts respectively. The resistance R673 and R674 are common to both chains. The junction of R673 and R674 has a voltage of approximately 100 volts above the -1800 volt line, and the screen of V655 is connected to this point.

272. Current through the valve divides between anode and screen, the anode current being approximately 6mA and the screen current .5 mA. The anode current is the feed current to the Klystron valve. The action of V655 is to maintain this feed current at a constant value in spite of fluctuations in the value of the nominal -1800 volt supply. Suppose, for instance, that this supply falls slightly, the current through R659 will fall and the grid voltage applied to V655 between grid and cathode, i.e. the bias, will fall, allowing the valve to become more conducting so that the resistance of the valve will fall and compensate for the reduced HT supply available. The reverse process will occur if there is any rise in the voltage of the line. By this means the current is kept steady.

273. This steady current flowing through the resistance R661in parallel with the variable resistance VR650, causes a constant voltage drop across this latter and a selected fraction of this voltage drop is applied from the slider of the potentiometer to the reflector electrode of V654. The value available is between 260 volts and 400 volts negative to the cathode of the Klystron; the minimum reflector voltage being set by the ratio of R662 to that of R661 and VR650 in parallel. C652 decouples the reflector electrode to the cathode of the Klystron.

274. The control VR650 is mounted on the front panel of the indicating unit and is labelled "mixer current". The meter which indicates the DC component of the current passing through the crystal mixer in the T^{2}R unit is also mounted on the indicator panel. This meter is coupled to the T^{2}R unit through pins 11 and 12 of the 18-way plain W-plug on the indicator, via. the junction box.

275. The connection between the crystal current and the reflector voltage is somewhat indirect and to understand how the alteration of reflector voltage affects crystal current and to see how the best setting of reflector voltage can be obtained, the following explanation is given. As has been stated in the paragraphs dealing with the T^{2}R unit, the DC component of the crystal current is obtained by rectification of the output of the local oscillator. The crystal current reading is therefore an indication of the joint performance of the crystal and local oscillator. If it has been established by measuring the back-to-front ratio of the crystal with an Avometer that the crystal performance is up to standard, then the crystal current reading is evidently a measure of the output of the local oscillator.

276. As VR650 is operated, the voltage on the reflector electrode of the Klystron is varied. This varies the spacing between the electron bunches which strike the rhumbatron orifice. The Klystron will oscillate most strongly when these bunches are arriving at exactly the right intervals on their return journey through the orifice to produce a field which is in phase with the field generated by them on their outward journey (see Klystron operation, S.D.0169, Chapter 9). The oscillation frequency is determined by the physical volume of the rhumbatron cavity. Slight changes in the power supply voltage will result in slight changes in the spacing between the bunches of electrons and the impulses will not be applied to the resonant cavity at exactly the right moment to cause maximum feed back of energy. The amplitude of oscillation will accordingly die down somewhat. The effect of changes in the power supply voltage on the oscillator amplitude can be minimised by carefully setting the reflector voltage.

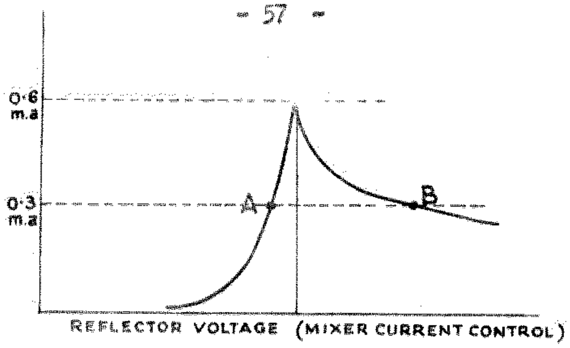

Fig. 60 Crystal current control

277. The relationship between crystal current and reflector voltage for different settings of the reflector voltage control is given in fig.60. This figure shows that as the voltage on the reflector is increased, the crystal current rises sharply to a maximum about .6 mA and then falls away rather more gradually. If the mixer current control therefore is turned through the maximum position until it arrives say at point B on the curve on the fairly flat portion past the maximum, it is obvious from the shape of the curve that small variations of reflector voltage will not result in serious fluctuations of the crystal current. Furthermore, should a sharp fall in supply voltage occur, such as might happen due to a sudden change in engine speed, there is no danger that the voltage will fall sufficiently far for the oscillations to die out. If, however, the equipment were being operated at the point A, a fall in reflector voltage might easily extinguish oscillation.

278. The procedure therefore in setting the controls is to turn it slowly from its extreme anti-clockwise position in a clockwise direction through the peak oscillation to a setting where the meter reading falls gradually but is stable. The peak should be about .6 mA and the stable reading obtained should be between .3 and .4 mA.

279. It is not desirable that too great a local oscillator voltage should be applied to the crystal mixer as this tends to swamp the received signals. The amount of energy transferred to the crystal mixer chamber can therefore be varied by varying the coupling between the concentric cable and the cavity at the local oscillator end. Energy is withdrawn from the cavity by means of a loop attached to the inner of the cable and projecting into the cavity.

280. The degree of coupling can be varied by rotating the plane of this loop so as to intersect more or less of the field in the cavity. Adjustment is made by loosening the screws holding down the clamping plate which in its turn secures the plug fixed to the panel. When the clamp plate screws are loosend, the plug, line and loop may be rotated together to adjust the coupling.

SCANNER AND HEADING CONTROL UNIT

281. These two items of the H_2S equipment will be considered together and with them will be considered briefly the action of the DR compass.

282. On the scanner unit there is the scanner mirror and its driving motor, the magslip for controlling the orientation of the picture of the P.P.I. tube in the indicator, and the repeater motor which controls the position of the stators of the magslip.

283. In the scanner assembly, which during operation is continually rotating, arrangement has to be made to feed the transmitter energy through a concentric cable part of which is attached to the stationary part of the scanner assembly and part of which rotates with the scanning mirror. The method of transferring the energy from the stationary concentric cable to the rotating section is to use a capacity sleeve. This is illustrated in fig.66.

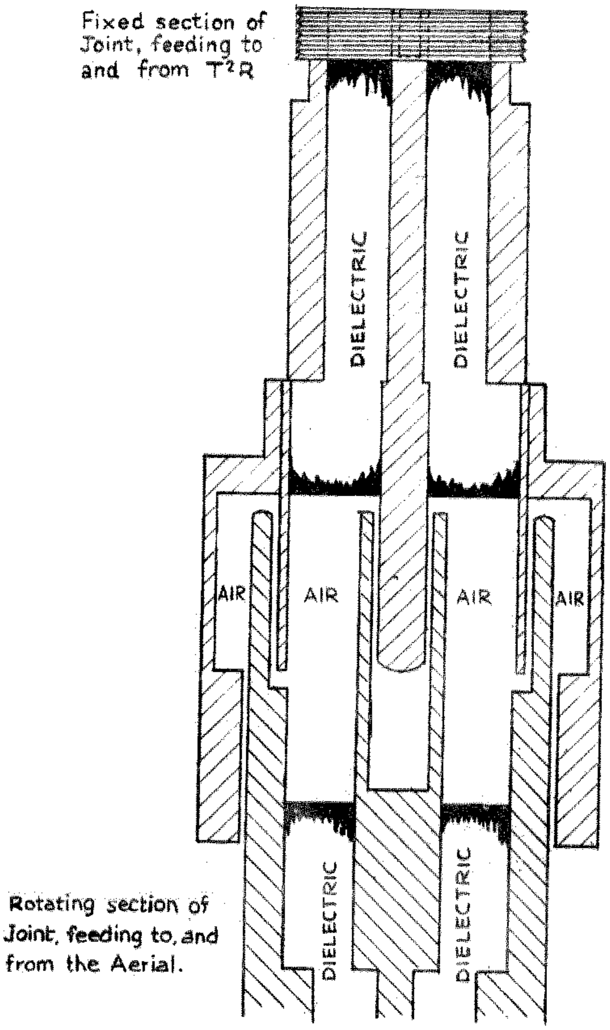

Fig. 66 Capacity Sleeve

284. A wave guide terminated by an orifice situated at the focus of the mirror radiates the R.F. pulses. A probe is used to convey the energy from the concentric cable to the wave guide which is rectangular in section. This probe which actually terminates the inner of the concentric projects into the side of the wave guide.

285. The motor driving the scanner is supplied from a 6-pin W-plug from the power unit, pins 1, 2 and 3 being paralleled to the positive side of the 24 volt aeroplane DC supply and pins 4, 5 and 6 being paralleled to the negative side. The magslip which is mounted on the scanner assembly is driven through a 1 : 1 gear from the scanner driving motor and the cam for operating the heading marker contacts is mounted on the same shaft as the magslip rotor. These units are shown on the circuit diagram, fig.65.

286. To vary the angle of tilt of the scanner mirror a circular wedge is used between the motor turntable and the back of the mirror. To ensure correct alignment engraved lines are provided on the scanner table and the rotating mirror. When assembling the thinnest part of the wedge must line up with both these lines. Three bolts mutually at 120 degrees. are used for fixing and incorrect mounting can throw the heading marker out by 120 degrees on either side.

287. The other item of equipment which is mounted on the scanner unit is the compass repeater motor, type M. Before going into details as to how this operates, we will give a short explanation of the operation of the DR Compass.

288. The DR Compass is a magnetically controlled compass and the actual compass needle is mounted in an instrument which can be stowed away in some part of the aircraft which is remote from magnetic influence (e.g. the engines).

289. In other parts of the aircraft where a compass indication is required, small repeater compasses are mounted which derive their operating impulses from the master compass. The system used to relay the direction of the master compass needle to these remote indicators is called a repeater motor system. The repeater motors are geared to the compass cards through a 60 : 1 step down ratio gearing and are fed by a 3-wire cable from the master compass. By an ingenious system of cams and contacts the compass repeaters can be made to take up twelve different angular positions, i.e. positions at every thirty degrees round the complete circle.

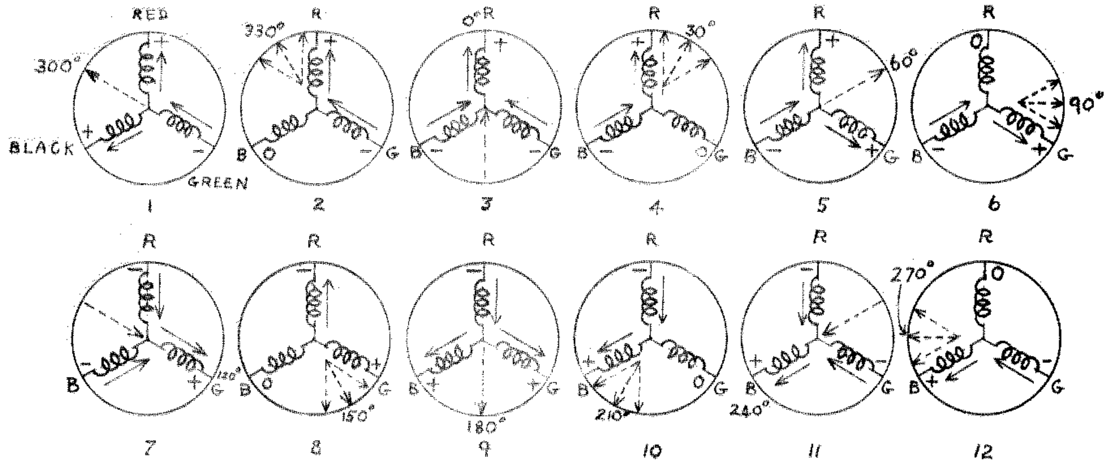

Fig. 68 Principle of the repeater motor

290. The way in which this is brought about is as follows - on the motor there are three field windings whose axes are mutually inclined to each other at 120 degrees as shown in fig.68. The inside ends of the three field windings are joined together as shown and either +24 volts or 0 volts or -24 volts can be applied to the outer ends of the windings. The twelve alternative positions are shown in fig.68, and the voltages which are applied in each case are as shown. These voltages arrive via three transmission lines which we will call I, II, III. The twelve sets of combinations we will call cam position or arrangement 1, 2, 3 ... 12. The application of positive, zero or negative volts in these different positions will then be in accordance with the table given in fig.67.

291. To see how the application of these voltages affects the resultant field in the repeater motor, let us examine a few of the alternative arrangements. Taking arrangement 1, we have that the winding connected to red has positive applied to it; that connected to black has also plus 24V applied to it and at green minus 24 is applied. The current will therefore flow in at the red and black connections and out at the green. If we obtain the vector sum of the fields due to the currents in the windings connected to red and black we find that this lies along the line corresponding to 300° and is in the same direction as the field due to the current in the winding connected to green. The rotor therefore sets in the direction indicated by the arrow (300°). Considering now arrangement 2, i.e. red positive, black zero and green negative current is flowing in at red and out at green and there is no field due to the winding connected to black. The fields due to red and green add up in the manner indicated and the resultant is along the 330° line. The reason for the directions of the resultant field in the remainder of the arrangements can be worked out from the figures.

292. To produce these positive, negative and zero voltages, a system of cams is used operating relay contacts, the whole being geared to the main shaft of the master compass. This system of cams and contacts is sometimes referred to as the transmitter.

293. Since the power obtainable from a single compass needle is quite inadequate to work all this machinery, the master compass has to incorporate some system which will be stable in operation and reasonably robust. The principle of the gyroscope is employed for this purpose because its axis of rotation is a comparatively stable thing in space.

294. The system employed is to use an electrical relay circuit which, as it were, interrogates the compass needle every six seconds to determine whether it has moved relative to its mountings, or to be more accurate, whether its mountings, which are actually attached to the aircraft frame, have turned round due to a change in the aircraft course whilst the compass needle has remained stationary pointing to magnetic North. If there has been relative motion in either direction, a correction is applied magnetically to the gyroscope to pull it round in the required direction. It is the position of the axis of the gyroscope which operates through a system of auxiliary motors and gear the cams and contacts which form the transmitter to energise the repeater motors and dials in other parts of the aircraft. Very steep banking in violent evasive action may destroy the balance of the gyroscope and accordingly provision is made for the direction of the repeater motors to be reset after such action. The unit used to perform this function is the heading control unit.

295. We have already said that the repeater motor is geared by a 60 : 1 step-down gear to the compass card. The transmitter cams in the master compass are so geared to the master unit scale that the compass card actually moves in step with the motion of this scale. When we use the repeater motor to control the position of the magslip stator windings which we do in the H_2S equipment, as we wish this to follow the direction of the compass needle we also introduce here a 60 : 1 gear.*

Heading Control Unit

296. This unit contains what is virtually a hand-operated transmitter motor for turning the magslip stators by hand when it is desired to set them at the commencement of a flight or after violent evasive action, as outlined above. It consists merely of a set of cams which are all mounted on one shaft, though shown separately for the sake of clearness in the diagram, and a set of three contacts exactly like the transmitter on the master compass. A manual-auto switch throws over the circuit from control by this motor to control by the DR compass.

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* Full details of the DR compass are given in A.P.1275B, Vol.I, Section 3, Chap.7.

INDICATING UNIT TYPE 162 REF. NO. 10QB/6010

Circuit Ref.	Ref. No.	Nomenclature
L650	10C/11968	Chokes, H.F. Type 424
C666	10C/4871	1.0 μF. ± 20%, 450V
	10C/11133	1.0 μF. ± 20%, 500V.
C662	10C/4214	0.5 μF. ± 10%, 2 KV.
C658	10C/5974	.23 μF. ± 20%, 450V.
C663, 670	10C/11952	.15 μF. ± 20%, 450V.
(C653, 654, (664, 665, (668, 669, (673, 678, (680.	10C/4801	.1 μF. ± 20%, 450V.
	10C/11127	.1 μF ± 20%, 500V.
C657	10C/5975	.05 μF. ± 20%, 450V.
	10C/11125	.05 μF. ± 20%, 500V.
C674, 677.	10C/11961	.02 μF. ± 20%, 2.5kV.
C655, 659, 672, 679.	10C/5977	.01 μF. ± 20%, 450V.
	10C/11123	.01 μF. ± 25%, 1,000V.
C652	10C/4176	.01 μF. ± 20%, 750V.
	10C/11123	.01 μF. ± 25%, 1,000V.
C650, 651	10C/11960	.01 μF. ± 20%, 1,000V.
	10C/11123	.01 μF. ± 25%, 1,000V.
C667	10C/12772	.01 μF. ± 20%, 1,500V.
C681	10C/13238	.0015 μF. ± 10%, 450V.
C671	10C/4190	.001 μF. ± 20%, 500V.
C682, 683	10C/12778	50 μμF. ± 5%, 2,500V.
	10AB/2919	Right angled drive, through bevel wheels for turning plunger on CV67 from front panel. Approx. 5" x 2" x 2" overall, with spindle 2½" x ¼" diam. at right angles.
	10C/4214	.5 μf - 10%, 2,000V, paper, rectangular metal case.
SL650	5L/276	Lamps, filament, 6.5V., 0.3 amp. M.E.S.
M.650	10A/13475	Milliammeter, Type N. 0 - 1 ma.
MO 650	10KB/928	Motor Unit, Type 15. Comprising motor, blower and filter unit.
R664	10C/10983	4.7 M. ± 5%, ½W.
R728	10C/10247	2.2 M. ± 20%, ½W.
R701, 702, 708, 709.	10C/9274	1.8 M. ± 5%, 1W.

Circuit Ref.	Ref. No.	Nomenclature
R677	10C/10245	1.2 M. ± 10%, ½W.
R671	10C/9280	1.5 M. ± 20%, ½W.
R663, 667 (2 in parallel to form R667)	10C/10984	1.2 M. ± 5%, ½W.
R654, 655, 656.	10C/9077	1 M ± 2%, 1W.
R726, 727.	10C/1207	1 M ± 10%. ¼W.
R713	10C/6962	1 M ± 20%, ¼W.
R718, 719.	10C/7885	1 M ± 5%, ¼W.
R693	10C/9282	680K ± 5%, ½W.
R694, 695 696, 697	10C/9105	620K ± 5%, ½W.
R667	10C/	600K 2 off 1.2 Mfg. resistances in parallel
R687	10C/8305	510K ± 5%, ½W.
R657	10C/6413	470K ± 5%, ½W.
R698	10C/8304	390K ± 10%. ½W.
R669, 670	10C/9279	390K ± 5%, ½W.
R665, 690	10C/7950	270K ± 10%, ¼W.
R692	10C/9281	180K ± 5%, ½W.
R652, 653	10C/9271	150K ± 20%, 2W.
R673	10C/6959	150K ± 20%, ½W.
R650, 651	10C/7312	100K ± 20%, 2W.
R658	10C/6629	100K ± 2%, ½W.
R672	10C/1968	100K ± 5%, ½W.
R674	10C/6961	100K ± 20%, ½W.
R730	10C/1303	100K ± 5%, ¼W.
R731	10C/9166	51K ± 5%, 2W.
R678, 679	10C/7907	47K ± 20%, ¼W.
R700, 706, 707, 714.	10C/9284	47K ± 5%, ¼W.
R729	10C/8188	47K ± 20%, ½W.
R686	10C/9113	47K ± 5%, ½W.
R662	10C/9272	43K ± 5%, 2W.
R661	10C/9273	24K ± 5%, 1W.

Circuit Ref.	Ref. No.	Nomenclature
R699	10C/8146	22K ± 20%, ¼W.
R703, 704, 710, 711	10C/9288	20K ± 5%, ¼W.
R724, 725	10C/1288	10K ± 5%, 1W.
R659	10C/6567	8K ± 2%, 1W.
R723	10C/10985	4.3K ± 5%, 1W.
R732	10C/9112	2.4K ± 5%, ½W.
R705, 712, 682, 688, 716, 717, 733.	10C/6398	2K ± 5%, ½W.
R660, 666	10C/6705	1K ± 20%, ¼W.
R691	10C/6654	1K ± 20%, 1/10W.
R734	10C/9252	270 ohms ± 5%, ½W.
R715	10C/9110	220 ohms ± 5%, ½W.
R721	10C/7860	200 ohms ± 5%, ¼W.
R680	10C/6663	100 ohms ± 20%, ½W.
VR655	10C/9291	1 Meg. ± 20%, 1W. variable.
VR650	10C/9303	1 Meg. ± 20%, 1W. variable.
VR656	10C/9304	1 Meg. ± 20%, 1W. variable.
VR657	10C/9310	1 Meg. ± 20%, 1W. variable.
VR651	10C/9312	500K ± 20%, 1W. variable.
VR653	10C/9313	500K ± 20%, 1W. variable linear.
VR654	10C/9311	200K ± 20%, 1W. variable.
VR652	10C/9314	100K ± 20%, 1W. variable.
VR659	10C/9315	5K ± 20%, 1W. variable.
R681, 689	10C/1820	10K ± 5%, 2W, carbon, non-insulated.
T650, 651, 652.	10KB/929	Transformer
T653	10KB/930	Transformer
V650, 651, 653.	10E/11446	Valves, Type VR65. Screen Pentode.
V652	10E/11448	Valves, Type VR67. Triode.
V655	10E/587	Valves, Type VT60A. Output tetrode.
V654	10E/CV67	Valves, Type CV67.
CRT650	10E/466	Valves, Type VCR139A.
CRT651	10E/758	Valves, Type VCR517.
V658, 659.	10E/11540	Valves, Type VR78. Diode.
V656, 657.	10E/105	Valves, Type VR92. Diode.

MODULATOR UNIT, TYPE 64 REF. NO. 10DB/956.

L4	10C/12116	4MH - 5%.
L2	10C/12115	1H. - 15%.
C2	10C/11281	.5 + .5μF ± 15%, 2.2kV. + 2.2kV. Wkg.

Circuit Ref.	Ref. No.	Nomenclature
C1, C3, C10.	10C/10823	1 μF. ± 10%, 250V., D.C. Wkg.
C13	10C/2391	.05 μF ± 10%, 3.5kV. Wkg.
C4, C5, C12.	10C/2448	1 uF ± 10%, 400V. D.C. Wkg.
L3, C11, R31.	10DB/1254	L.F. Unit, Type 2 Tuned circuit to 25 kc/s.
L3	10C/12476	Choke, 4 mH ± 5%, wound on 1½" O.D. former ½" long.
C11	10C/4927	.01 μF. ± 10%, 350V. D.C.
R31	10C/1847	2.2K ± 20%, ½W.
C.7	10C/5022	.002 μF. ± 10%, 350V. D.C. Wkg.
C.8	10C/5144	.0005 μF. ± 2%, 350V. D.C. Wkg.
C.6	10C/2017	.0003 μF. ± 2%, 350V. D.C. Wkg. Silvered mica, protected, wire ends.
C.9	10C/4271	.0001 μF. ± 10%, 350V. D.C. Wkg.
R.23	10C/8373	3.9M ± 5%, ½W.
R.20	10C/6115	100K. ± 5%.
R.21	10C/9475	33K. ± 5%, 2W.
R.39	10C/1850	4.7K. ± 20%, ½W.
R.19	10C/6476	1.2K. ± 10%, ½W.
R.27	10C/9690	160 ohms. ± 5%, ½W.
R.26	10C/10494	110 ohms. ± 5%, ½W.
R1, R2, R3, R4.	10C/8225	1M. ± 20%, 1W.
R.18	10C/6320	470K. ± 20%, ½W.
R.16	10C/6840	100K. ± 20%, ½W.
R.17	10C/6838	22K. ± 20%, ½W.
R.14	10C/1850	4.7K. ± 20%, ½W.
R.15	10C/6322	1M ± 20%, ½W.
R.8	10C/9481	68 ohms. ± 5%, 1W.
R10, R11	10C/6356	4.7K. ± 10%, 3W.
	or 10C/8655	100K. ± 20%, 1W, Variable.
R22	10C/8373	3.9M. ± 5%, ½W.
R13	10C/10493	1.1M ± 5%, 2W.
R32	10C/8225	1M. ± 20%, 1W.
R33	10C/9042	240K. ± 5%, ½W.
R28	10C/6083	1K. ± 20%, ½W.

Circuit Ref.	Ref. No.	Nomenclature
R9	10C/9926	6.8K. ± 20%, 3W.
R.29	10C/1089	3.9K. ± 10%, $\frac{1}{2}$W.
R.12	10C/1842	150 ohms. ± 10%, $\frac{1}{2}$W.
R.25, R.30	10C/6927	47 ohms. ± 20%, $\frac{1}{2}$W.
R.34, R.35	10C/1954	Resistance, Type 1954
T.4	10KB/807	Pulse, Intervalve Transformer
T.1	10KB/1052	Transformer, Input: 80V. A.C. Output: 114V., 5.5mA; 6.3V, 1.5A; 4.2V, 2.5A; 29/16" x 2 5/16" x $1\frac{3}{4}$" overall.
V6	10E/587	Valve, VT60A
.DCD.WT.V_1, V_2	10E/211	Valve, VU133 OR
	10E/CV54	Valve, CV54
V_4, V_5	10E/92	Valve, VR91
V_7	10E/CV73	Valve, CV73
V_8	10E/CV85	Valve, CV85
	POWER UNIT, TYPE 280	10KB/747
CK303	10C/11972	Choke, L.F. Type 353 5 H. @ 10mA $1\frac{3}{8}$" x $1\frac{1}{4}$" x $2\frac{1}{2}$"., 2 fixing holes 3200 turns @ 37 SWG.
CK302	10C/12899	Chokes, L.F., Type 420 2.6 H. @ 200 mA, 1kV insulation. Laminated iron core. 2100 turns @ 33 SWG.
CK300, 301	10C/11971	Chokes, L.F., Type 352 21 H. @ 40mA, D.C. 5500 turns of 38 SWG, "Presspalm" former, 13/16" square.
C302	10C/NIV	8 μf ± 10%, 400V D.C.
	10C/9806	8 μf ± 10%, 400V. D.C.
C303	10C/NIV	2 μf ± 10%, 250V.
	10C/9382	2 μf - 10%, 250V.
C300, 301	10C/NIV or 10C/11975	Condener 1μf ± 10%, 2,000V. Condenser, Type 3701 1 μf - 10%, 2,000V.
C304	10C/NIV or 10C/4330	Condenser: 1 μf - 10%, 400V D.C. Condenser, Type 2235, 1 μf - 10%, 400V D.C.
MR300 (W300,) 301 (W301.)	10DB/1177	Rectifier, Selenium. 2.23" long x $\frac{3}{8}$" 4 B.A. threads.
MR302 (W302,) 303 (W303.)	10DB/1488	Rectifier, Selenium. $1\frac{3}{4}$" long x $\frac{1}{2}$" diam. 4 B.A. mounting threads, and side tags.

Circuit Ref.	Ref. No.	Nomenclature
RY300(A)	10FB/651	Relays, Magnetic, Type 468.
RY301(B)	10FB/652	Relays, Magnetic, Type 469.
RY302(C)	10FB/653	Relays, Magnetic, Type 470.
RY303(D)	10FB/654	Relay 6250 ohms to operate on 4.5 mA H.V. insulation, L.V. spring sets. Left Hand:- 1M.1B. light Right Hand:- 1 C/O light.
RY304(E)	10FB/655	Relay 1,000 ohms to operate on 18V. Double relay, H.V. insulation. Left Hand:- 1B. light, 1M. heavy. Right Hand:- 1 + 3M. light.
RY305(F)	10FB/656	Relay 1,000 ohms coils, 18V min. operating voltage. Double relay. Left Hand:- 2M. heavy (5A; 24V) Right Hand:- 1M. light (60mA. 24V)
R328	10C/8192	2.2M ± 20%, $\frac{1}{4}$W.
R304, 305, 306, 310, 311, 332.	10C/10785	500K ± 5%.
R333, 338	10C/1796	470K ± 10%, 2W
R325	10C/8304	390K ± 10%, $\frac{1}{2}$W.
R330	10C/9126	390K ± 10%, $\frac{1}{4}$W.
R309, 331	10C/10786	300K ± 5%, 1W.
R318	10C/9649	300K ± 2%, $\frac{1}{2}$W.
R334, 339	10C/9276	250K ± 5%
R326	10C/9125	150K ± 20%, $\frac{1}{4}$W.
R316	10C/6629	100K ± 2%, $\frac{1}{2}$W.
R329	10C/8151	100K ± 2%, $\frac{1}{4}$W.
R320	10C/8173	33K ± 20%, 2W.
R324	10C/6844	33K ± 20%, 1W.
R321	10C/8782	27K ± 10%, 2W.
R313, 314	10C/8186	22K ± 20%, $\frac{1}{2}$W.
R307, 308, 317, 319.	10C/6706	10K ± 20%, $\frac{1}{4}$W.
R322	10C/1830	10K ± 20%, 1W.
R323	10C/6595	10K ± 20%, $\frac{1}{2}$W.
R340	10C/9090	2.2K ± 5%, $\frac{1}{2}$W.
R300	10C/9317	1.2K ± 5%, 5W.
R342	10C/10932	680 ohms ± 5%, 2W.

Circuit Ref.	Ref. No.	Nomenclature
R327	10C/6705	Resistance, Type 6785, 1K.
R337	10C/10788	Resistance, Type 3574, 10 ohms.
T300	10KB/931	Transformer, Type 1113 Overload relay. Primary:- 700 turns, of 32 SWG enam. copper wire. Secondary:- (i) 6 turns, 17 SWG enam. copper wire. (ii) 4 turns, 17 SWG enam. copper wire.
T302	10KB/932	Transformer, Type 1114 H.T. High Voltage. Primary:- 80V, 500-2800 cycles per second. Secondary:- 2460V RMS 2 identical secondaries, each with filament winding 4K, tapped on 5 turns, 2335½ turns, 514 turns.
T301	10KB/933	Transformer, Type 1115. Heater. Primary:- 80V A.C. Secondary:- 4V 2A, 1800V insulation.
T303	10KB/934	Transformer, Type 1116 H.T. and Bias. Primary:- 80V A.C. Secondary:- (i) 5V 3A. (ii) 6.3V, 6A. (iii) 310-30-0-30-310V.

RECEIVER TYPE R3515 REF. NO. 10DB/6060

C424, C425	10C/11958	2µF ± 10%, 400V.
C426, 440	10C/4871	1µF ± 20%, 450V.
	or 10C/11133	1µF ± 20%, 500V.
C421, 430	10C/11952	.15µF ± 20%, 450V.
C400, 401, 423, 427, 452, 453.	10C/4801	.1µF ± 20%, 450V.
	or 10C/11127	.1µF ± 20%, 500V.
C429	10C/5356	.1µF ± 5%, 450V.
C402, 428, 463.	10C/5975	.05µF ± 20%, 450V.
	or 10C/11125	.05µF ± 20%, 500V.
C441	10C/11953	.05µF ± 5%, 450V.
C442	10C/11957	.023µF ± 20%, 450V.
C432, 410, 439.	10C/5977	.01µF ± 20%, 450V.
	or 10C/11123	.01µF ± 25%, 1,000V.
C422	10C/11956	.0035µF ± 10%, 450V.
C431	10C/4872	230µµF ± 2%, 350V.

Circuit Ref.	Ref. No.	Nomenclature
C461	10C/4798	150 µµF - 2%, 350V.
C403, 462	10C/5989	35 µµF - 2%, 350V.
C405, - C409	10C/11965	Inductance - Condenser Unit, Type 29. 2 units on single mounting (i) Single transit delay of 1 µS and characteristic impedance of 2,000 ohms. (ii) Single transit delay of ½ µS and characteristic impedance of 4,000 ohms.
C411 - C420	10C/11966	Inductance - Condenser Units, Type 30. Single transit delay of 2 µS. and characteristic impedance of 270 ohms.
C449 - C461	10C/11967	Inductance - Condenser Units, Type 31 Single transit delay of 8 µS. and characteristic impedance of 1,000 ohms.
L4	10C/11962	74 turns, 30 SWG.
L1, 2, 3, 6.	10C/4152	85 Micro-Henries, 195 turns, 41 SWG.
L5	10C/11963	85 Micro-Henries, 195 turns 41 SWG. eureka.
L7,8,9,10, 11,12,13.	10C/11964	8 tappings, 7 sections, 44 turns in each, 20 SWG. enamelled copper.
C1,4,6,7,8, 9,10,11,13, 15,16,17,18, 19,20,21,22, 23,24,25,26, 27,28,29,30, 31,32,33,35, 36,37,38,40, 41,42,43,44, 45,46,47,48.	10C/4192	.0023 mfd. ± 20%, 500V.
C2,5,12,14.	10C/5983	.0001 mfd ± 2%, 350V.
C3,39.	10C/5356	.1 mfd ± 5%, 450V.
C34	10C/11937	5 pfd. ± 5%, 750V. Silvered mica, tropical.
R60	10C/1823	75K ± 5%, 2W.
R5.	10C/7057	40K ± 2%, ½W.
R59	10C/10784	36K ± 5%, 1W.
R55, 56	10C/1005	27K ± 5%, ¼W
R63	10C/9087	24K ± 5%, ½W.
R61	10C/8186	22K ± 20%, ½W.
R20, 21	10C/9082	20K ± 5%, 1W.
R19, 37.	10C/8092	15K ± 5%, ¼W.
R33	10C/9243	15K ± 20%, ¼W.
R40, 50.	10C/6623	15K ± 20%, ½W.

Circuit Ref.	Ref. No.	Nomenclature
R25, 26	10C/1955	10K ± 20%, ¼W.
R16	10C/9081	10K ± 5%, 1W.
R6	10C/7284	10K ± 2%, ½W.
R29, 45	10C/990	6.8K ± 5%, ¼W.
R54, 62.	10C/10346	6.2K ± 5%, ¼W.
R22, 38.	10C/8766	5.6K ± 5%, ¼W.
R30, 46.	10C/6937	3.6K ± 5%, ¼W.
R2, 8	10C/1980	3K ± 5%, ¼W.
R51	10C/1115	2K ± 5%, ¼W.
R11	10C/8332	1.5K ± 5%, ¼W.
R7,9,10,13, 14,17,18, 27,28,32, 35,36,39, 43,44,49, 52,53,57, 58.	10C/1867	1K ± 20%, ¼W.
R4,15,24,34, 42,48.	10C/1038	180 ohms ± 10%, ¼W.
R1	10C/851	51 ohms ± 5%, ¼W.
R3,23,12, 31,41,47.	10C/8821	10 ohms ± 20%, ¼W.
L14, 15.	10KB/912	1 Transformer Type 1094
L16,17.	10KB/913	1 Transformer Type 1095
L18, 19 and L22, 23.	10KB/914	2 Transformer, Type 1096
L20, 21 and L24, 25.	10KB/915	2 Transformer, Type 1097
L26, 27.	10KB/916	1 Transformer, Type 1098
V7	10E/105	Type VR92. Diode.
V1, 2, 3, 4, 5, 6.	10E/11446	Screened Pentode. Type VR65
V8	10E/11399	Type VR 53
RY400(A)	10FB/650	Relays, Magnetic Type 467.
RY401(B)	10FB/667	Relays, Magnetic Type 482.
R425	10C/9115	4.7M ± 20%, ½W.
R435	10C/9075	2 M ± 2%, 1W.
R434	10C/9073	1.5M ± 2%, 1W.
R444, 453, 401, 407, 448, 458.	10C/6605	1M ± 20%, ½W.

Circuit Ref.	Ref. No.	Nomenclature
R416, 418, 461.	100/7364	1M ± 5%, ½W.
R437	100/9077	1M ± 1%, 1W.
R460	100/9123	510K ± 5%, ½W.
R400	100/6754	500K ± 2%, ½W.
R464	100/6589	500K ± 1%, ½W.
R419	100/9353	350K ± 2%, ½W.
R433	100/9072	300K ± 2%. 1W.
R431	100/9120	240K ± 5%, ½W.
R420	100/9069	200K ± 2%, ½W.
R430	100/9119	91K ± 5%, ½W.
R427	100/9116	51K ± 5%, ½W.
R410	100/9113	47K ± 5%, ½W.
R428	100/9117	39K ± 5%, ½W.
R426	100/9071	35K ± 2%, ½W.
R450	100/6148	30K ± 5%, ½W.
R436	100/6756	25K ± 2%, ½W.
R439	100/1541	20K ± 5%, ½W.
R406, 443.	100/1916	15K - 5%, 2W.
R423	100/9355	13K ± 2%, 1W.
R452, 463.	100/6595	10K ± 20%, ½W.
R404	100/7957	10K ± 10%, ½W.
R422	100/9070	10K ± 2%, 1W.
R429	100/9118	7.5K ± 5%, ½W.
R438	100/9122	5.1K ± 5%, ½W.
R459	100/8149	4.7K ± 20%, ½W.
R462	100/9124	4.7K ± 5%, ½W.
R445	100/7059	4K ± 2%, ½W.
R456	100/6401	3K ± 5%, ½W.
R403	100/9112	2.4K ± 5%, ½W.
R442	100/6398	2K ± 5%, ½W.
R409	100/7042	2K ± 2%, ½W.
R466	100/10292	1.8K ± 10%, ¼W.

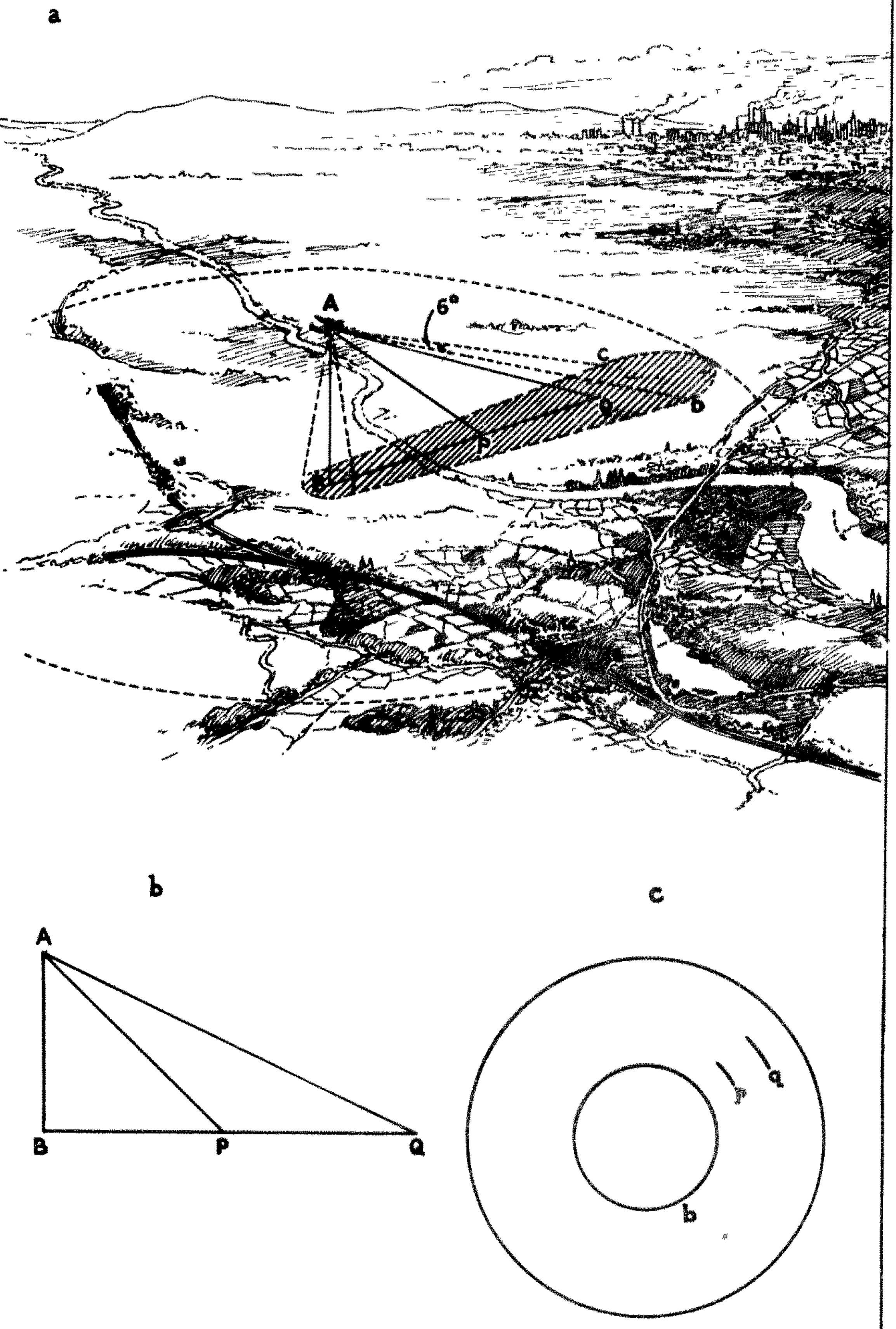
Circuit Ref.	Ref. No.	Nomenclature
R455	10C/6393	1.5K ± 5%, ½W.
R405, 408, 411, 424, 441, 447, 465, 454, 445.	10C/8762	1K ± 20%, ½W.
R451, 457.	10C/1678	1K ± 5%, ½W.
R449	10C/9107	510 ohms ± 5%, ½W.
R414	10C/9252	270 ohms ± 5%, ½W.
R415	10C/9110	220 ohms ± 5%, ½W.
R432	10C/9121	180 ohms ± 10%, ½W.
R421	10C/9251	140 ohms ± 2%, ½W.
S400	10FB/665	S.P. 9 way, single wafer.
T402	10KB/917	Heater transformer. <u>Primary</u> 80V. 1400-2800 c.p.s. <u>Secondary</u>: 6.3V, 4.5 A. 6.3V, 3.5A. C.T. 6.3V, 2.0A. C.T.
T101	10KB/919	Pulse 1:1 transformer <u>Primary</u> 160 turns <u>Secondary</u> 80 + 80 turns 39 S.W.G. Primary between 2 secondaries.
T100	10KB/918	Pulse 1:3 transformer <u>Primary</u> 200 turns, 35 S.W.G. <u>Secondary</u> 300 + 300 turns 35 S.W.G. Primary between 2 secondaries.
V403, 404, 411, 409.	10E/11446	Screened Pentode. Type VR65
V401, 402, 407, 408, 412.	10E/11402	Screened Pentode, International octal. Type VR56.
V400, 405, 406.	10E/11401	Double diode-triode, International octal. Type VR55.
TRANSMITTER RECEIVER, TYPE TR.3191 REF. NO.10DB/1003		
V410	10E/11400	Double diode, International octal. Type VR54.
C100	10C/11959	.05/uf ± 20%, 1000V. D.C.
V100, R106, R107.	10AB/1791	Valve CV43 with heater.
R101	10C/8225	1 Meg. ± 20%, 1W.
R100	10C/9599	430K ± 5%, 1W.
R105	10C/9142	4K ± 15%, 20W.
R102	10C/950	75 ohms ± 5%, ¼W.
T101	10KB/889	Transformer, <u>Primary</u>: 80 volts <u>Secondary</u>: (i) 4V. (ii) 6.3V.

Circuit Ref.	Ref. No.	Nomenclature
T102	10KB/890	Transformer: <u>Primary</u> 40½ turns of 26 SWG. enam. copper wire. <u>Secondary</u>: 70 + 70½ turns of 32 SWG. enam. copper wire 3kV. input; Output via 13½" matched braided output conductor. Oil filled version in sealed container.
V101	10E/CV64	Valves, Type CV64.
V102	10E/146	Valves, Type VU111
V103	10E/CV101	Valves, Type CV101
V125	10E/386	Valves, Type VR136
WAVEFORM GENERATOR TYPE 26 REF. NO. 10VB/6004		
C500	10C/5977	.01 mfd ± 20%, 450V.
C501, 514, 515, 510, 517, 523.	10C/4801	0.1 mfd. ± 20%, 450 V.
C502, 512.	10C/5974	0.23 mfd. ± 20%, 450 V.
C503, 509, 511, 526, 527.	10C/4871	1 mfd ± 20%, 450V.
C504, 505, 506, and 507.	10C/11935	.01 mfd ± 1%, 350 V.
C508, 535.	10C/11952	0.15 mfd ± 20%, 450V.
C525, 513.	10C/4197	.0005 mfd ± 2%, 350 V.
C516	10C/5795	0.5 mfd ± 20%, 450V.
C519	10C/11953	0.05 mfd ± 5%, 450V.
C520, 530, 529.	10C/2003	0.1 mfd ± 10%, 450V.
C522	10C/3526	0.001 mfd ± 20%, 450V.
C521	10C/5975	0.05 mfd ± 20%, 450V. D.C.
	10C/4190	.001 mfd ± 20%, 500V. D.C.
C524, 532	10C/5356	0.1 mfd ± 5%, 450V.
C528	10C/11936	50 pfd ± 1%, 350V. D.C.
C531	10C/2890	1 mfd ± 10%, 450V.
C533	10C/11954	1 mfd ± 5%, 450V.
C534	10C/11955	0.15 mfd ± 5%, 450V.
C518, 539	10C/5782	0.0015 mfd ± 5%, 350V.
C538, E.M.I. version only.	10C/10887	6 mfd ± 10%, 400V.
R.P.U. version only. 3 used in parallel.	or 10C/3128	2 mfd ± 10%, 400V.
500(N) and 501(M)	10FB/725	Relays
R500	10C/6471	220K ± 20%, ½W.

Circuit Ref.	Ref. No.	Nomenclature
R501, 537, 552, 555.	10C/6840	100K ± 20%, ½W.
R502	10C/9057	750K ± 2%, ½W
R503	10C/7282	250K ± 2%, ½W.
R504, 515	10C/9464	36K ± 5%, ½W.
R505	10C/9356	24K ± 5%, ½W.
R511	10C/9058	27K ± 1%, ½W.
R507	10C/9059	18K ± 1%, ½W.
R508	10C/9060	20K ± 1%, ½W.
R509	10C/7572	40K ± 1%, ½W.
R510	10C/7057	40K ± 2%, ½W.
R514	10C/1207	1 Meg. ± 10%, ½W.
R516	10C/9061	15K ± 1%, ½W.
R517	10C/9062	35K ± 1%, ½W.
R518, 524	10C/9245	50K ± 1%, ½W.
R519	10C/9601	3.3K ± 5%, ½W.
R520	10C/8418	1.5K ± 5%, ½W.
R521	10C/9468	2.2K ± 5%, ½W.
R506, 522	10C/9063	25K ± 1%, ½W.
R523	10C/754	560K ± 10%, ½W
	10C/9064	30K ± 1%, ½W.
R526	10C/10496	270K ± 5%, ½W.
R527	10C/1848	2.7K ± 5%, ½W.
R529, 550, 553, 560, 561, 569.	10C/6322	1 Meg. ± 20%, ½W.
	10C/7525	150K ± 2%, ½W.
	10C/6754	500K ± 2%, ½W.
	10C/8342	250K ± 1%, ½W.
R534	10C/6758	350K ± 1%, ½W.
R535	10C/7048	400K ± 1%, ½W.
R536	10C/7828	150K ± 20%, ½W.
R538	10C/7466	2.2 Meg ± 20%, ½W.
R539	10C/1001	2K ± 5%, ½W.
R540	10C/6838	22K ± 20%, ½W.

Circuit Ref.	Ref. No.	Nomenclature
R541	100/6115	100K ± 5%, ½W.
R543	100/6319	680K ± 20%, ½W.
	100/6629	100K ± 2%, ½W.
For Replacement if necessary, on test, of 100K ± 2%, ½W. Hayes Type 72511 R.	100/9069	200K ± 2%, ½W.
	100/9603	120K ± 2%, ½W.
	100/6617	50K ± 2%, ½W.
	100/6756	25K ± 2%, ½W.
	100/7525	150K ± 2%, ½W.
	100/9625	75K ± 2%, ½W.
R546	100/6083	1K ± 20%, ½W.
R547	100/9602	9.1K ± 5%, ½W.
R548	100/7754	47 ohms ± 20%, ½W.
R549	100/1619	300 ohms ± 5%, ½W.
R512	100/6475	200K ± 5%, ½W.
R556	100/8389	68K ± 5%, ½W.
	100/9065	400K ± 5%, ½W.
R567, 568	100/777	10K ± 5%, ½W.
R559	100/9603	120K ± 5%, ½W.
R563	100/6597	250K ± 5%, ½W.
R562	100/9604	620K ± 5%, ½W.
R5	100/56	20K ± 5%, 2W.
R566	100/1109	1K ± 5%, ½W.
R568	100/1051	7.5K ± 5%, 1W.
	100/1299	15K ± 5%, 1W.
R572	100/9066	1.5 Meg. ± 2%, ½W.
R573	100/9592	1.3K ± 5%, ½W.
R575	100/1844	510 ohms ± 5%, ½W.
R576	100/670	130 ohms ± 5%, ½W.
R577	100/8724	68 ohms ± 5%, ½W.
R580	100/9583	220 ohms ± 5%, ½W.

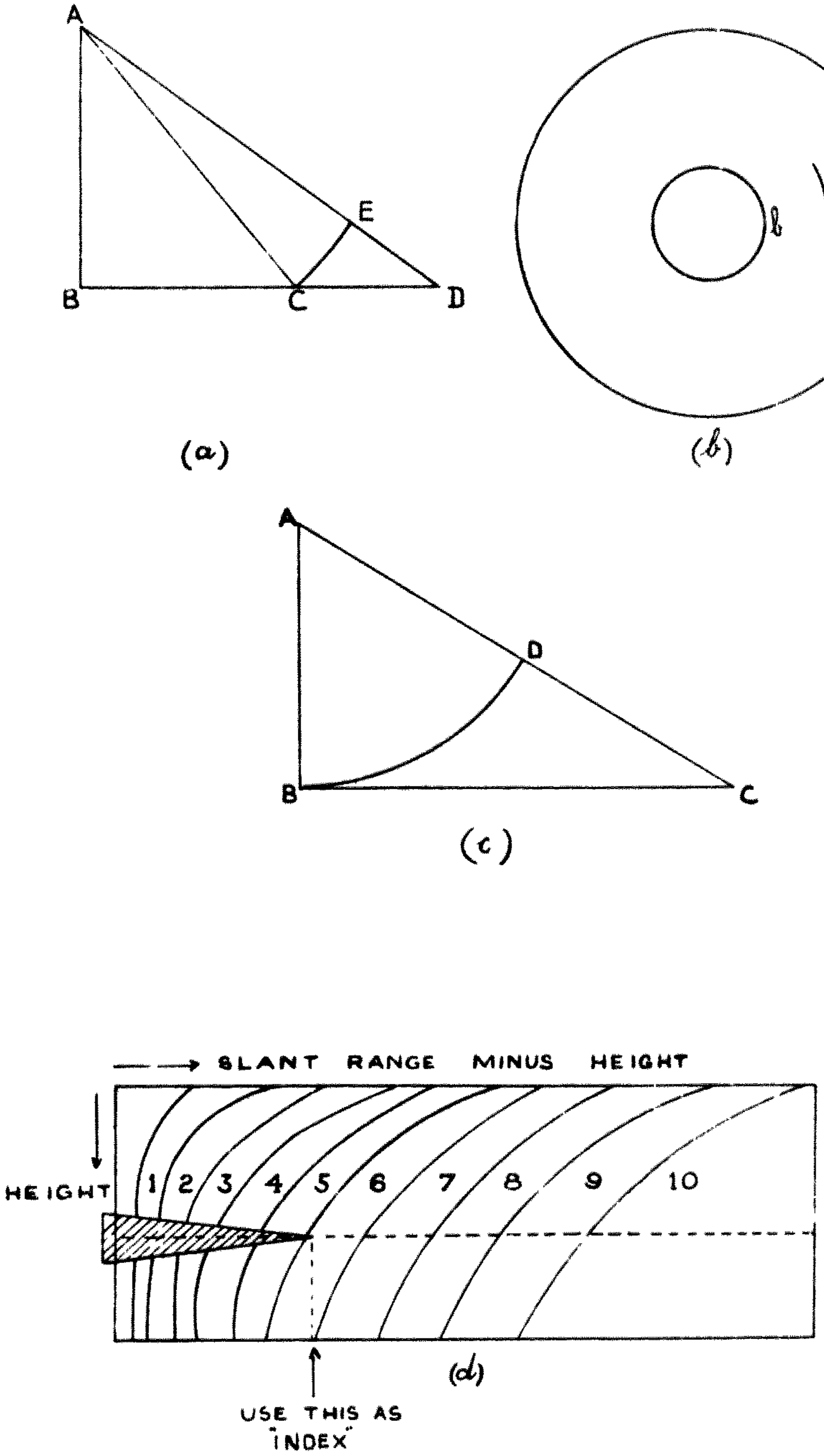
Circuit Ref.	Ref. No.	Nomenclature
R581	10C/7756	6.2K ± 5%, $\frac{1}{2}$W.
R582	10C/930	1 Meg. ± 5%, $\frac{1}{2}$W.
R586	10C/6615	1 Meg. ± 2%, $\frac{1}{2}$W.
R587	10C/9067	2 Meg. ± 2%, $\frac{1}{2}$W.
R554	10C/7669	2 Meg. ± 20%, $\frac{1}{2}$W.
R523	10C/754	560K ± 10%, $\frac{1}{2}$W.
R551	10C/927	220K ± 10%, $\frac{1}{2}$W.
R558	10C/6079	10K ± 20%, $\frac{1}{2}$W.
R585	10C/8192	2.2 Meg. ± 20%, $\frac{1}{4}$W.
R584	10C/6705	1K ± 20%, $\frac{1}{4}$W.
R513	10C/9619	55K ± 2%, $\frac{1}{2}$W.
R500	10C/9613	25K ± 20%, 1W.
T500	10KB/911	Transformer, Type 1093 <u>Primary</u>: 80V. 1400- 2800 cs/sec. <u>Secs</u>: 3.15-0-3.15V., 4A; 3.15-0-3.15V., 2A.
T501	10KB/910	Transformers, Type 1092 <u>Primary</u>: 3200 turns, 42 SWG enamelled copper wire, plus 3200 turns 38 SWG enamelled copper wire. <u>Sec</u>: (i) 800 + 800 turns 42 SWG. enamelled copper wire. (ii) 265 turns 31 SWG enamelled copper wire + 265 turns 31 SWG enamelled copper wire.
V504, V505, V506, V507, V508, V512.	10E/11446	Valves, VR65
V500, V501, V503.	10E/11402	Valves, VR56
V502	10E/11401	Valves, VR55
V509, V510	10E/11400	Valves, VR54
V511	10E/266	Valves, VR116



H_2S PROJECTIONS

FIG. 1

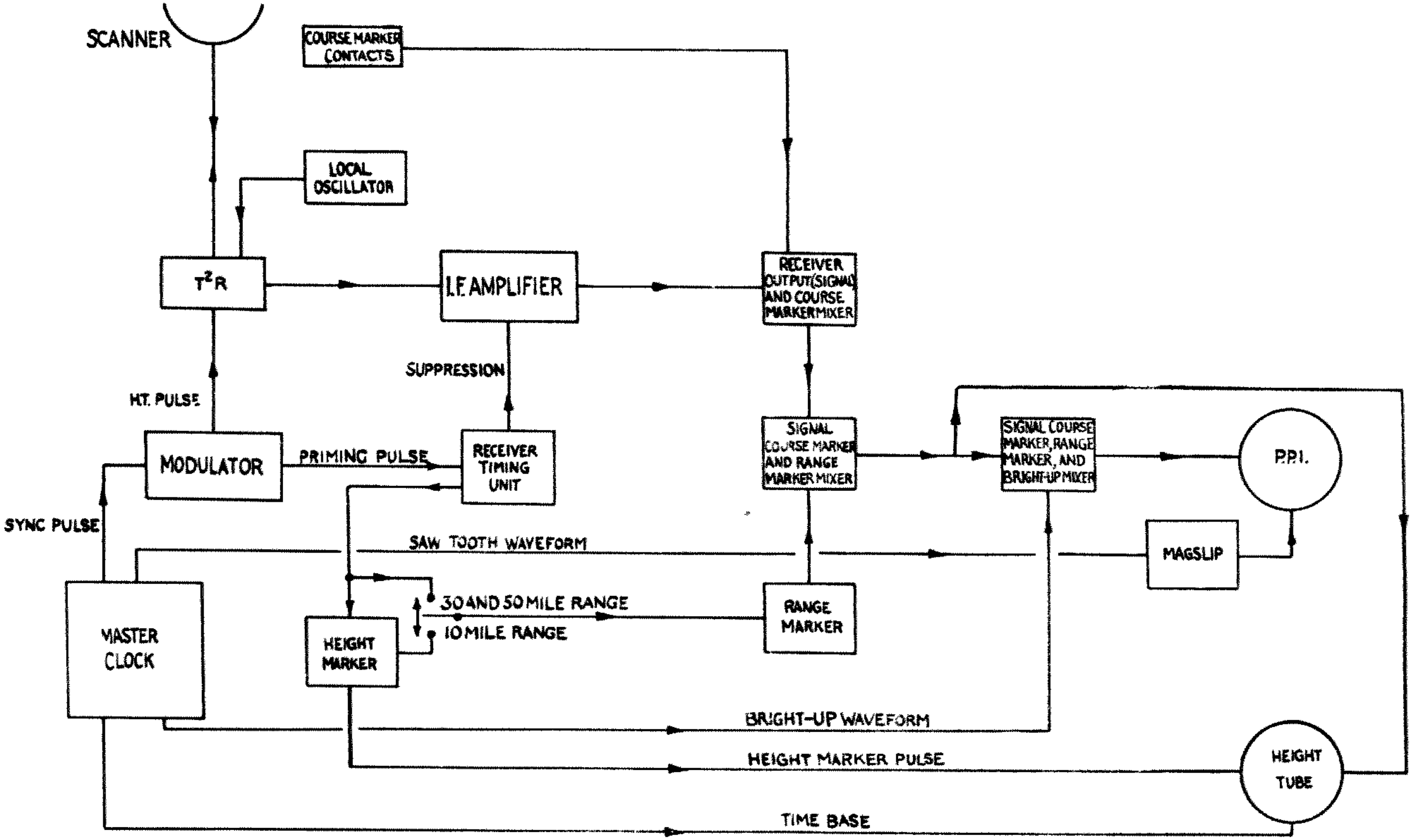
FIG. 1



CALCULATION OF INCREMENT

FIG. 2

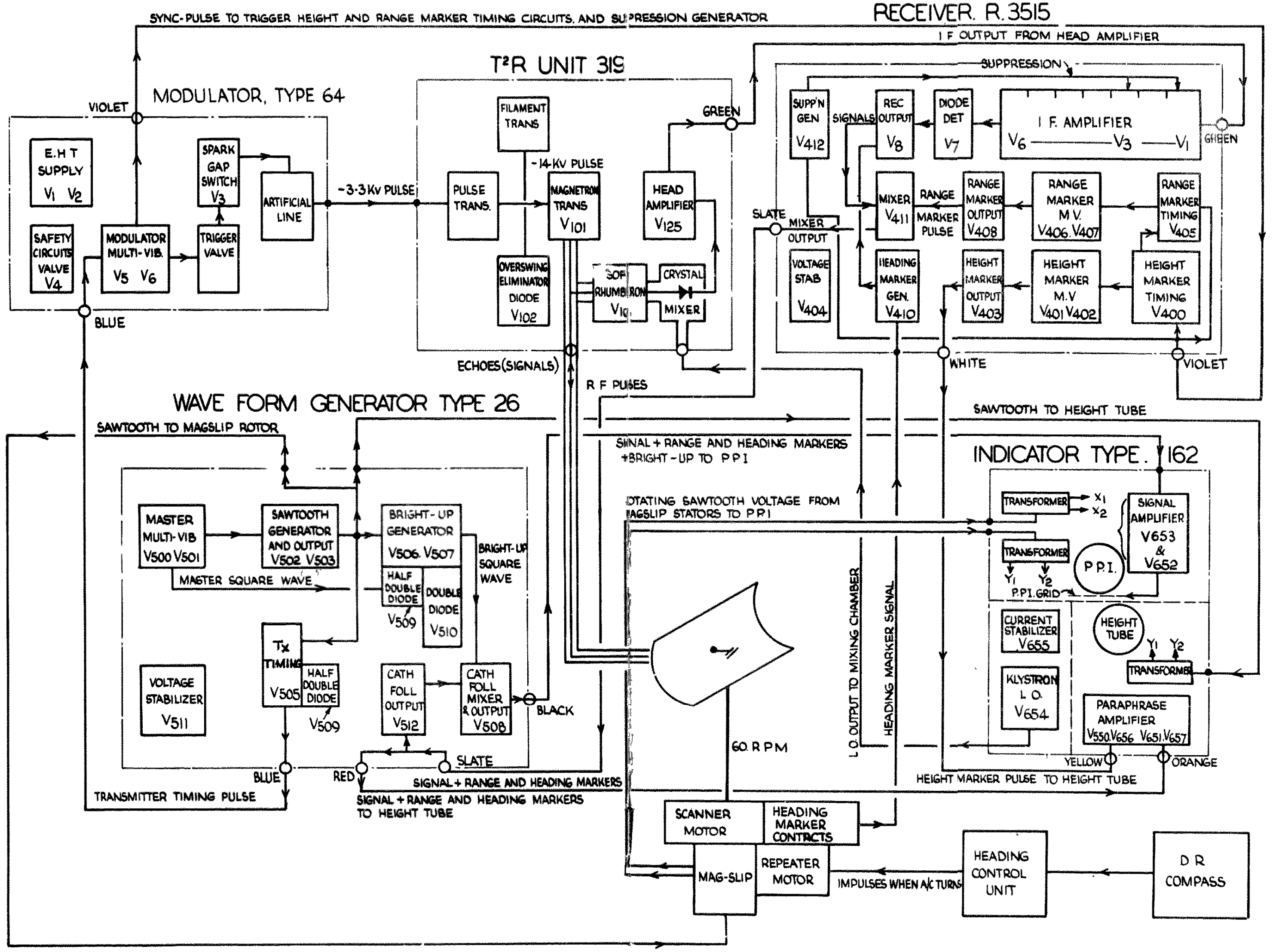
FIG. 2



SIMPLIFIED BLOCK SCHEMATIC.

FIG. 3

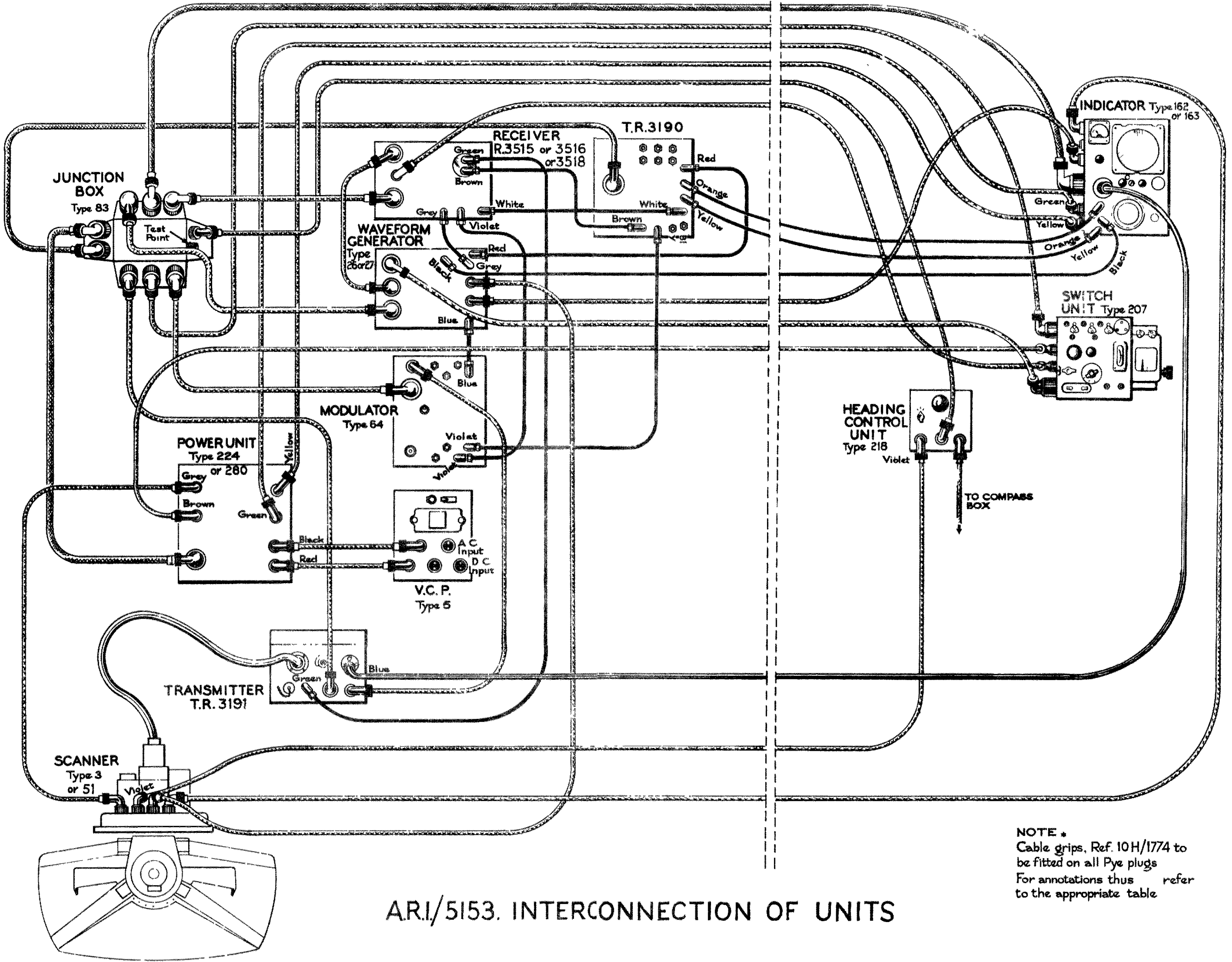
FIG. 3



DETAILED BLOCK SCHEMATIC

FIG 4

FIG 4

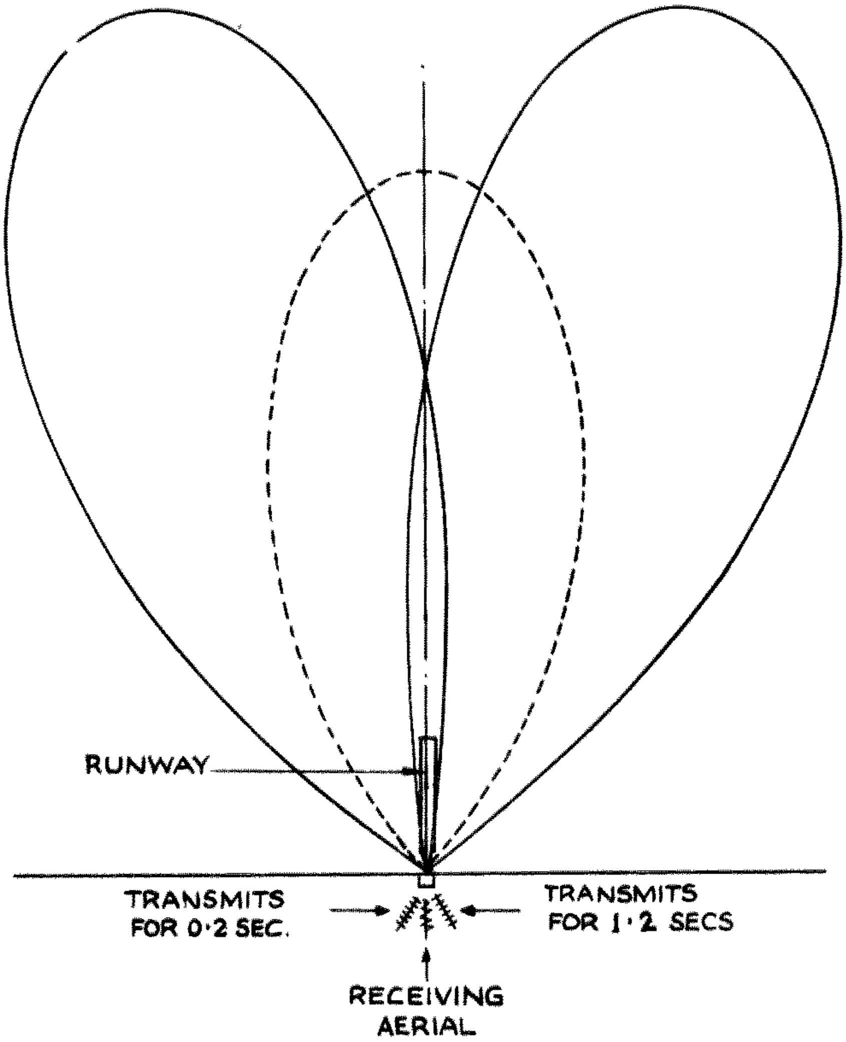


NOTE *
Cable grips, Ref. 10H/1774 to be fitted on all Pye plugs
For annotations thus refer to the appropriate table

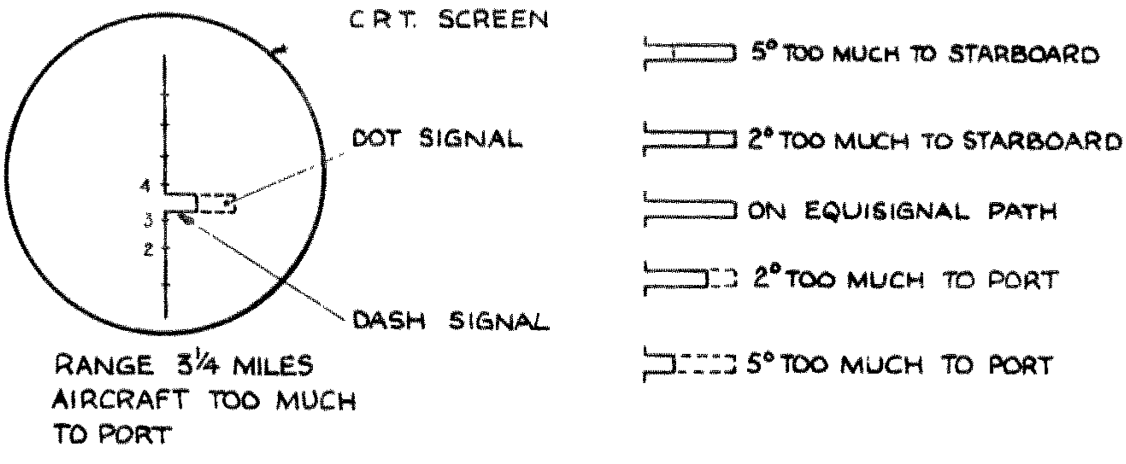
A.R.I./5153. INTERCONNECTION OF UNITS

FIG. 5

FIG. 5



(a) POLAR DIAGRAMS

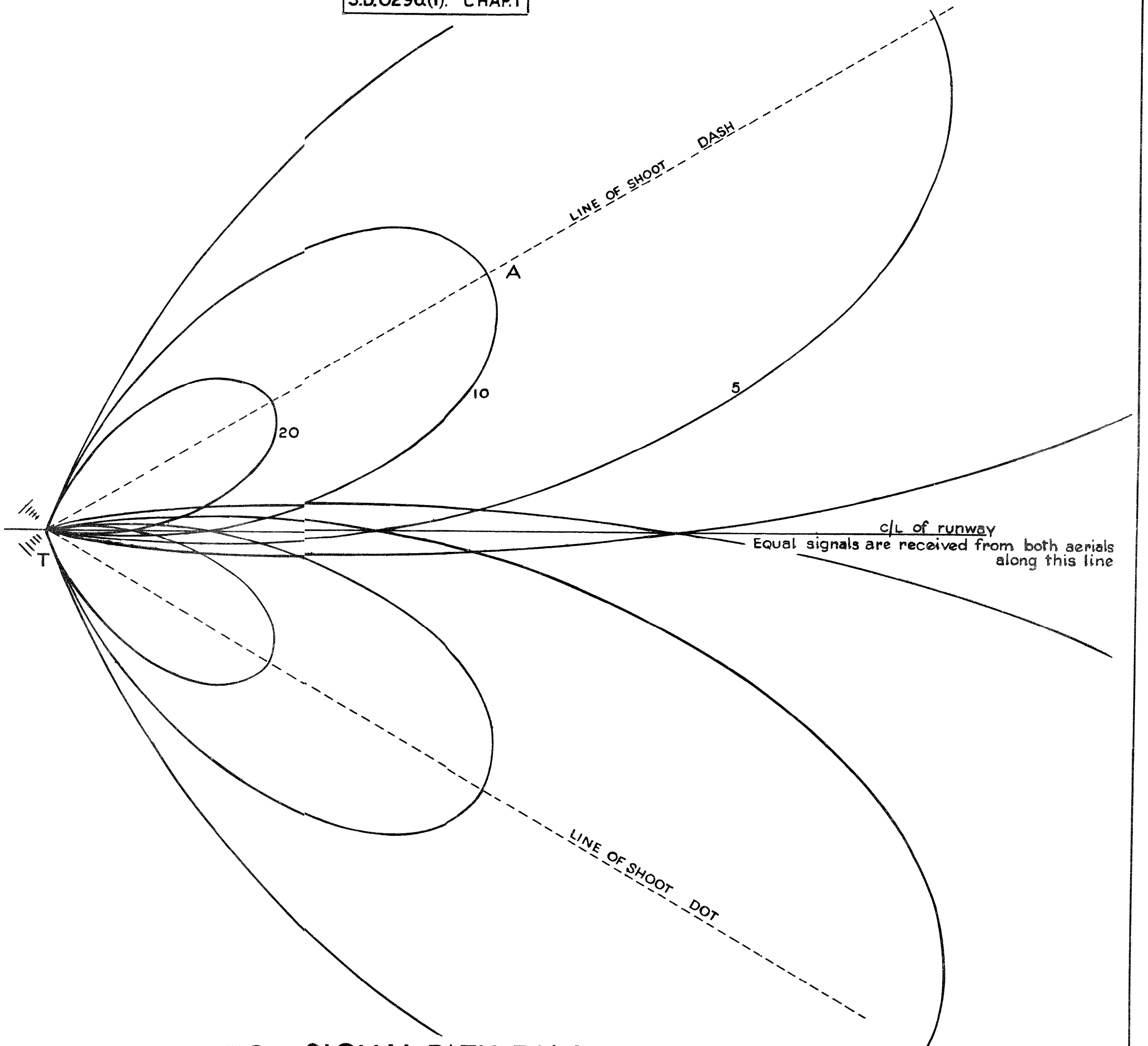


(b) INDICATIONS

BEAM APPROACH

FIG.6.

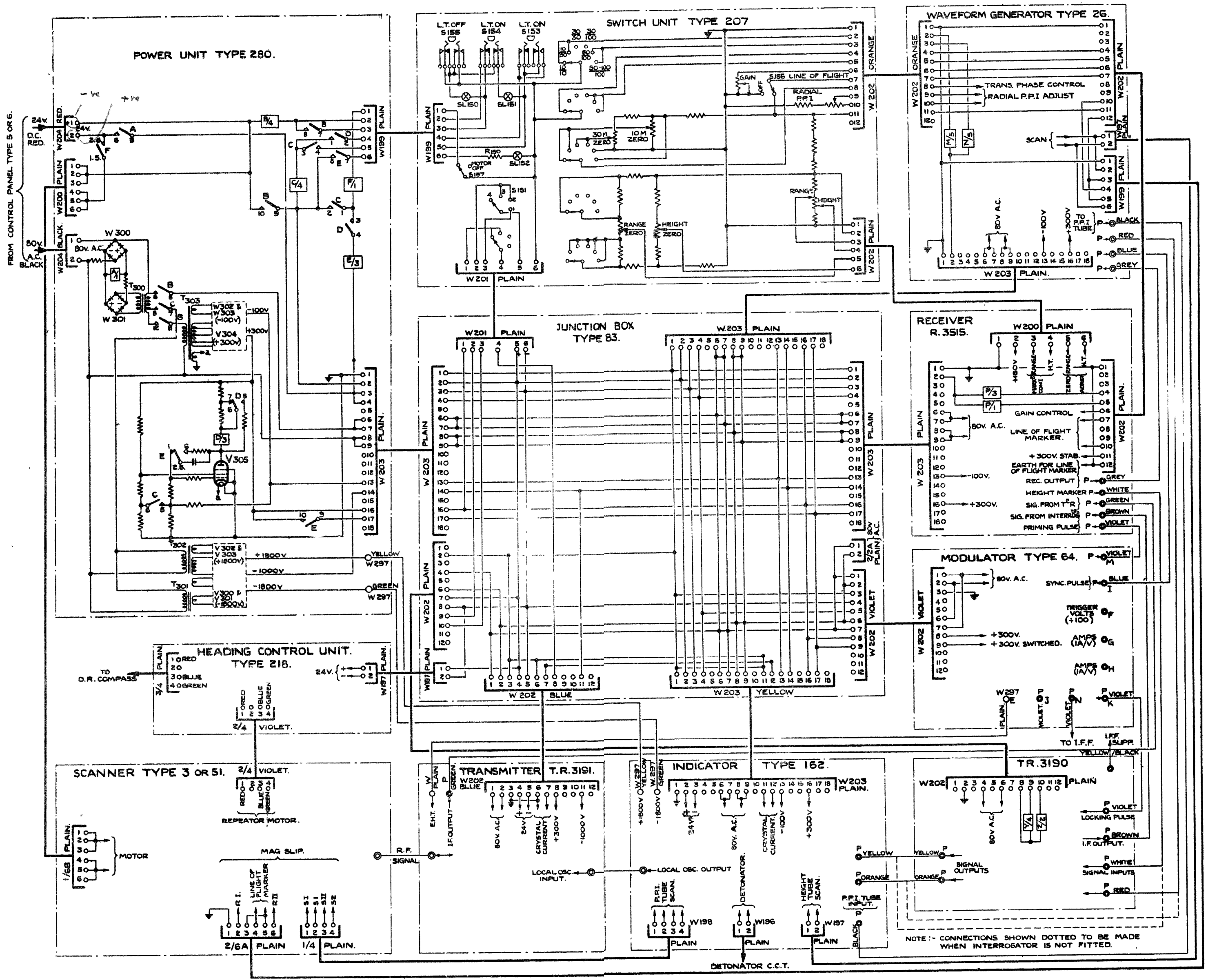
FIG. 6.



EQUISIGNAL PATH DIAGRAM

FIG. 7

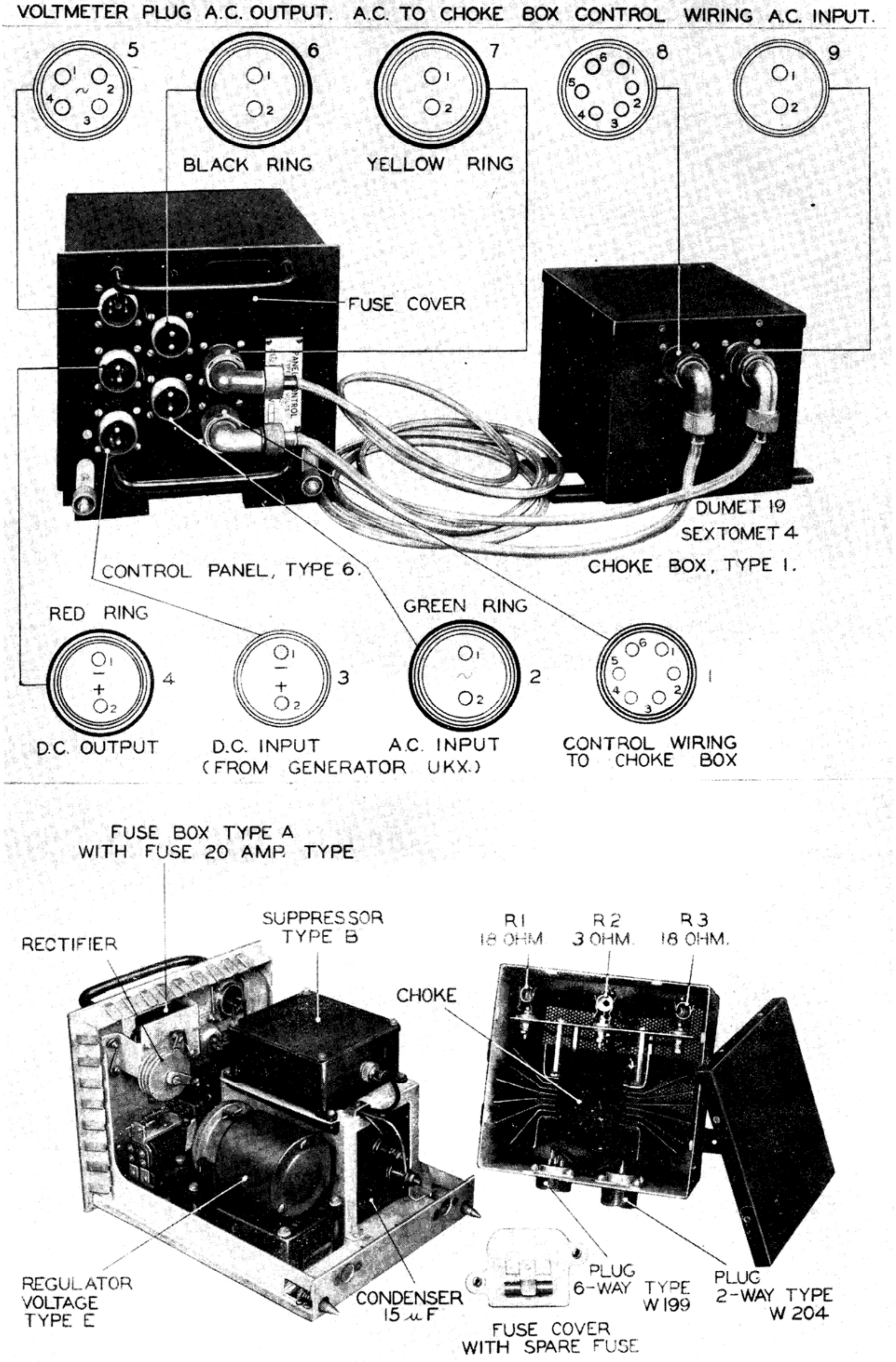
FIG. 7



WIRING DIAGRAM.

FIG.8

FIG.8



CONTROL PANEL TYPE 6 AND CHOKE BOX, TYPE I. FIG.9

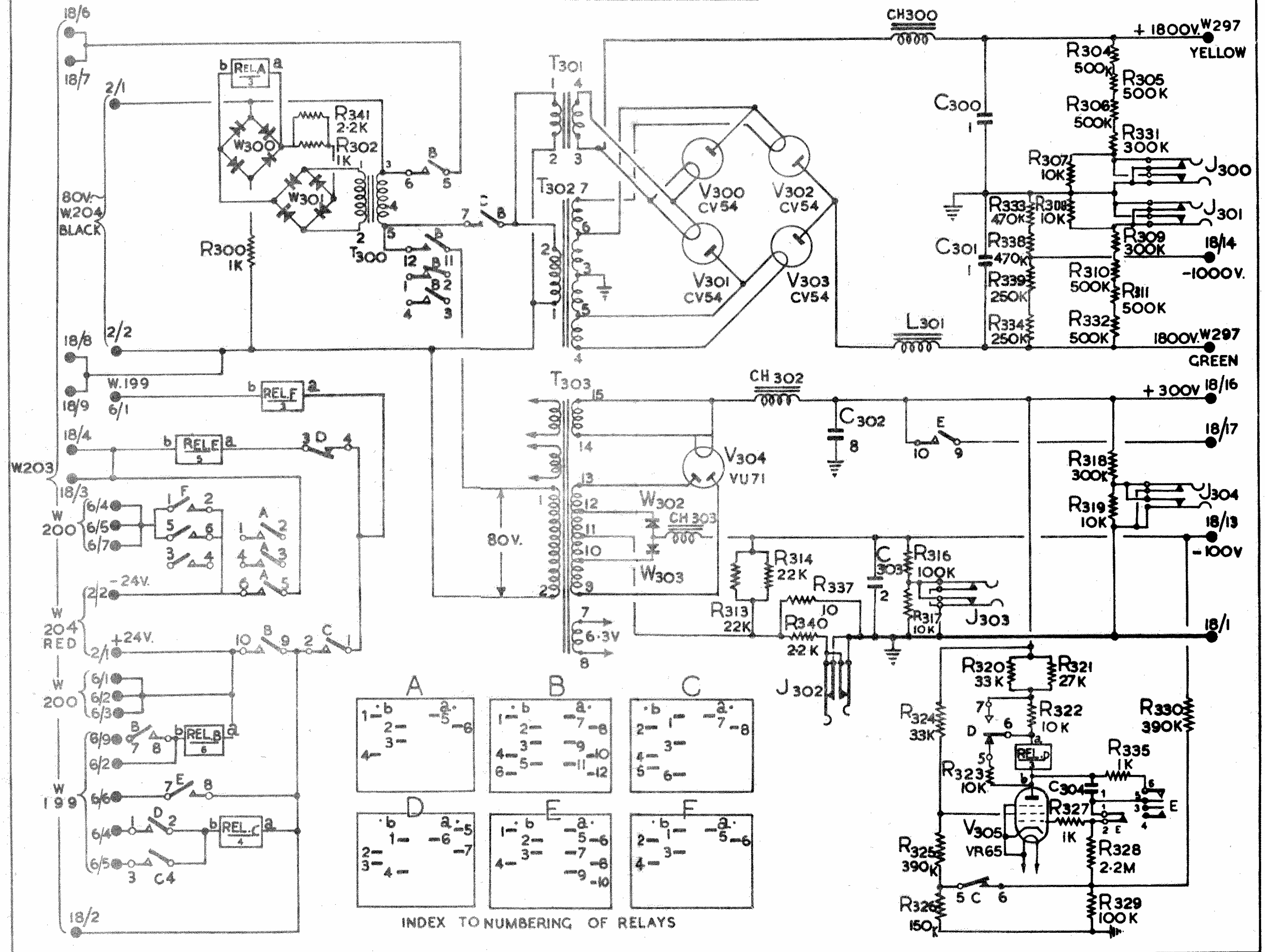
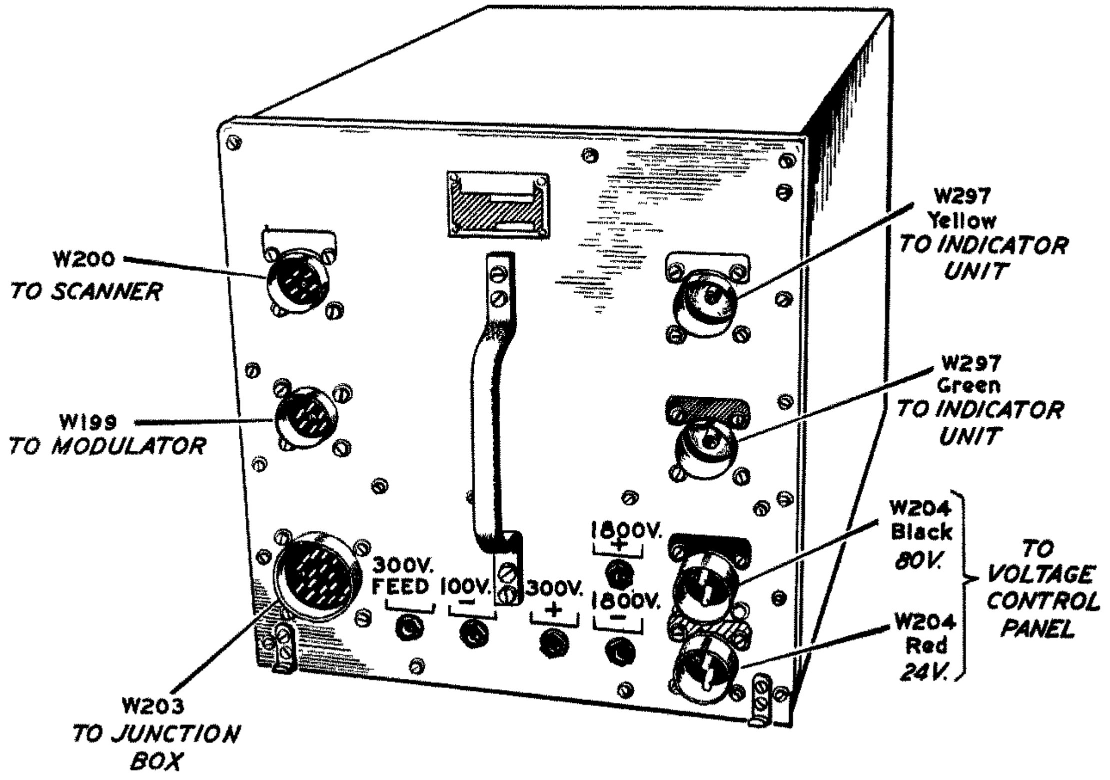


FIG. 10

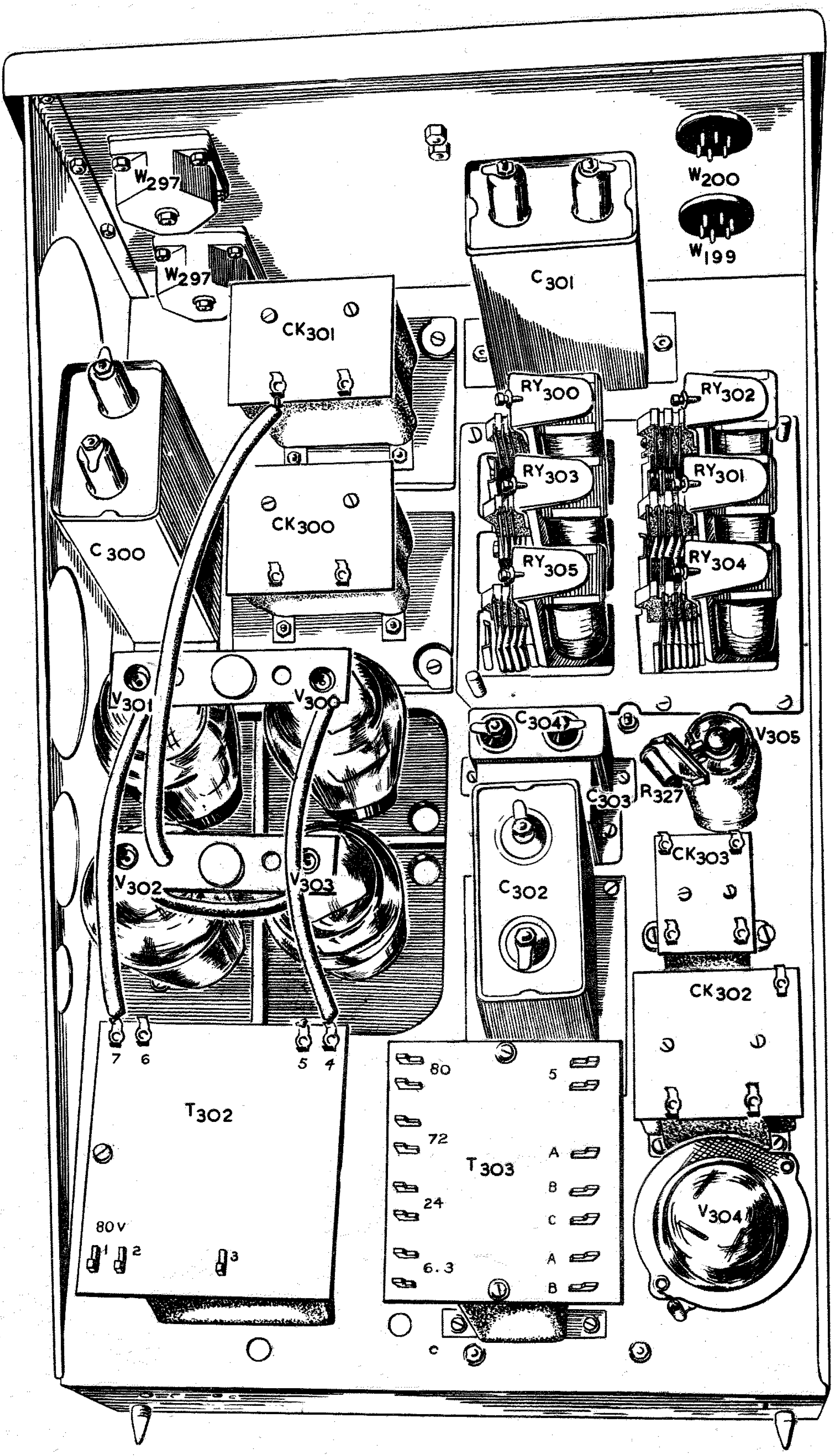
POWER UNIT TYPE 280, CIRCUIT

FIG. 10



POWER UNIT TYPE 280

FIG. 11

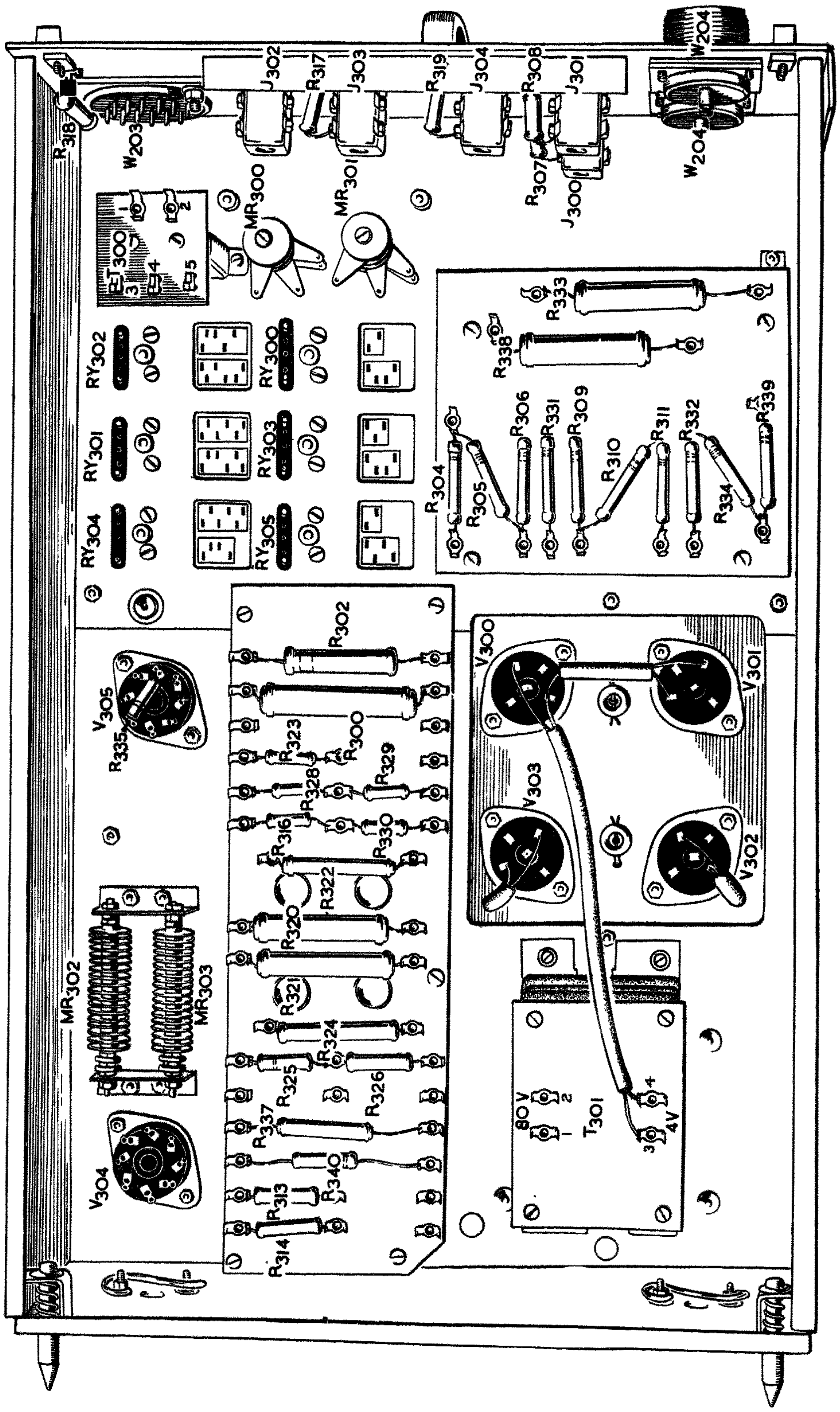


POWER UNIT TYPE 280

TOP VIEW OF CHASSIS

FIG.12

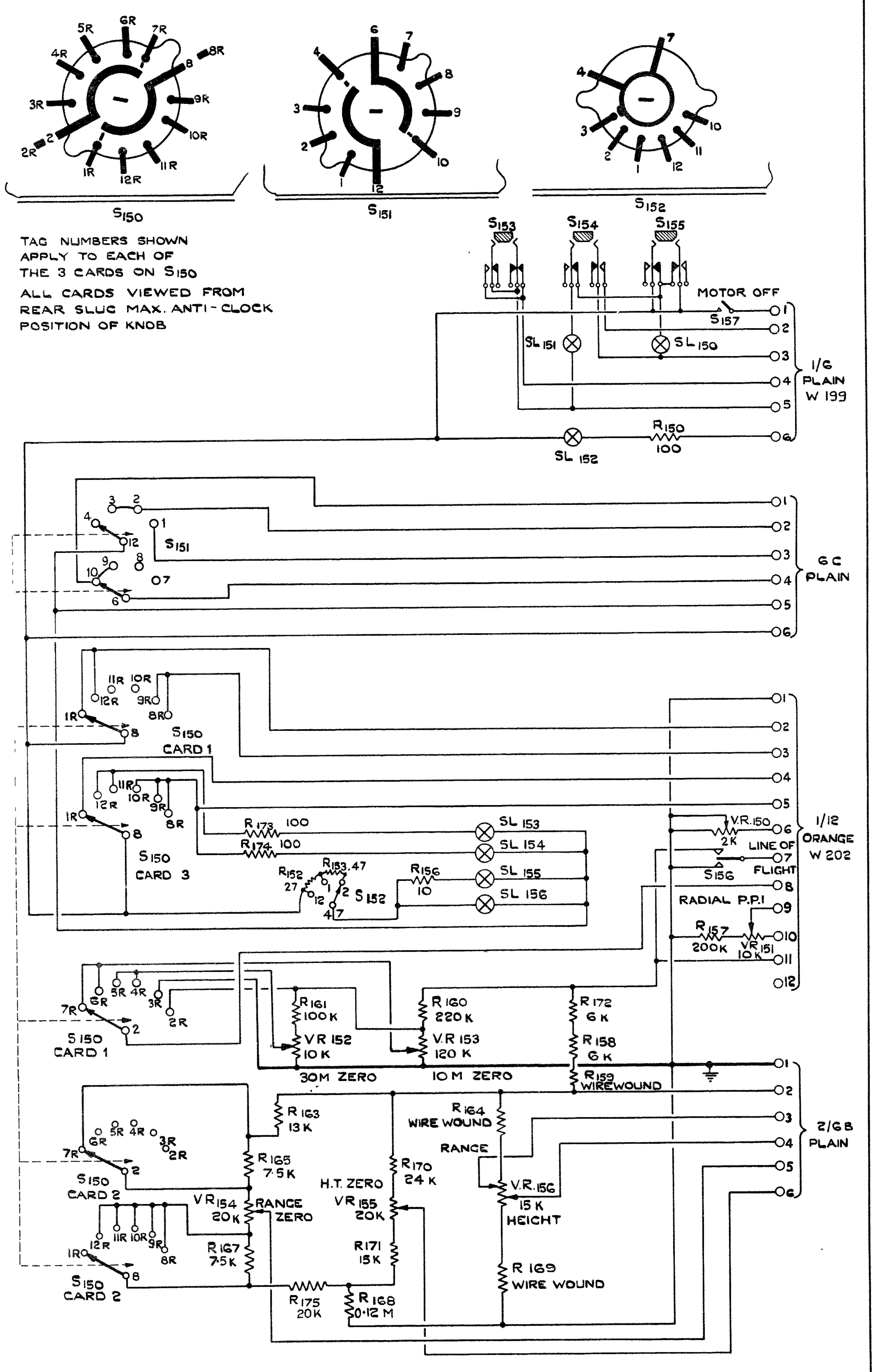
FIG.12



POWER UNIT TYPE 280
UNDERSIDE VIEW

FIG. 13

FIG. 13



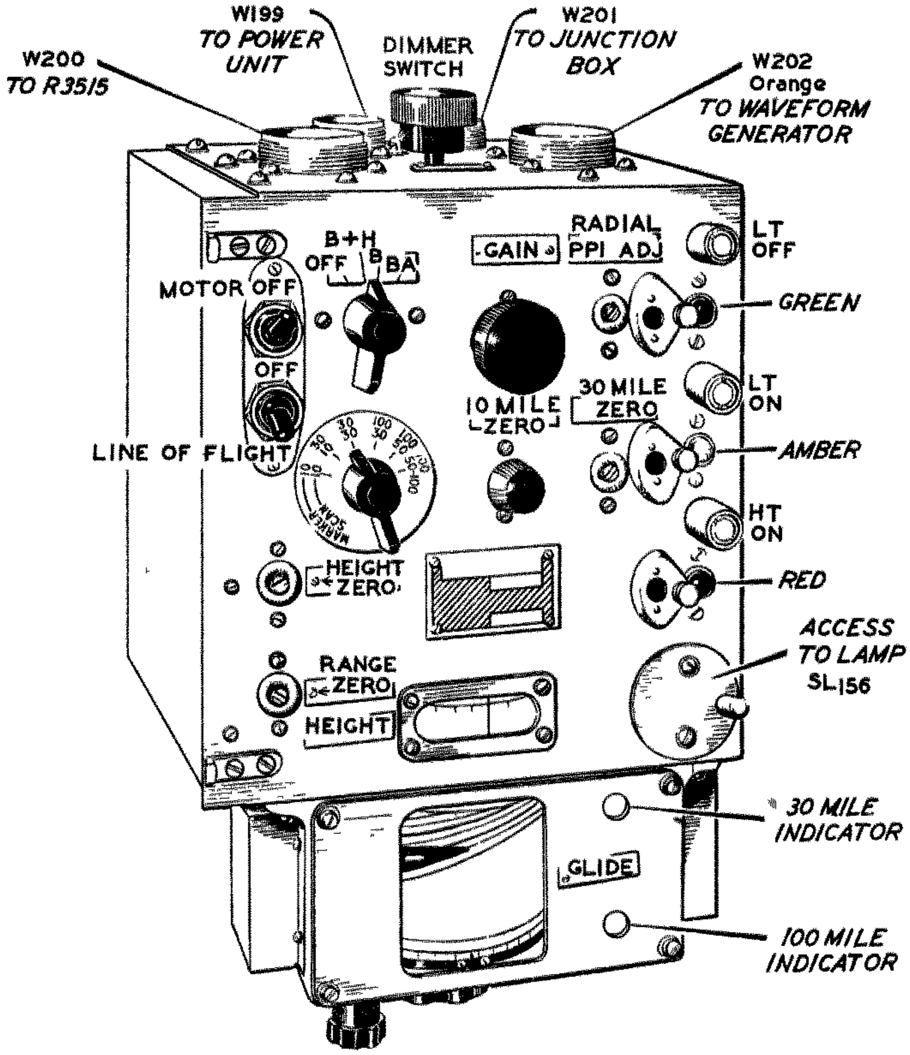
TAG NUMBERS SHOWN APPLY TO EACH OF THE 3 CARDS ON S150

ALL CARDS VIEWED FROM REAR SLUG MAX. ANTI-CLOCK POSITION OF KNOB

SWITCH UNIT, TYPE 207—CIRCUIT

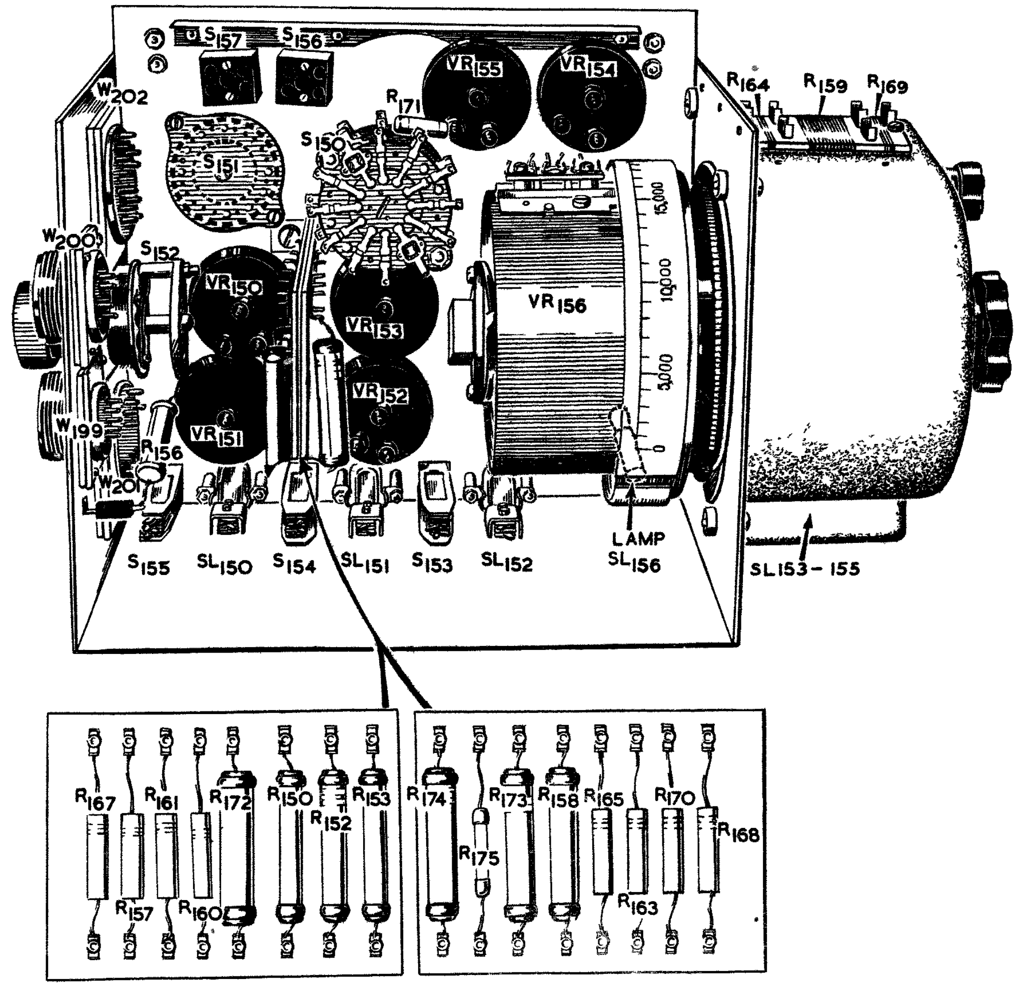
FIG.14

FIG.14



SWITCH UNIT TYPE 207

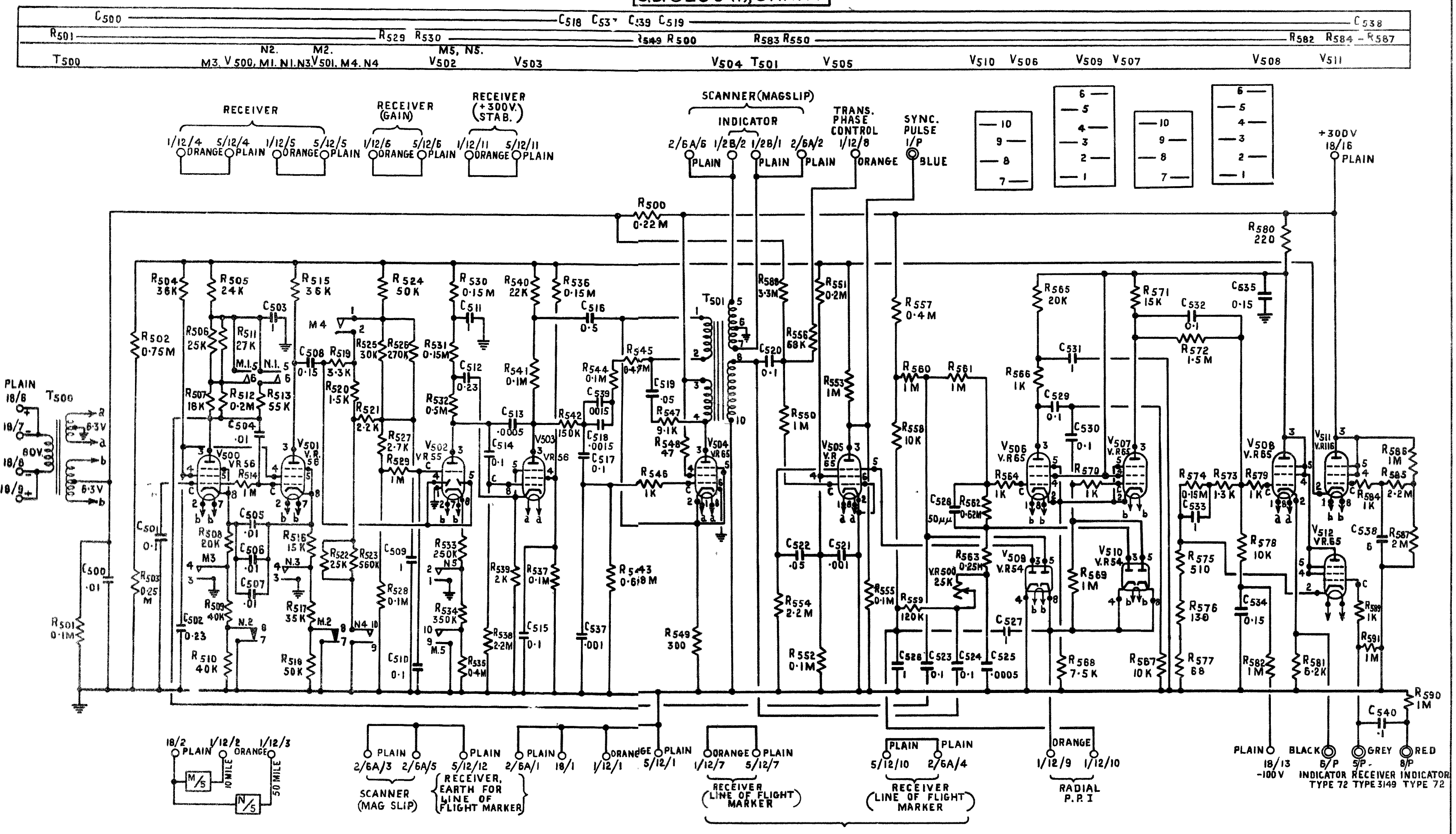
FIG.15



SWITCH UNIT TYPE 207
INTERNAL VIEW

FIG. 16

FIG. 16



WAVEFORM GENERATOR, TYPE 26, CIRCUIT

FIG. 17

FIG. 17

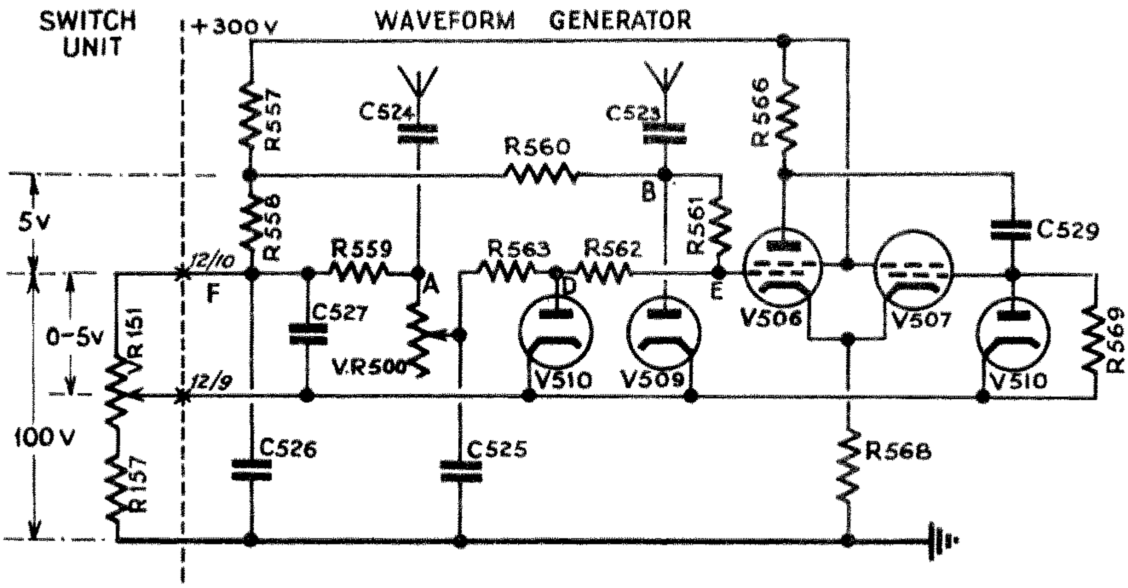


FIG.18. SIMPLIFIED CIRCUIT BRIGHTENING MULTIVIBRATOR

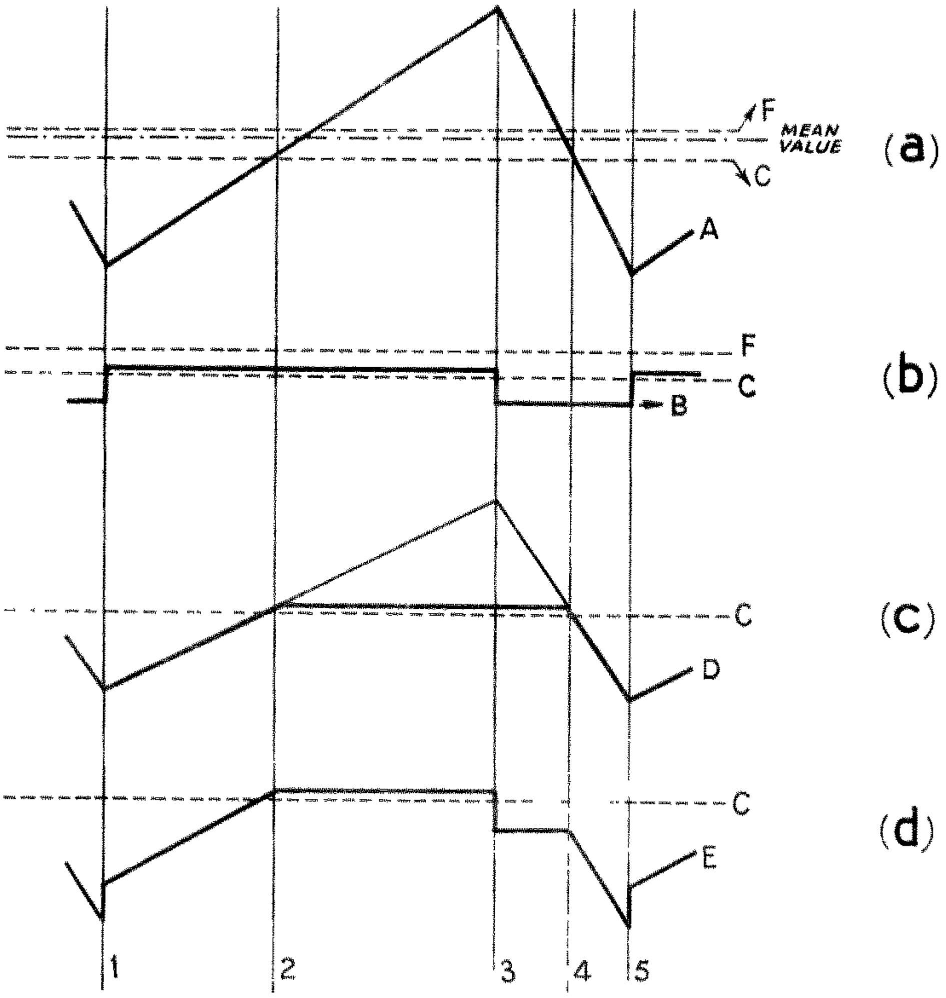
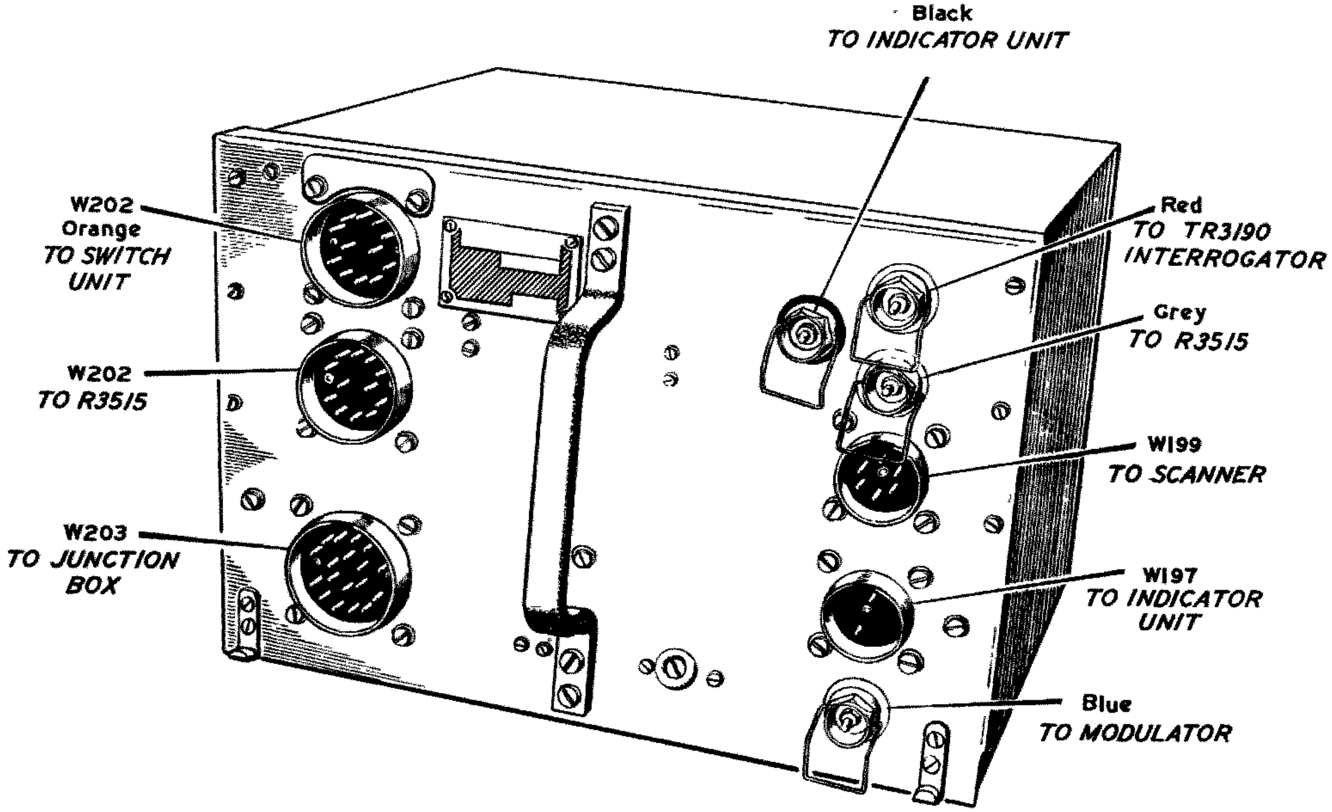


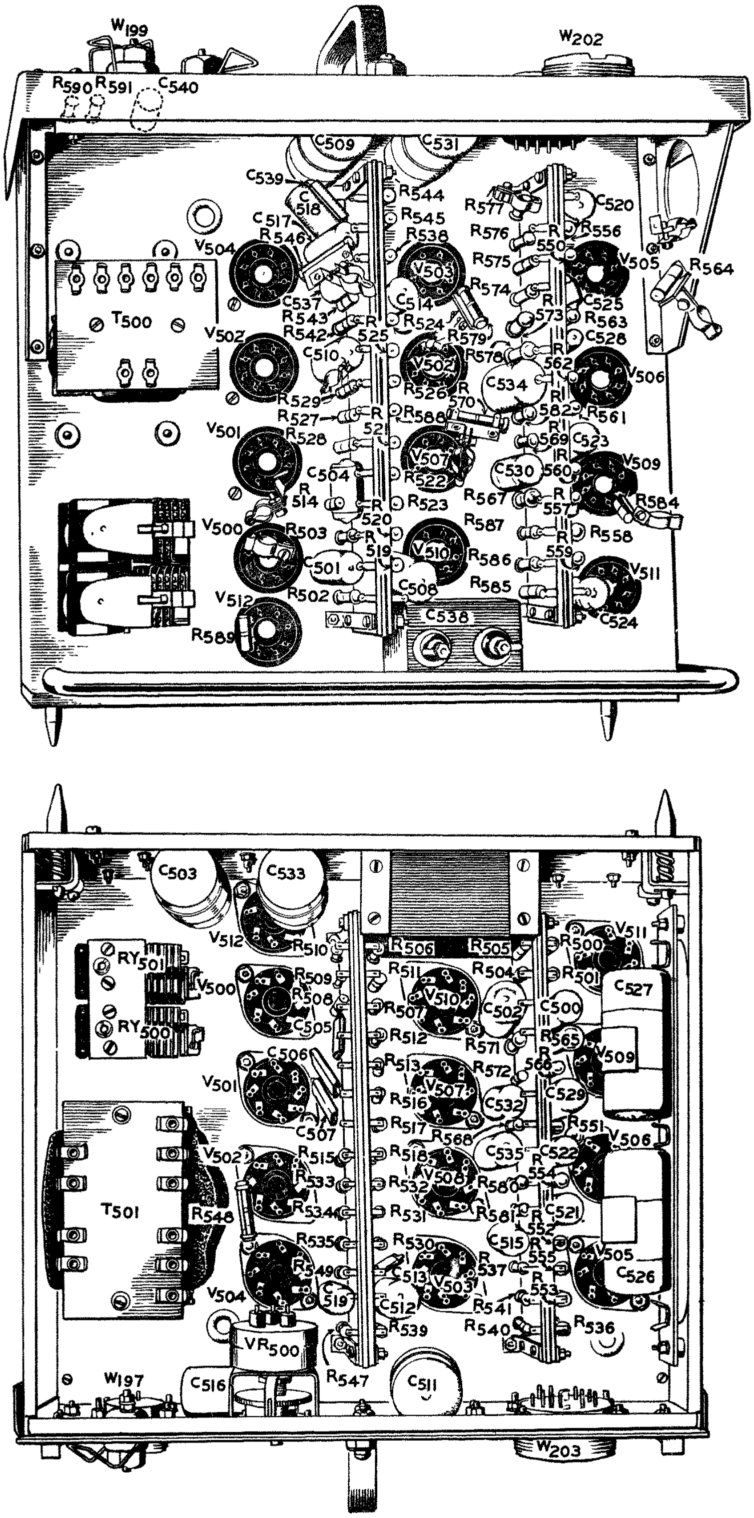
FIG.19. BRIGHTENING CIRCUIT INPUT WAVEFORMS

FIG 20



WAVEFORM GENERATOR TYPE 26

FIG.20

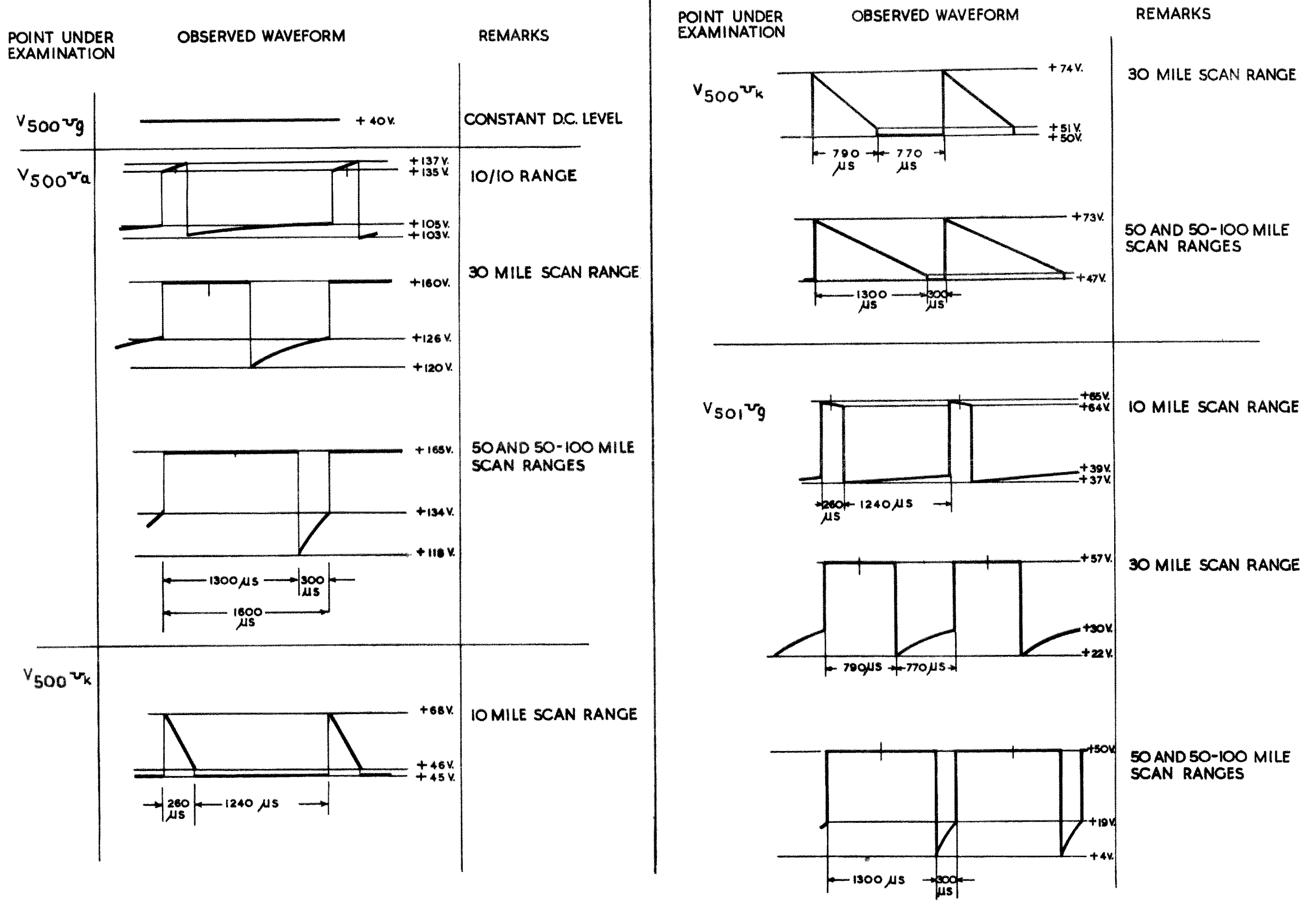


WAVEFORM GENERATOR TYPE 26

VIEWS OF CHASSIS

FIG. 21

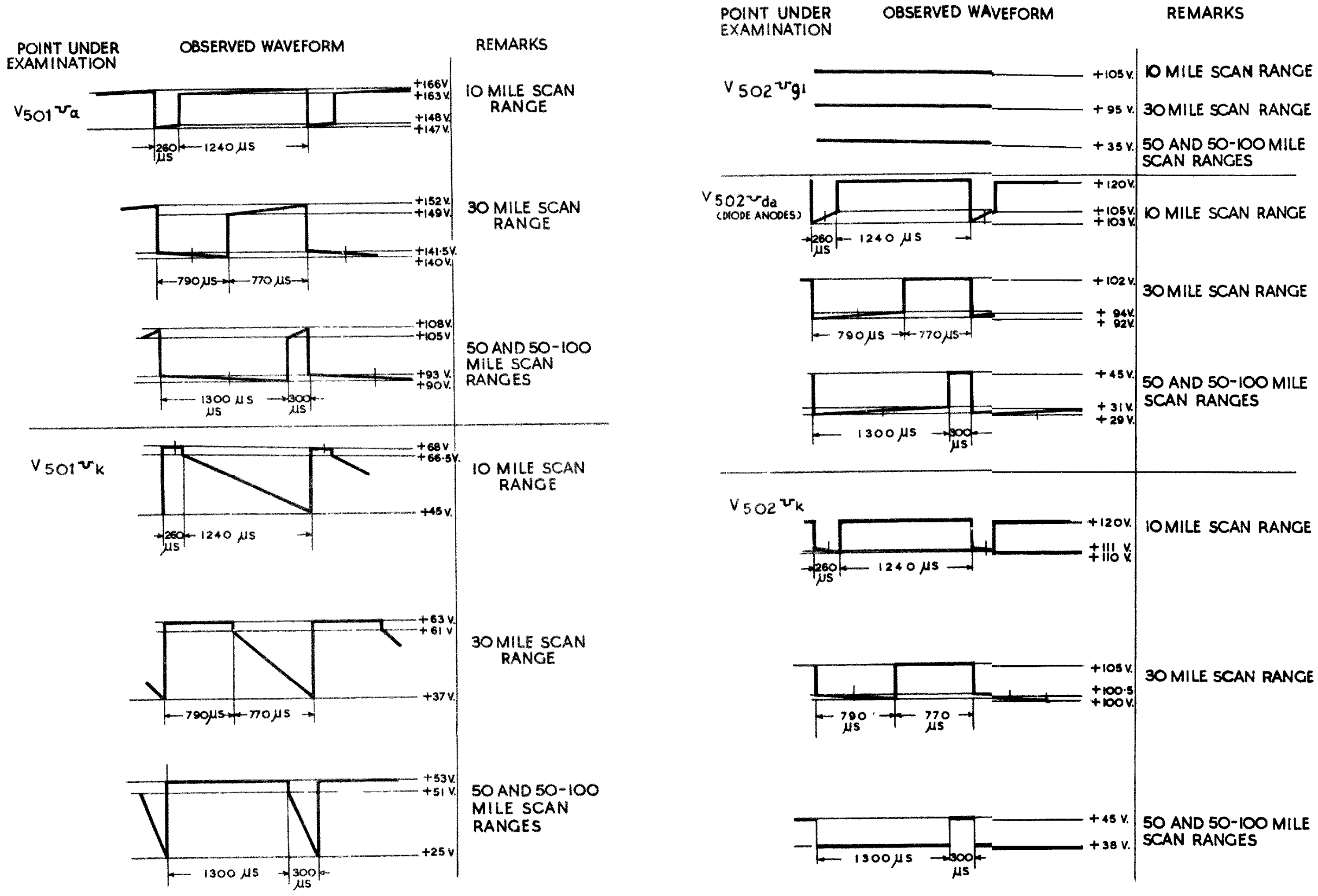
FIG. 21



WAVEFORM GENERATOR TYPE 26 — WAVEFORMS (I)

FIG.22

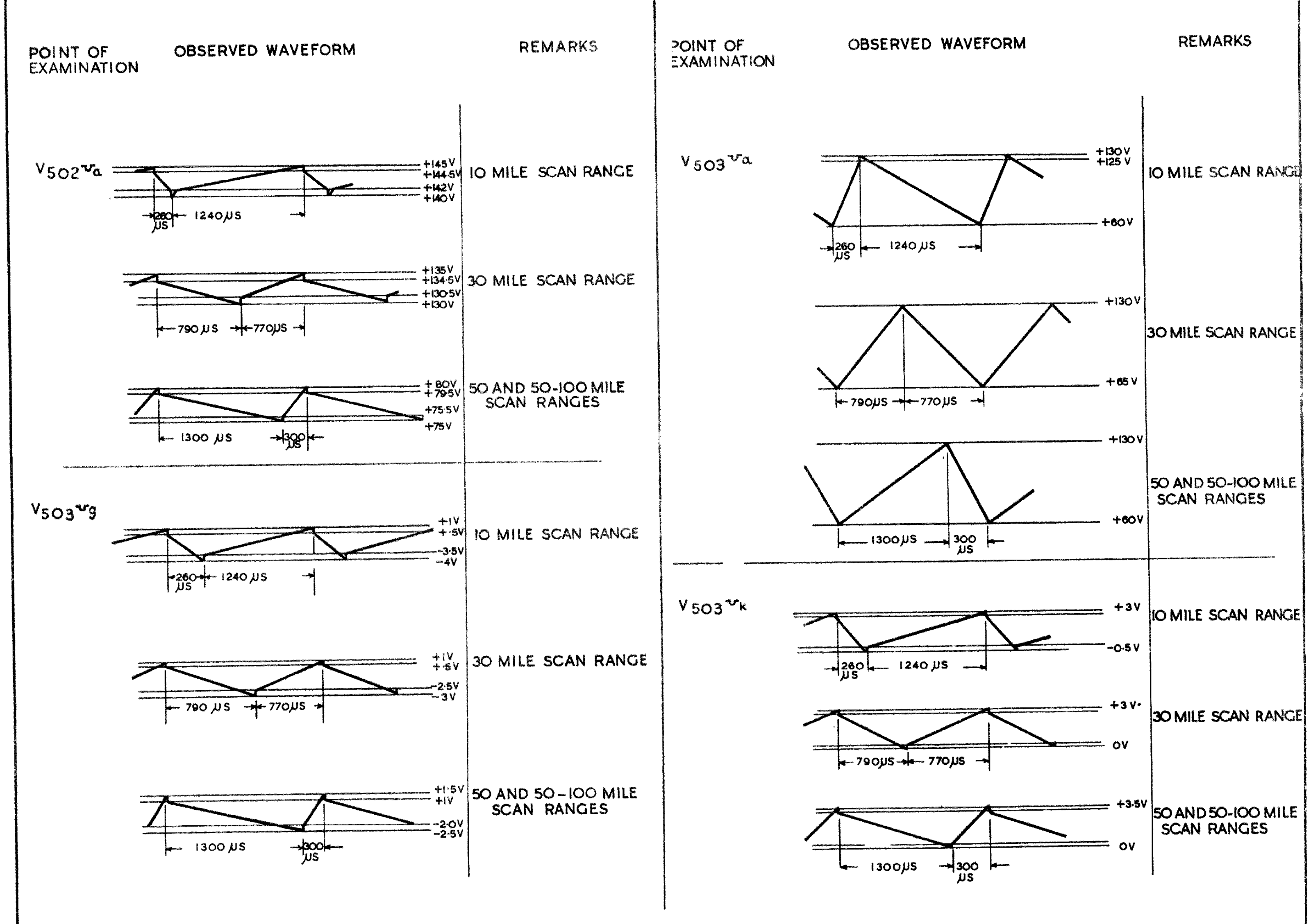
FIG.22



WAVEFORM GENERATOR TYPE 26 — WAVEFORMS 2)

FIG. 23

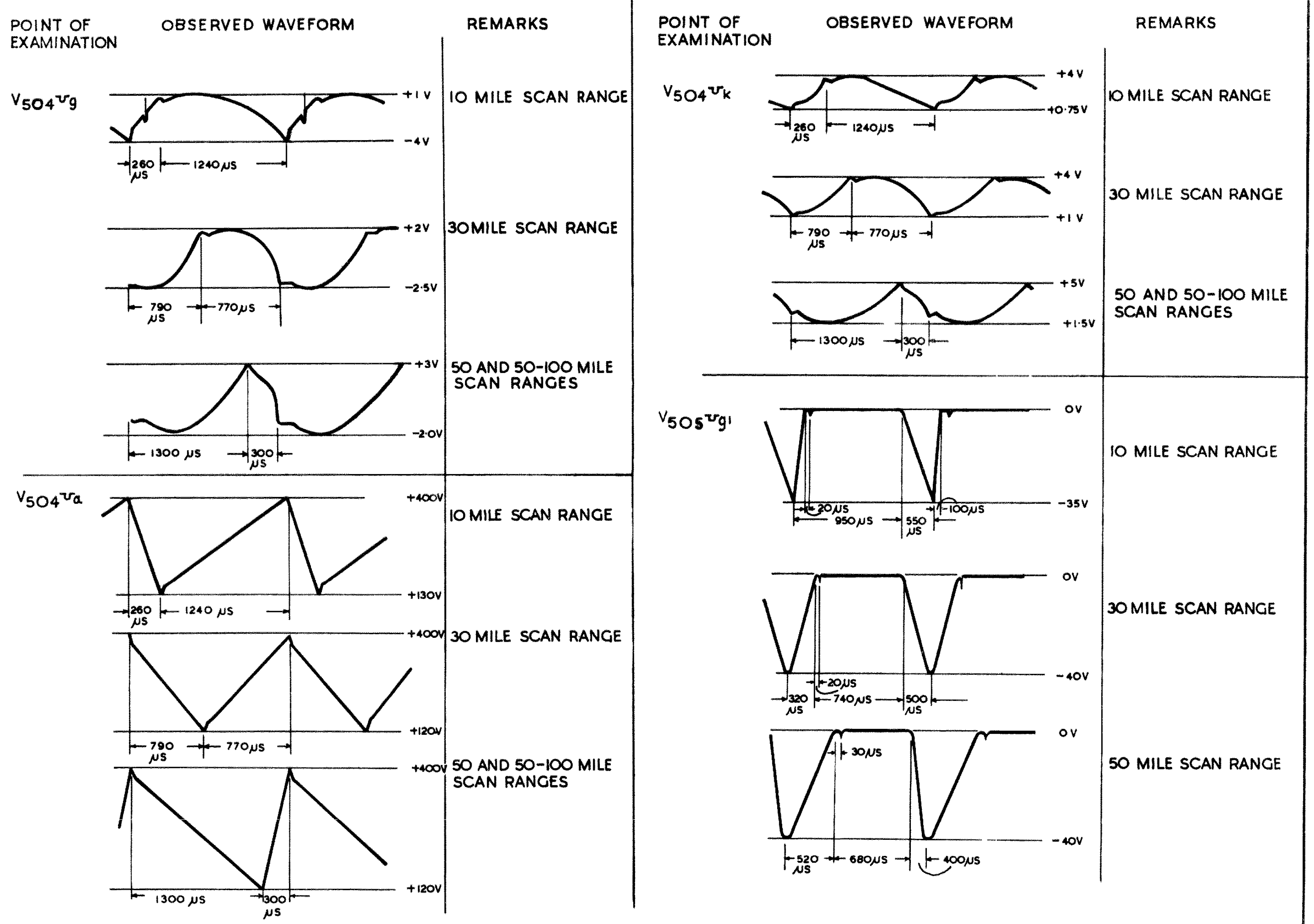
FIG. 23



WAVEFORM GENERATOR TYPE 26 — WAVEFORMS (3)

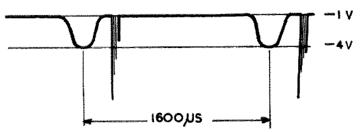
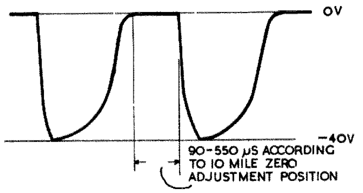
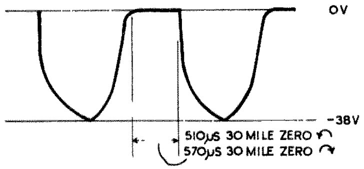
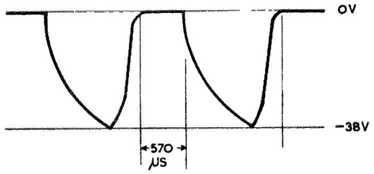
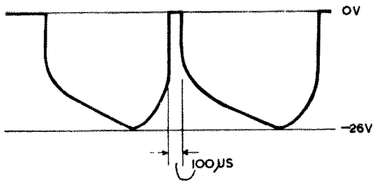
FIG. 24

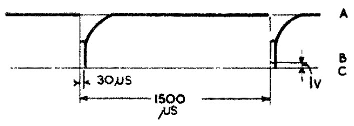
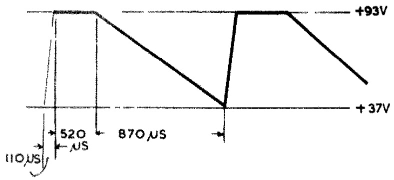
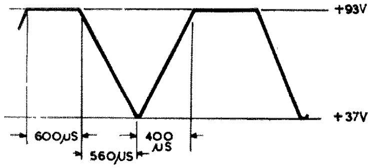
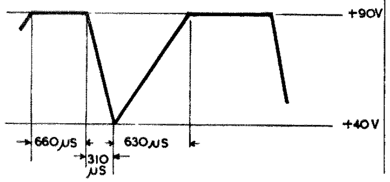
FIG. 24



WAVEFORM GENERATOR TYPE26 — WAVEFORMS (4)

FIG. 25

POINT OF EXAMINATION	OBSERVED WAVEFORMS	REMARKS
V_{505} v_{g1}		50-100 MILE SCAN RANGES TIMING AFFECTED BY PRESENCE OF TEST SET LEAD.
V_{505} v_{g3}		10 MILE SCAN RANGE TIMING AFFECTED BY 10 MILE ZERO ADJUSTMENT.
		30 MILE SCAN RANGE TIMING AFFECTED BY 30 MILE ZERO ADJUSTER.
		50 MILE SCAN RANGE TIMING UNAFFECTED BY PRESENT CONTROLS
		50-100 MILE SCAN RANGE

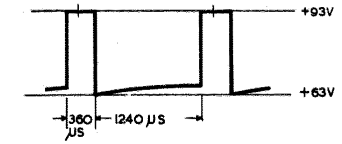
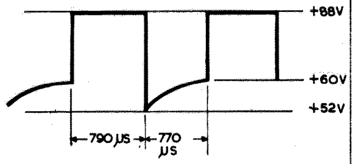
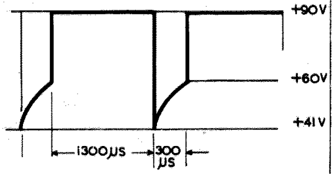
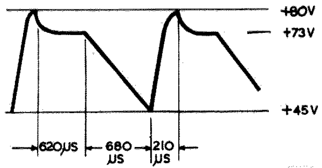
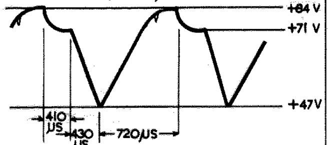
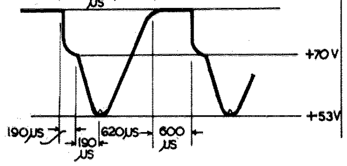
POINT OF EXAMINATION	OBSERVED WAVEFORMS	REMARKS
V_{505} v_{g2}	AS V_{505} v_{g3} BUT LIMITS OF VOLTAGE AS UNDER REMARKS →	10 MILE SCAN RANGE VOLTAGE LIMITS +20 TO +56 30 MILE SCAN RANGE VOLTAGE LIMITS +20 TO +56 100 MILE SCAN RANGE VOLTAGE LIMITS +20 TO +56 100/50-100 MILE RANGE VOLTAGE LIMITS +17 TO +45
V_{505} v_{a}		WAVE SHAPE UNALTERED BY RANGE VOLTAGES ON VARIOUS RANGES
V_{519} v_{da} (NO 1 DIODE ANODE)		10 MILE SCAN RANGE
		30 MILE SCAN RANGE
		50 AND 50-100 MILE SCAN RANGES

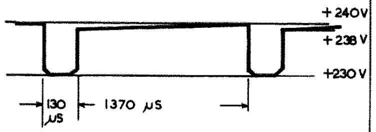
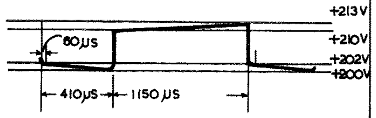
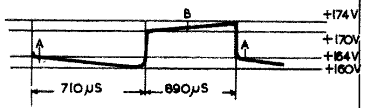
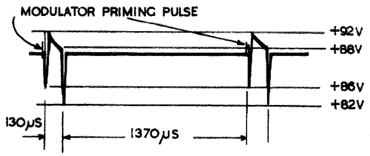
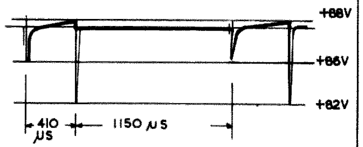
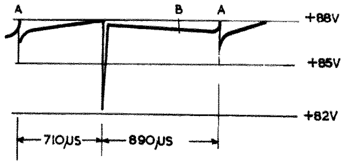
RANGE	A	B	C
10 MILE	+16V	+9·5	+8·5
30MILE	+16V	+9·0	+8·0
100MILE	+16V	+9·5	+7·5
100/50-100	+16V	+4·5	+2V

WAVEFORM GENERATOR TYPE 26 — WAVEFORMS (5)

FIG. 26

FIG. 26

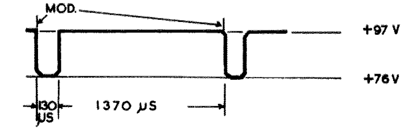
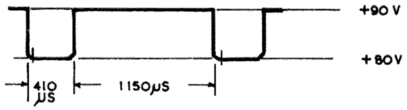
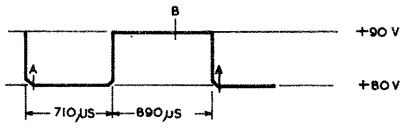
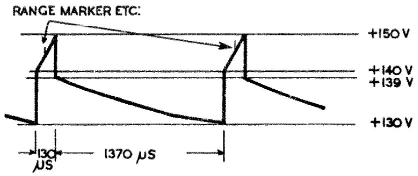
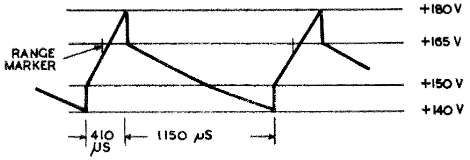
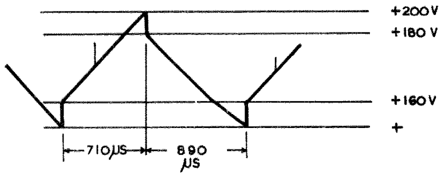
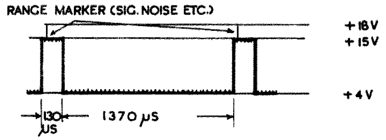
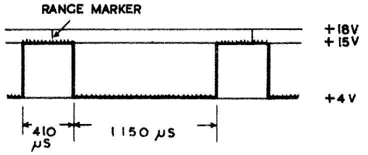
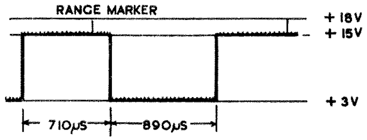
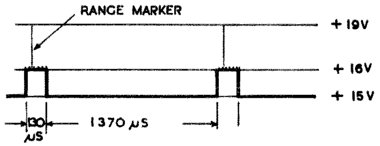
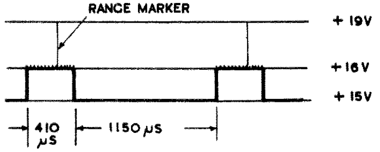
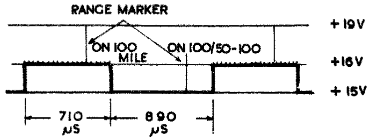
POINT OF EXAMINATION	OBSERVED WAVEFORM	REMARKS
$V_{510}\ v_{d2a}$ (No 2 DIODE ANODE)		10 MILE SCAN RANGE
		30 MILE SCAN RANGE
		50 AND 50-100 MILE SCAN RANGES (NOTE RADIAL P.P.I. ADJUSTMENT ALTERS D.C. LEVEL OF SQ. WAVE BY ABOUT 7 VOLTS)
$V_{506}\ v_{g1}$		10 MILE SCAN RANGE
		30 MILE SCAN RANGE
		50 AND 50-100 MILE SCAN RANGES

POINT OF EXAMINATION	OBSERVED WAVEFORM	REMARKS
$V_{506}\ v_{a}$		10 MILE SCAN RANGE
		30 MILE SCAN RANGE
		50 AND 50-100 MILE SCAN RANGES NOTE: MODULATOR PIPS APPEAR AT POINT A ON 100/50 " " " B ON 100/50-100
$V_{506}\ v_{k}$ $V_{507}\ v_{k}$		10 MILE SCAN RANGE
		30 MILE SCAN RANGE
		50 AND 50-100 MILE SCAN RANGES POSITION OF MODULATOR PRIMING PULSE: A 100/50 MILE RANGE B 100/50-100 " "

WAVEFORM GENERATOR TYPE 26 — WAVEFORMS (6)

FIG. 27

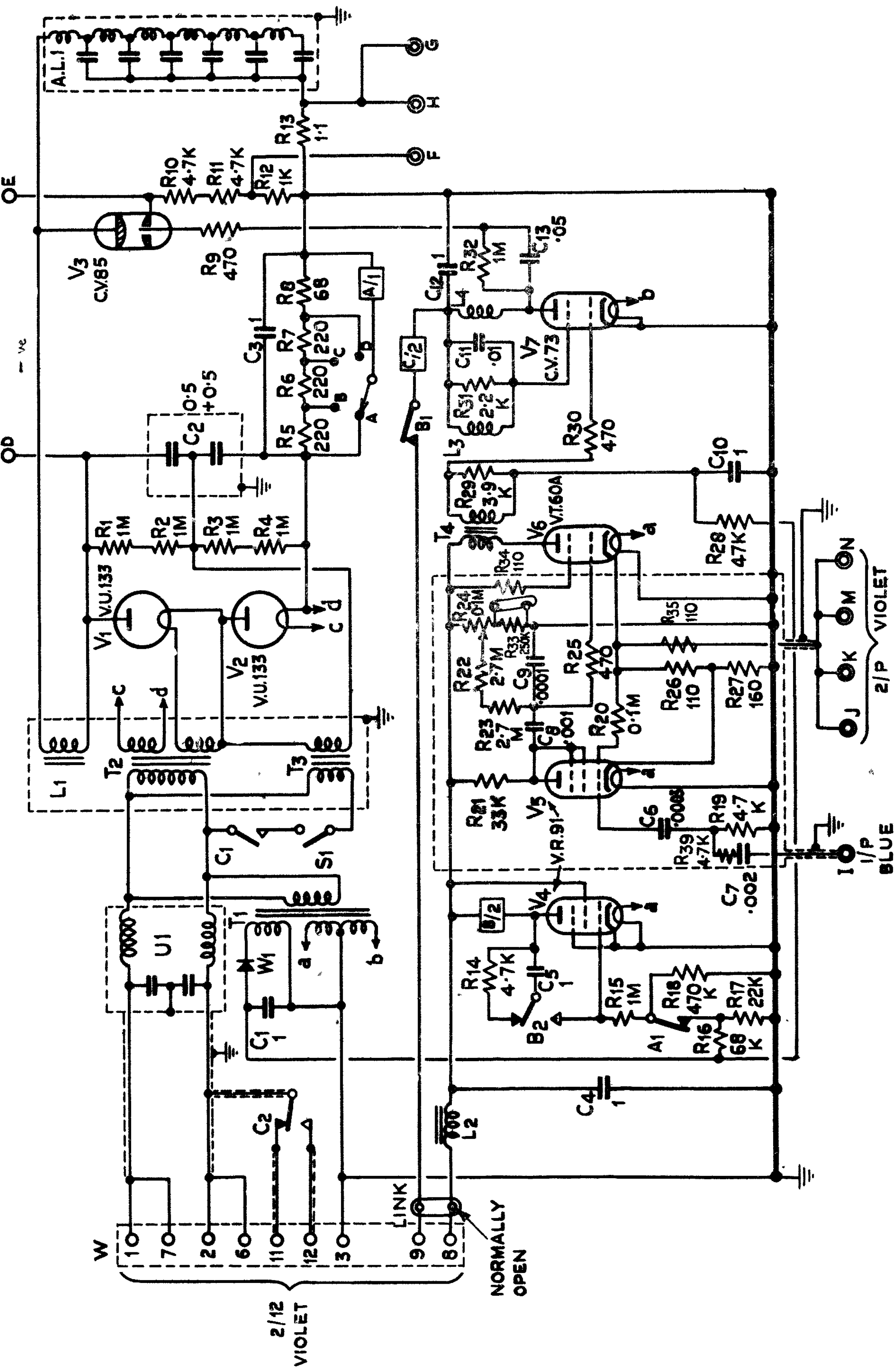
FIG. 27

POINT OF EXAMINATION	OBSERVED WAVEFORM	REMARKS
$V_{507}\,v_g$		IO MILE SCAN RANGE
		30 MILE SCAN RANGE
		50 AND 50-100 MILE SCAN RANGES A.B AS BEFORE
$V_{507}\,v_a$		IO MILE SCAN RANGE
		30 MILE SCAN RANGE
		50 AND 50-100 MILE SCAN RANGES
$V_{508}\,v_g$		IO MILE SCAN RANGE
		30 MILE SCAN RANGE
		50 AND 50-100 MILE SCAN RANGES
$V_{508}\,v_k$		IO MILE SCAN RANGE
		30 MILE SCAN RANGE
		50 AND 50-100 MILE SCAN RANGES

WAVEFORM GENERATOR TYPE 26 — WAVEFORMS (7)

FIG. 28

FIG. 28



MODULATOR UNIT, TYPE 64 — CIRCUIT

FIG.29

FIG.29

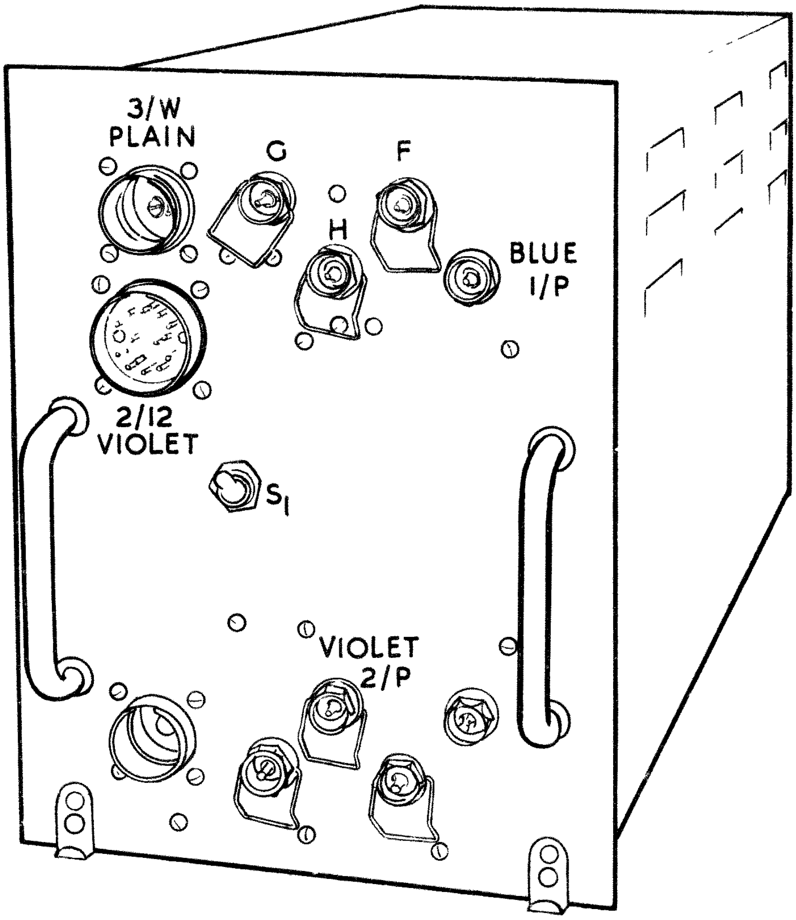


FIG.30-LAYOUT OF FRONT PANEL

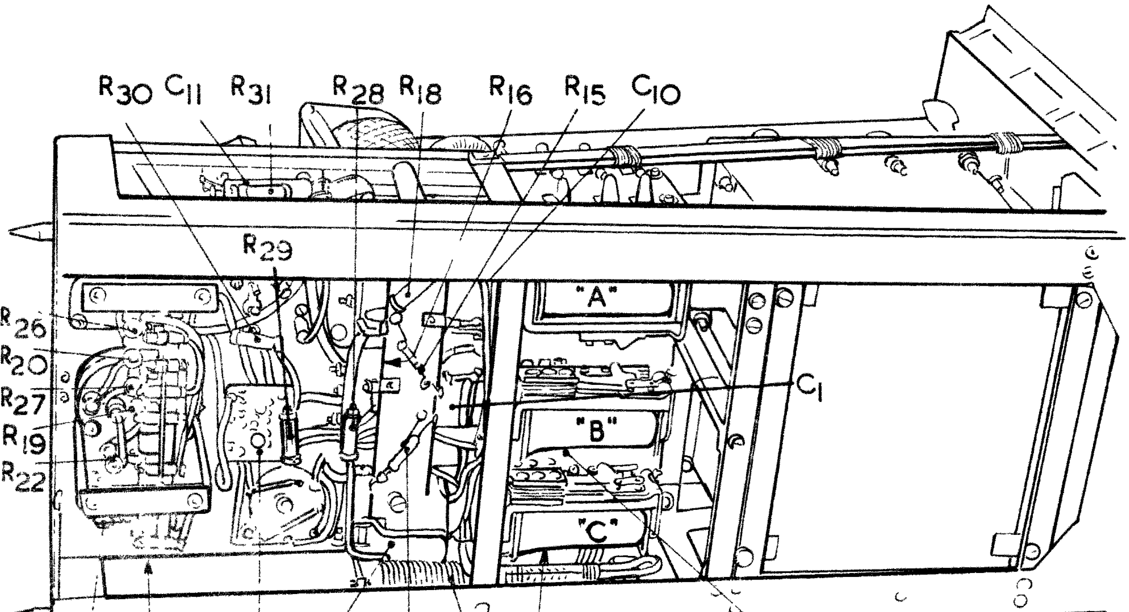
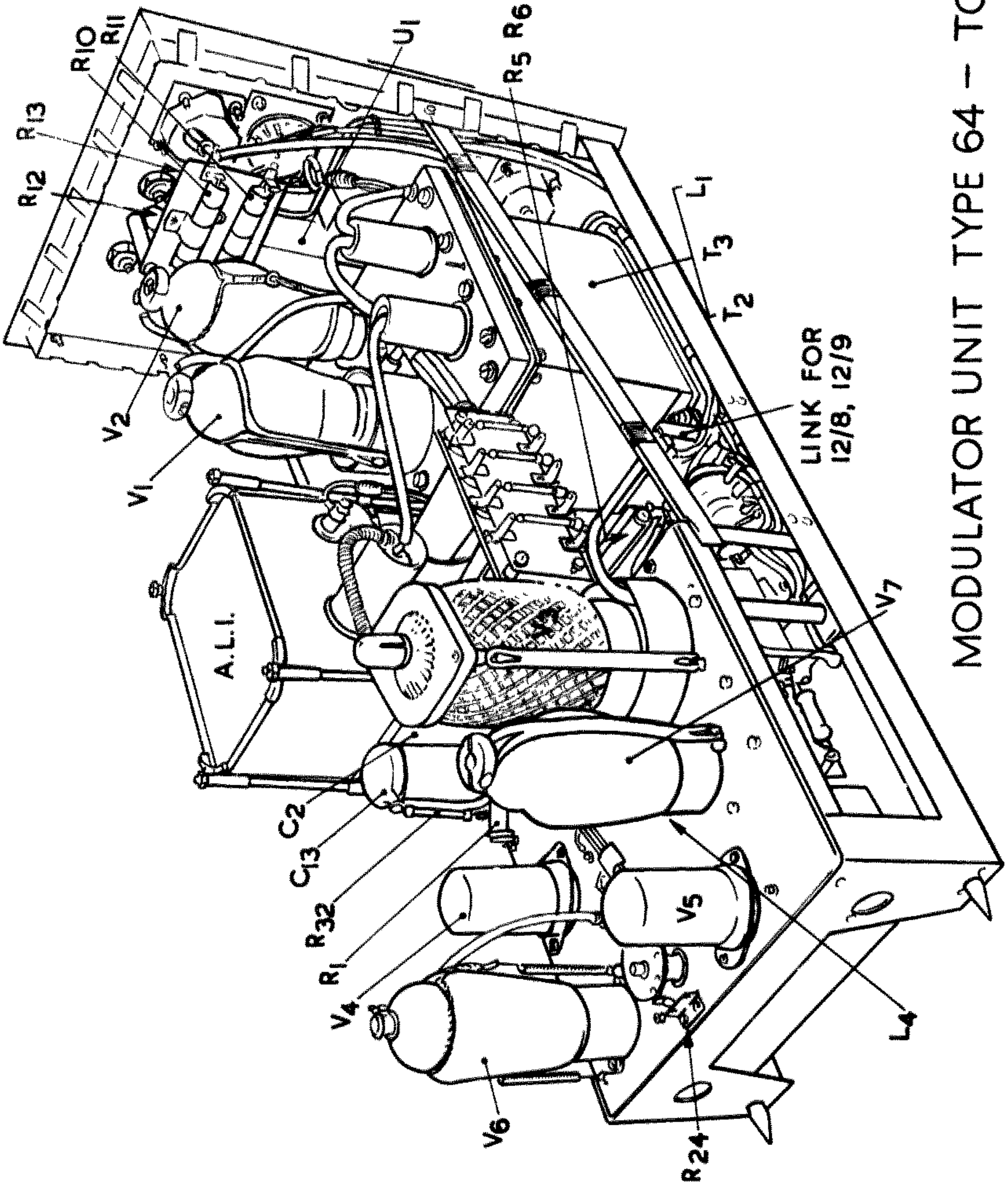


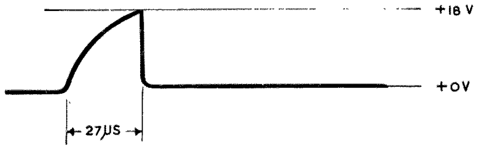
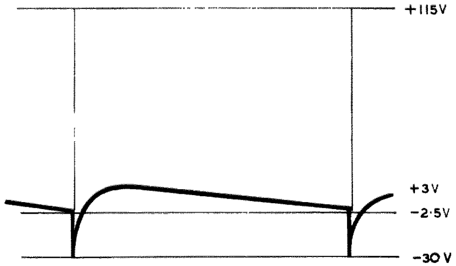
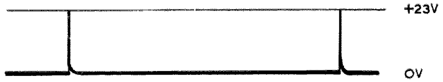
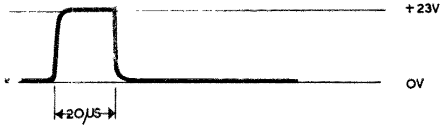
FIG.31- MODULATOR UNIT TYPE 64, UNDERSIDE

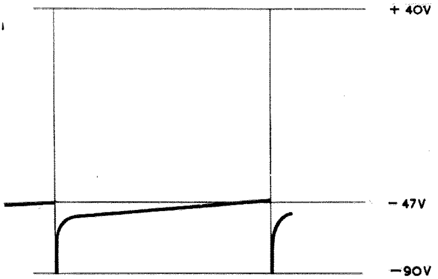
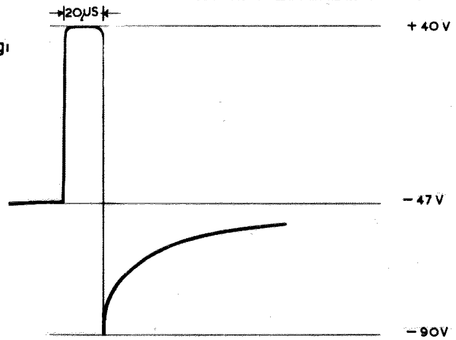
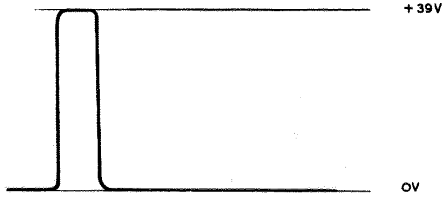


MODULATOR UNIT TYPE 64 — TOP VIEW

FIG. 32

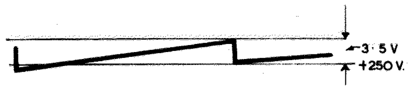
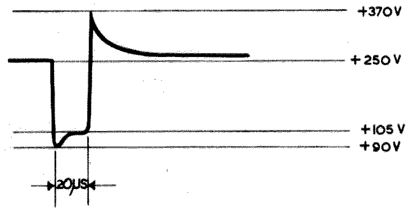
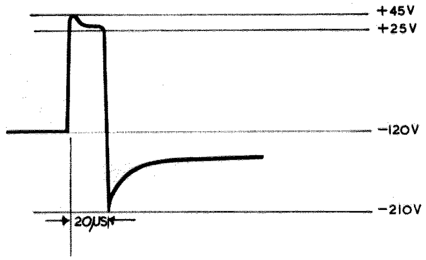
FIG. 32

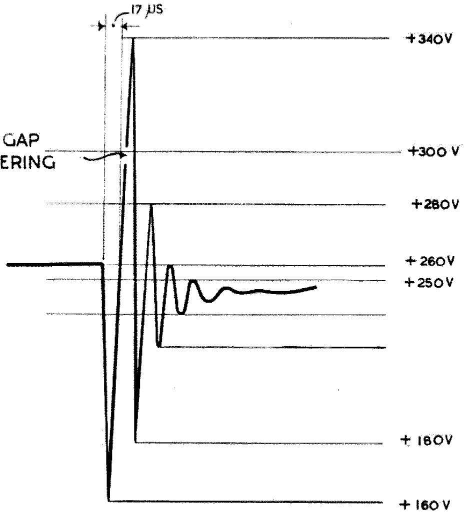
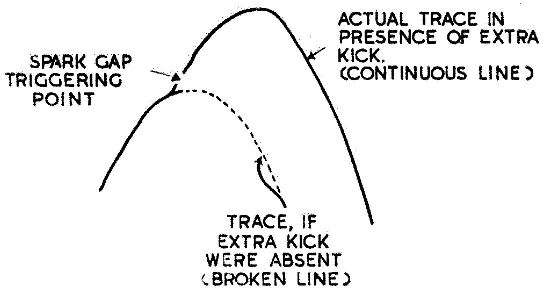
POINT UNDER EXAMINATION	OBSERVED WAVEFORM	REMARKS
$V_5 v_{g1}$		
$V_5 v_a$ also $V_5 v_{g2}$ also $V_5 v_{g3}$		P.R.F. AS FOR MASTER MULTIVIBRATOR
$V_5 v_{k(1)}$		P.R.F. AS FOR MASTER MULTIVIBRATOR
$V_5 v_{k(2)}$		AS $V_5 v_{k(1)}$ BUT WITH EXPANDED TIME BASE

POINT UNDER EXAMINATION	OBSERVED WAVEFORM	REMARKS
$V_6 v_{g1}$		D.C. LEVELS ARE VARIABLE THROUGH ABOUT 20V. BY THE PRESET GRID POTENTIOMETER (R24). VOLTAGES SHOWN ARE FOR CORRECT PRESET ON SET EXAMINED. P.R.F. AS FOR MASTER MULTIVIBRATOR
$V_6 v_{g1}$		AS $V_6 v_{g1}$ BUT WITH EXPANDED TIME BASE
$V_6 v_k$		P.R.F. AS FOR MASTER MULTIVIBRATOR

MODULATOR UNIT – TYPE 64 – WAVEFORMS (1)

FIG. 33

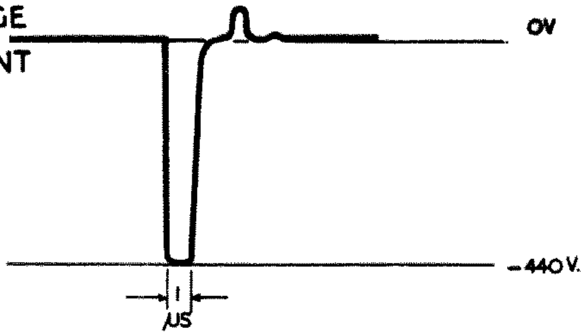
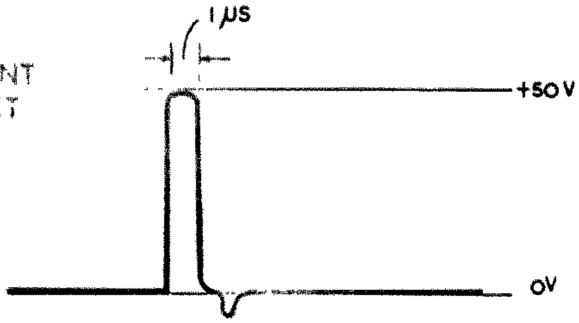
POINT UNDER EXAMINATION	OBSERVED WAVEFORM	REMARKS
$V_2 \upsilon_{g2}$ also $V_4 \upsilon_{g2}$		P.R.F. AS FOR MASTER MULTIVIBRATOR
$V_6 \upsilon_a$		P.R.F. AS FOR MASTER MULTIVIBRATOR
T_4 TAG.5		P.R.F. AS FOR MASTER MULTIVIBRATOR
$V_7 \upsilon_{g1}$		P.R.F. AS FOR MASTER MULTIVIBRATOR

POINT UNDER EXAMINATION	OBSERVED WAVEFORM	REMARKS
$V_7 \upsilon_{g2}$		TRIGGERING OCCURS ON RISING PORTION OF FIRST POSITIVE PEAK
		DETAIL OF FIRST POSITIVE PEA ON EXPANDED TIME BASE SHOWING EXTRA KICK PRODUCED AT CUT-OFF

MODULATOR UNIT - TYPE 64 - WAVEFORMS (2)

FIG. 34

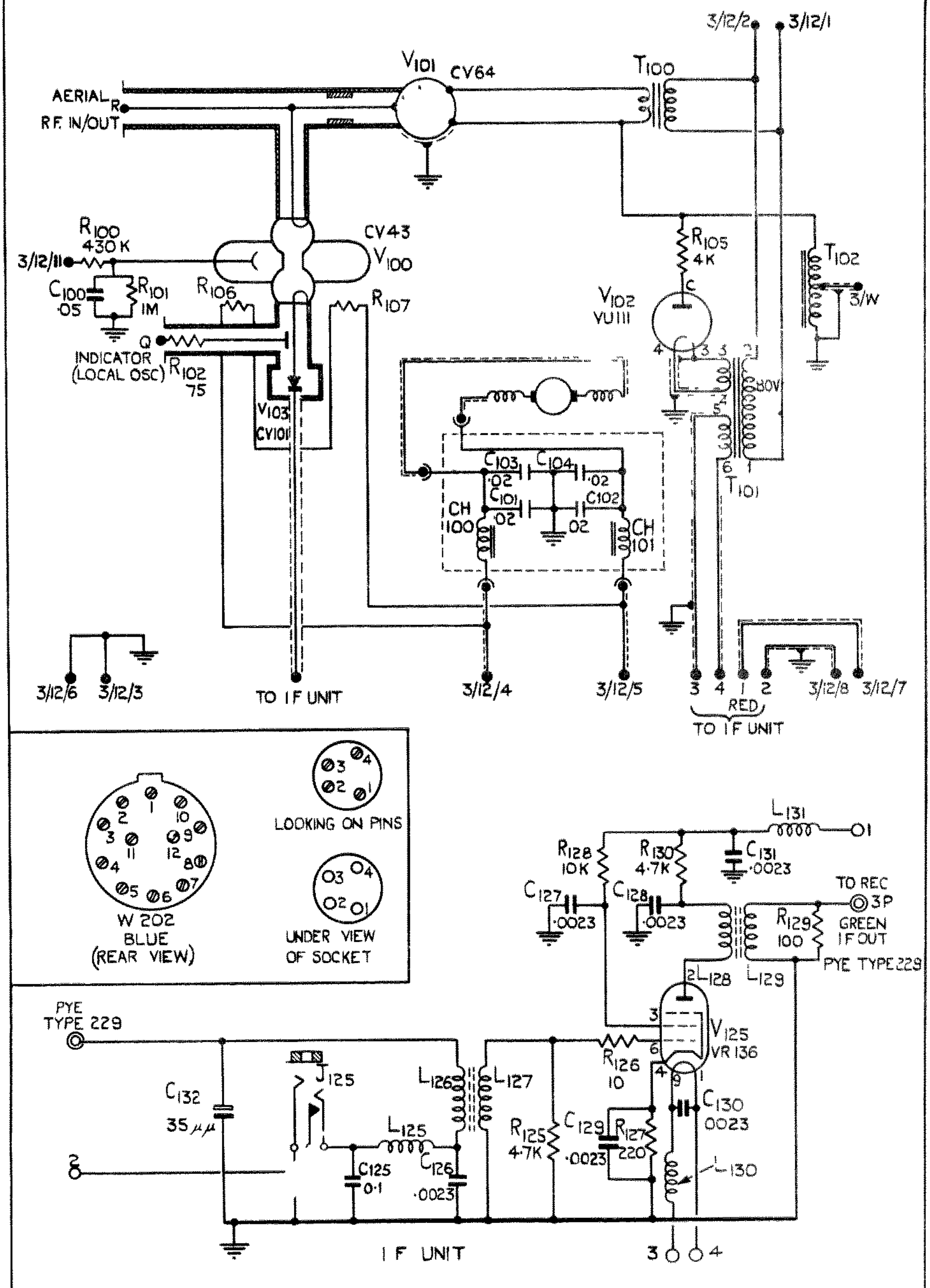
FIG. 34

POINT UNDER EXAMINATION	OBSERVED WAVEFORM	REMARKS
PULSE VOLTAGE MONITOR POINT		BOTH VOLTAGE AND CURRENT PULSE WAVE FORMS WERE OBSERVED WITH THE MODULATOR FEEDING INTO A DUMMY LOAD OF NOMINAL VALUE 92 Ω P.R.F. AS FOR MASTER MULTIVIBRATOR
PULSE CURRENT MONITOR POINT		OWING TO DEFECTS IN TEST SET ON WHICH WAVEFORMS ARE OBSERVED, THE PULSE IS NOT IN GENERAL SO SHARPLY DEFINED AS IS SHOWN. THIS ALSO OCCURS TO A LESSER DEGREE ON THE VOLTAGE PULSE. P.R.F. AS FOR MASTER MULTIVIBRATOR

MODULATOR UNIT - TYPE 64 - WAVEFORMS (3)

FIG 35

FIG 35

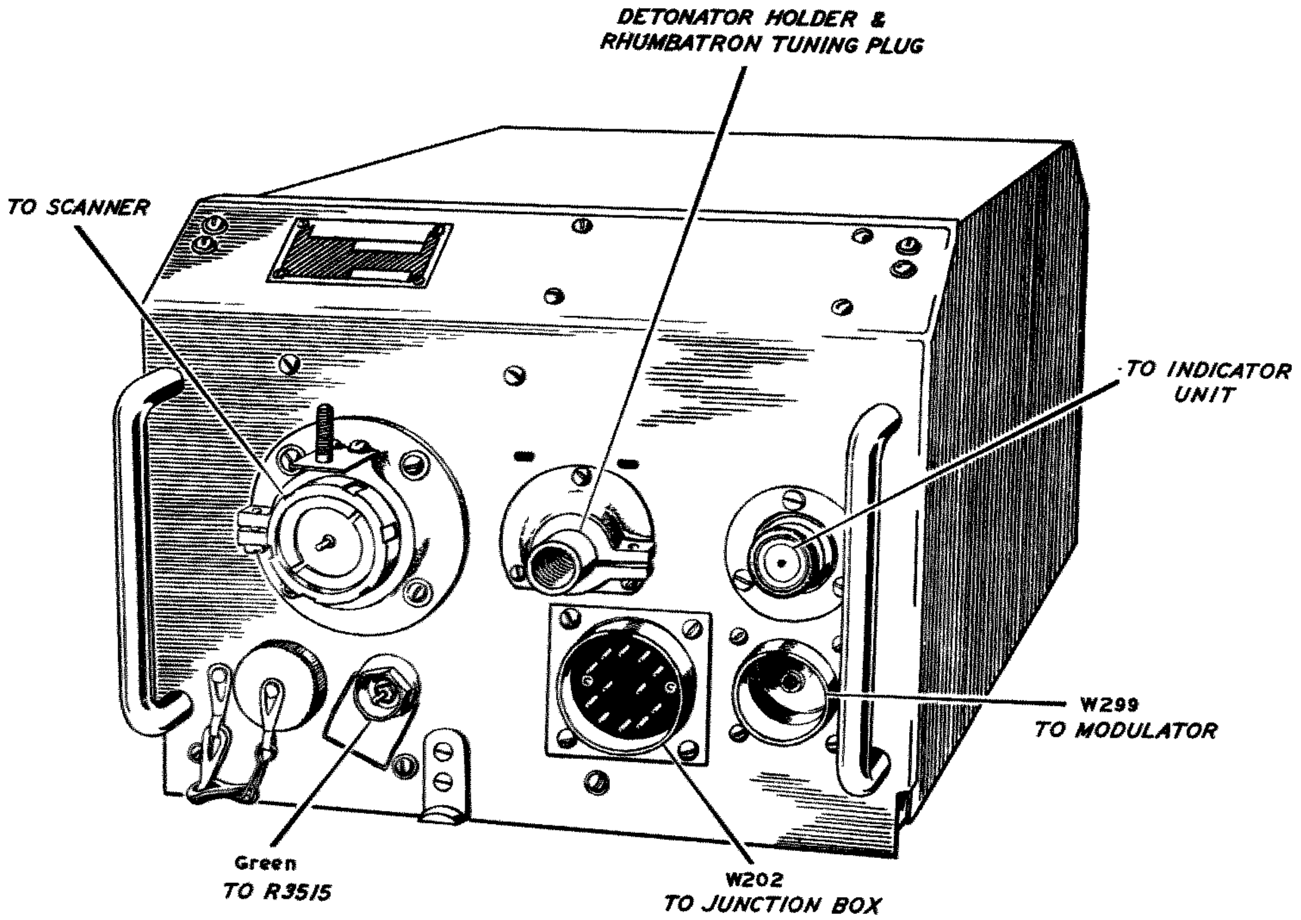


T² R UNIT, T.R.3191 – CIRCUIT

FIG. 36

FIG. 36

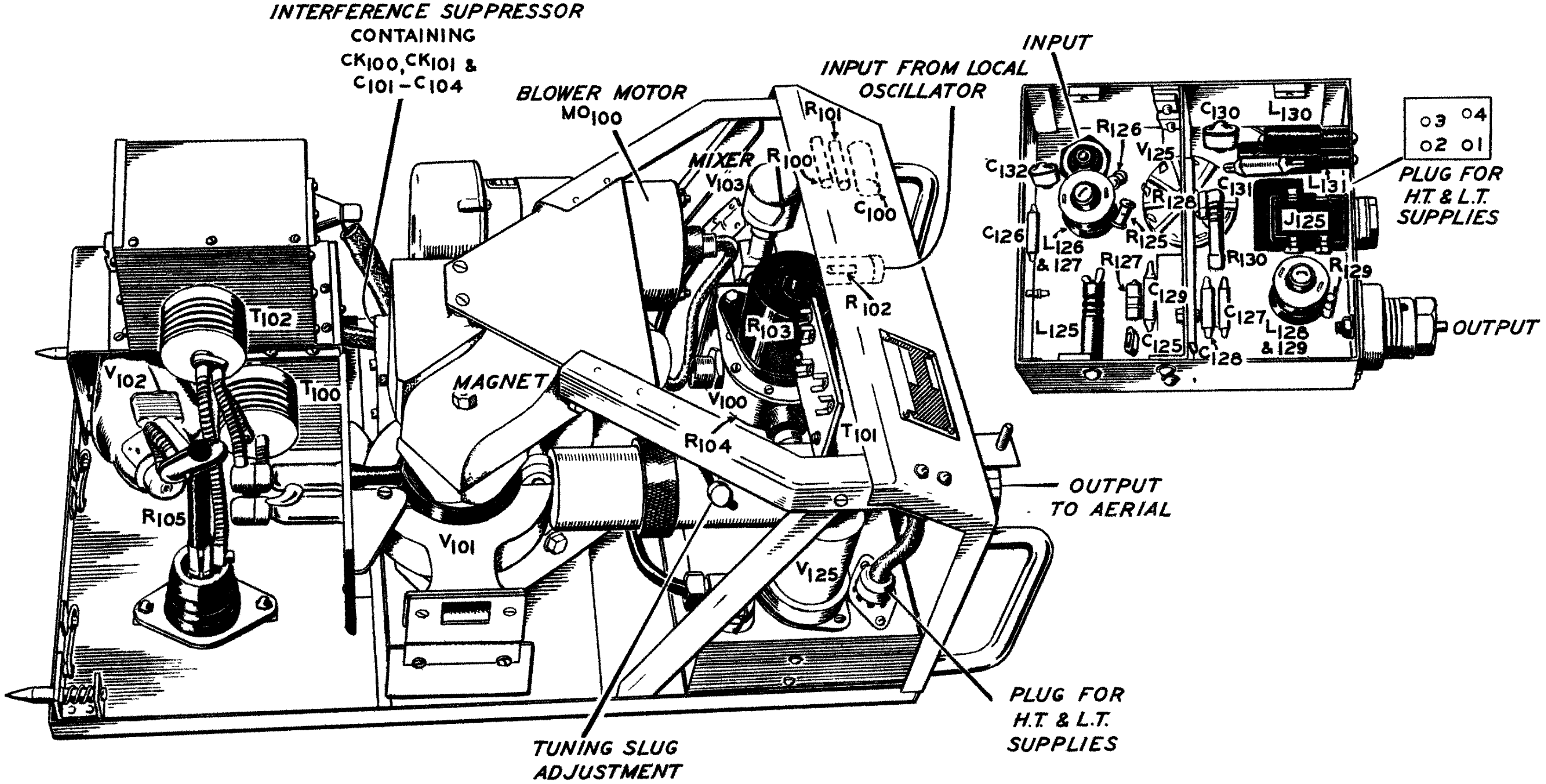
FIG.37



TRANSMITTER - RECEIVER TYPE TR3191

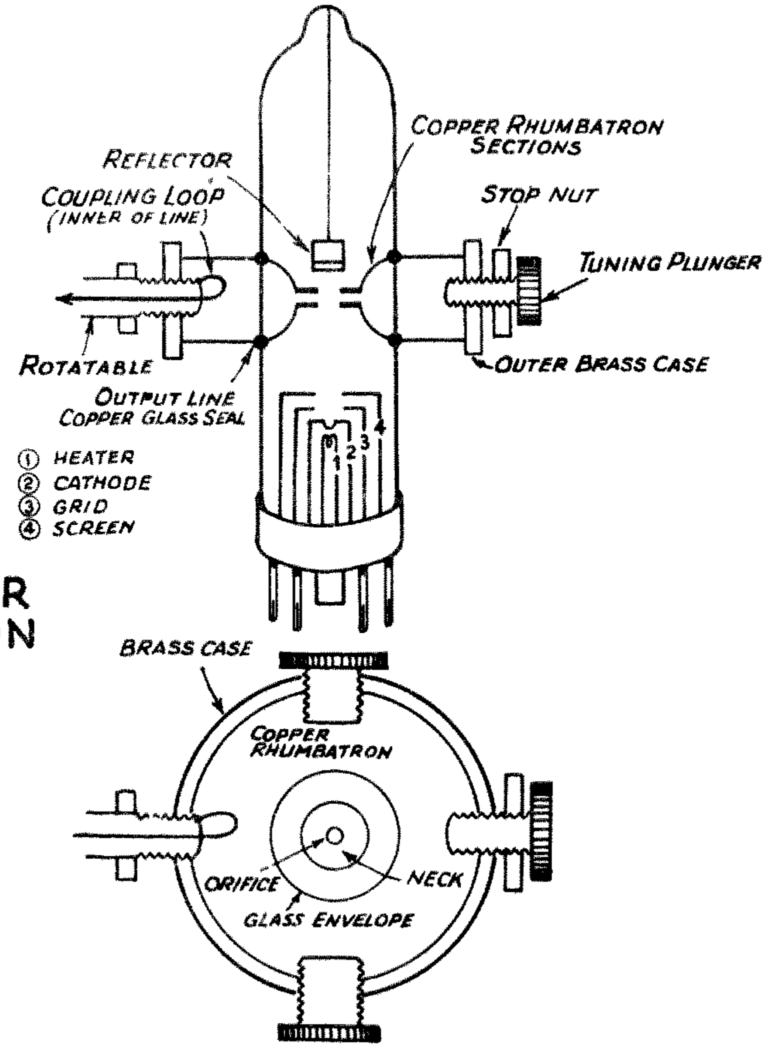
FIG.37

FIG. 38

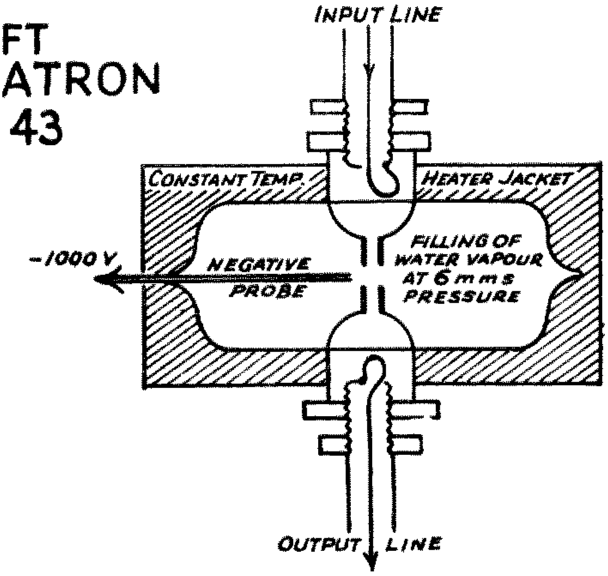


INTERNAL VIEWS OF TRANSMITTER-RECEIVER TYPE TR3191

FIG. 38



REFLECTOR KLYSTRON CV.67

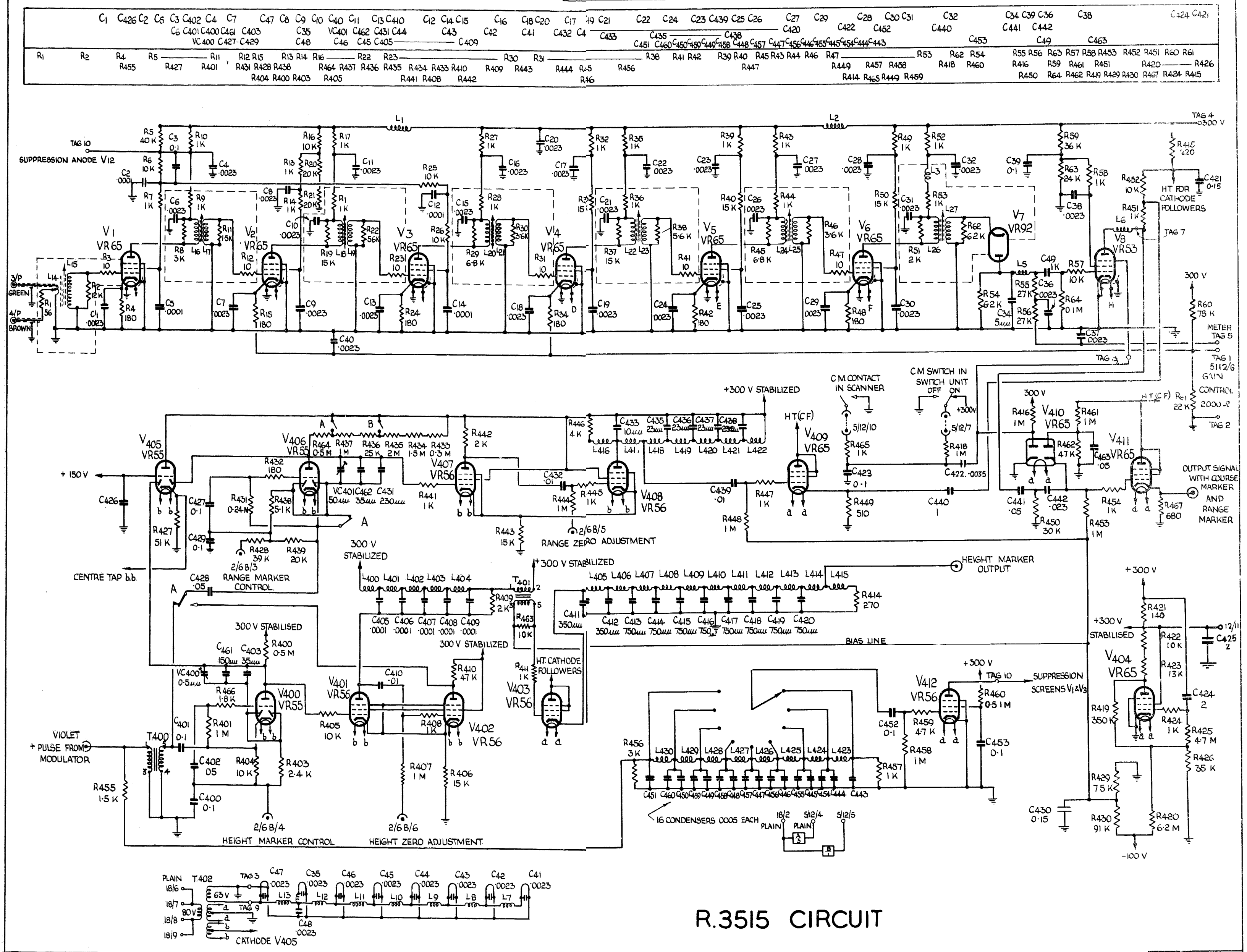


SOFT RHUMBATRON CV.43

CONSTRUCTION OF KLYSTRON AND SOFT RHUMBATRON

FIG. 39

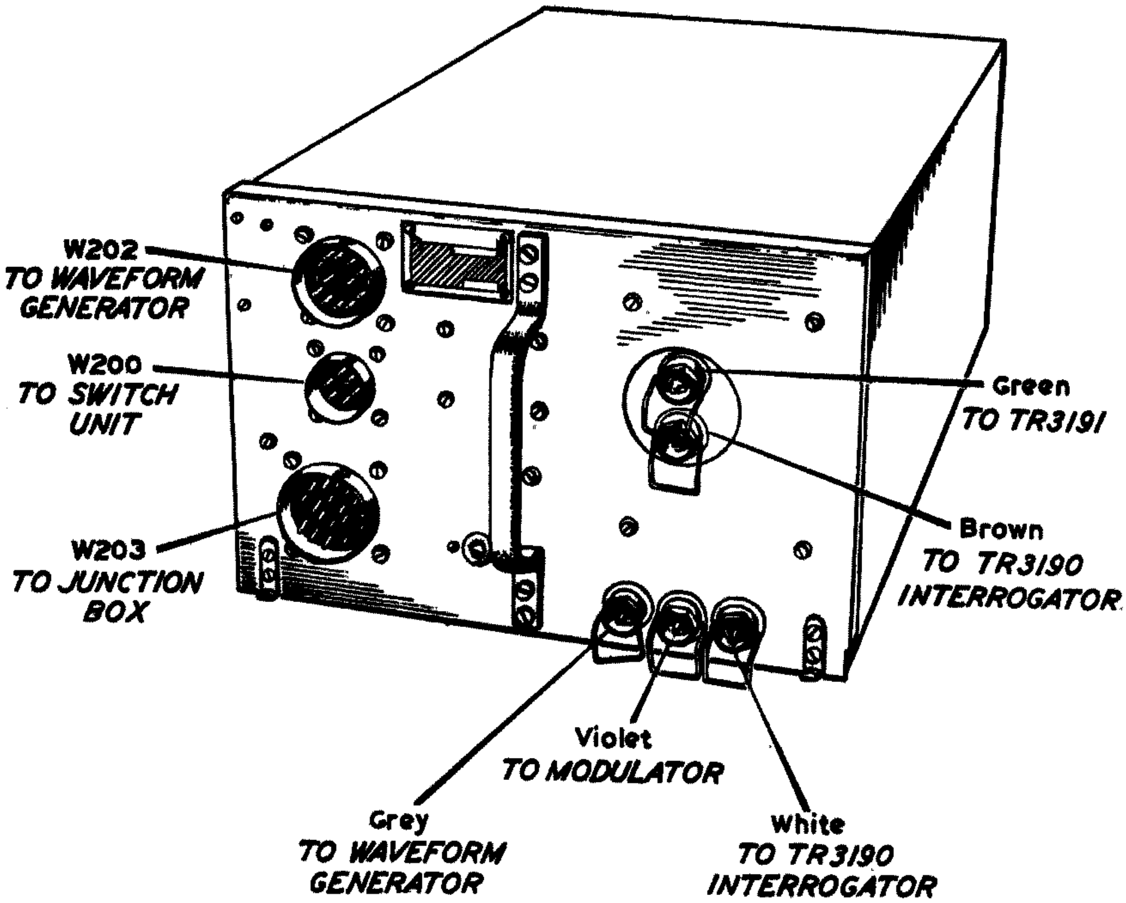
FIG. 39



R.3515 CIRCUIT

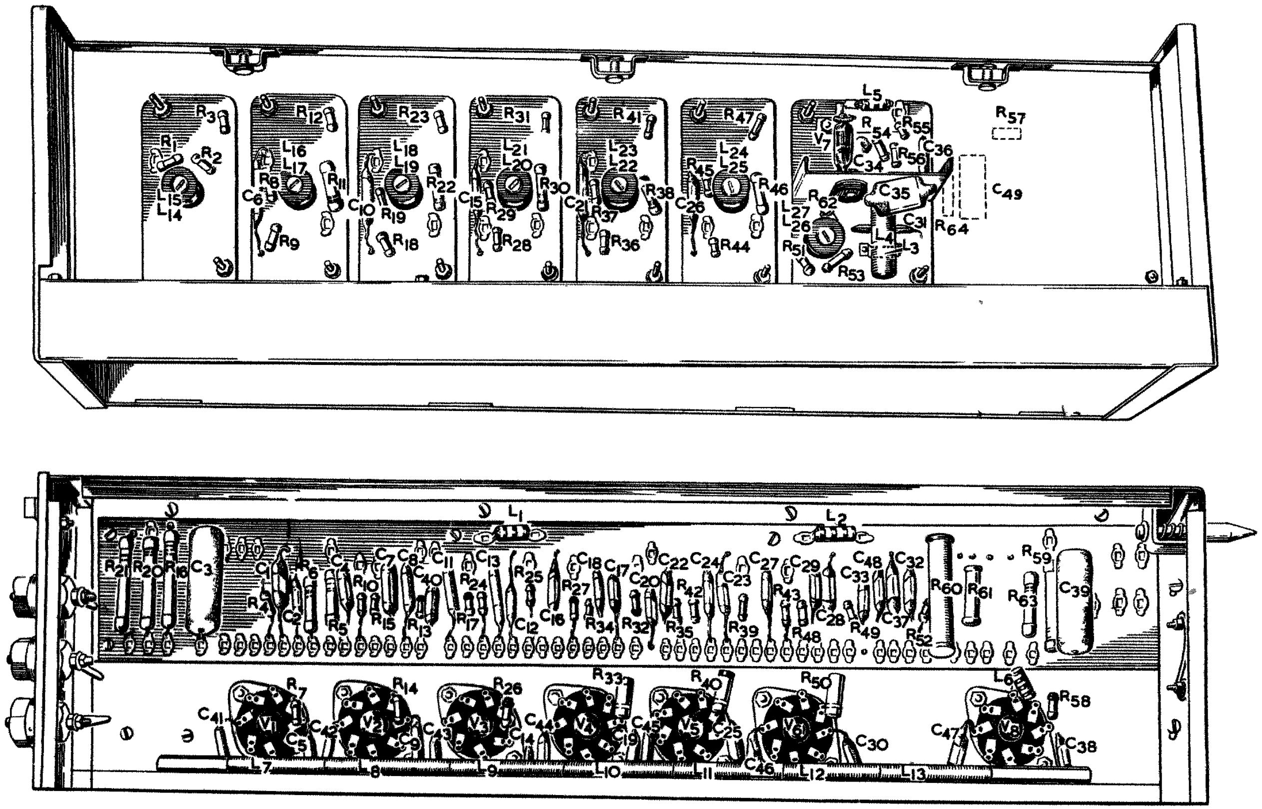
FIG. 40

FIG. 40



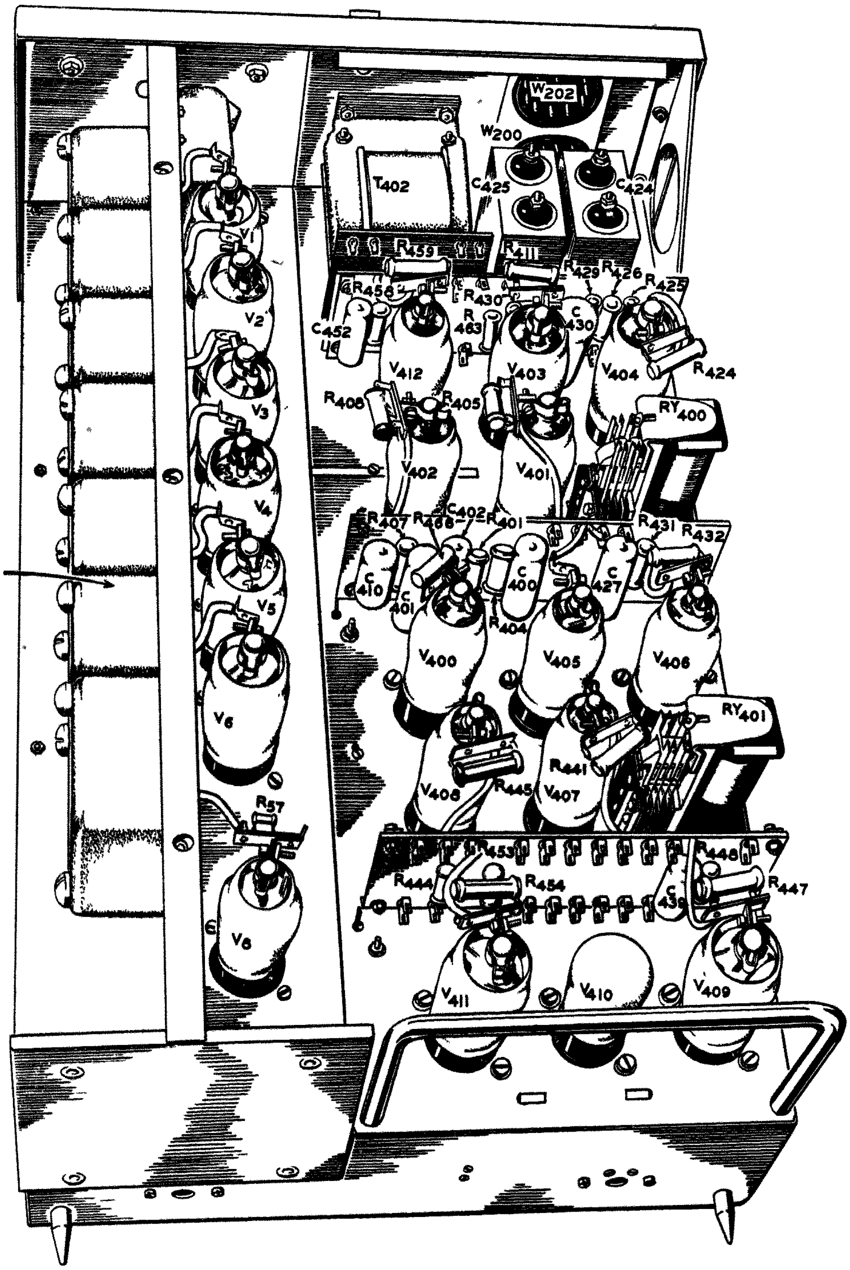
RECEIVER UNIT TYPE 3515

FIG. 42



RECEIVER UNIT TYPE 3515
VIEWS OF RECEIVER CHASSIS

FIG. 42

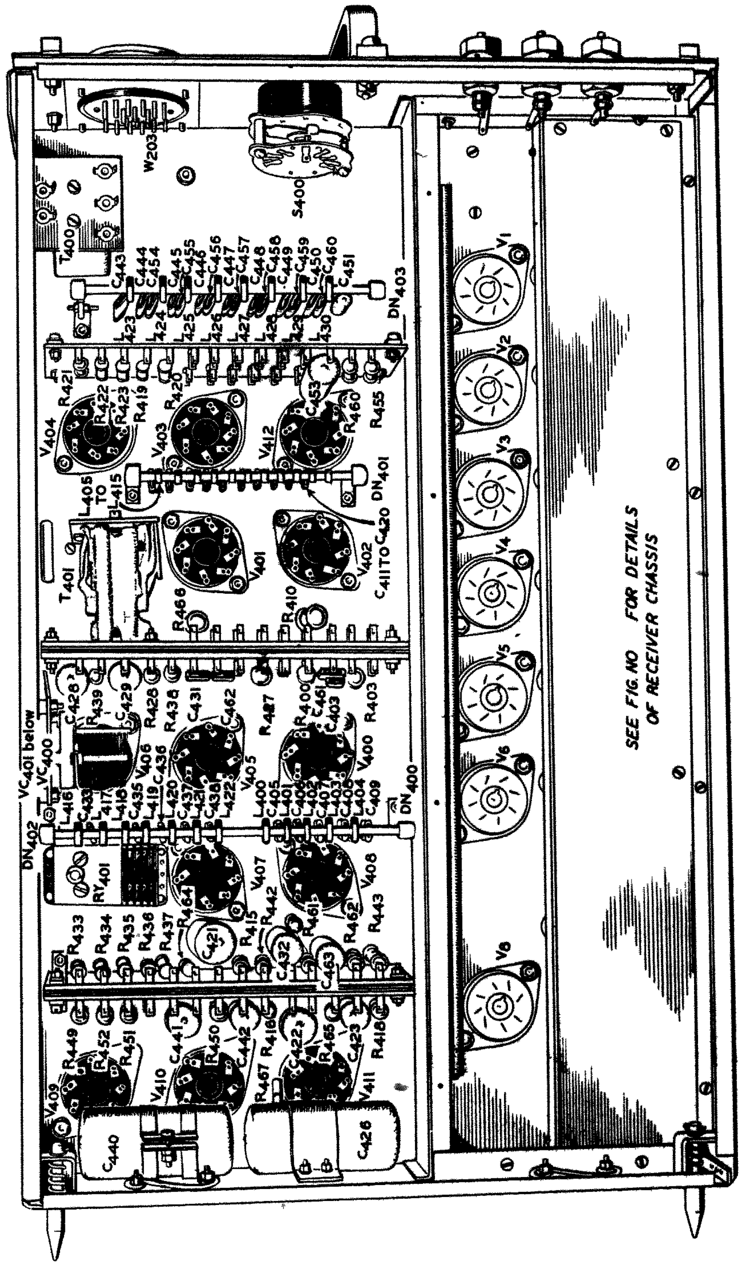


SEE FIG. NO.
FOR DETAILS OF
RECEIVER CHASSIS

TOP VIEW OF RECEIVER UNIT TYPE 3515
DETAILS OF TIMING CHASSIS

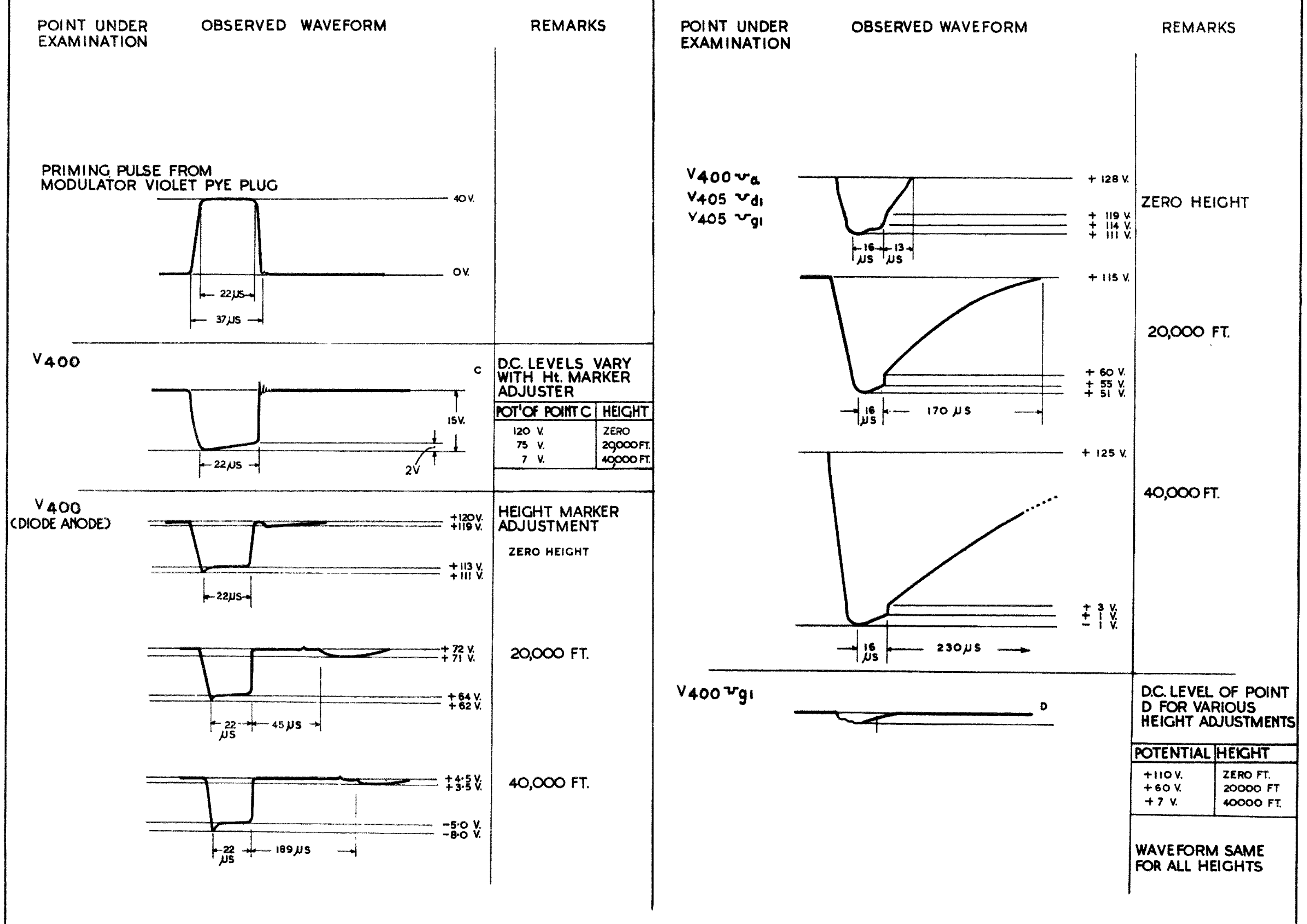
FIG. 43

FIG. 43



UNDER VIEW OF RECEIVER UNIT TYPE 3515
DETAILS OF TIMING CHASSIS

FIG. 44 FIG. 44



POT'OF POINT C	HEIGHT
120 V.	ZERO
75 V.	20,000 FT.
7 V.	40,000 FT.

POTENTIAL	HEIGHT
+110 V.	ZERO FT.
+60 V.	20000 FT
+7 V.	40000 FT.

RECEIVER TIMING – R3515 – WAVEFORMS (1)

FIG. 45

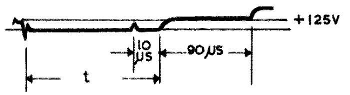
FIG. 45

POINT UNDER EXAMINATION	OBSERVED WAVEFORM	REMARKS

$V_{405}v_g$

$V_{405}v_a$

$V_{405}v_k$

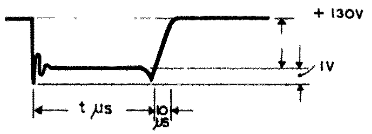


VALUES OF t AT VARIOUS HEIGHTS

t	HEIGHT
26 µs	ZERO FT.
71 µs	20,000 FT.
120 µs	40,000 FT.

$V_{401}v_{g1}$ AS $V_{400}v_a$

$V_{401}v_k$ ALSO $V_{402}v_k$

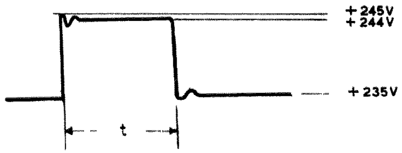


VALUES OF t

t	HEIGHT
0 µs	ZERO FT.
40 µs	20,000 FT.
100 µs	40,000 FT.

V IS VARIED FROM ZERO TO 8V BY HEIGHT ZERO PRESET CONTROL

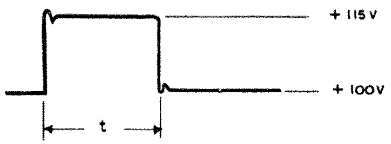
$V_{401}v_a$



VALUES OF t

t	HEIGHT
21 µs	ZERO FT.
60 µs	20,000 FT.
100 µs	40,000 FT.

$V_{402}v_{g1}$



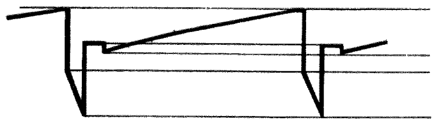
VALUES OF t

t	HEIGHT
21 µs	ZERO FT.
60 µs	20,000 FT.
100 µs	40,000 FT.

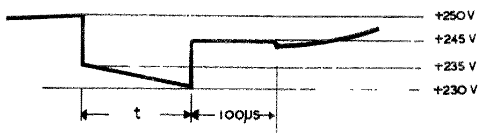
VARIATION OF HEIGHT ZERO PRESET CONTROL MOVES D.C. LEVEL OF WAVE THROUGH 7 VOLTS AND ALTERS VALUES OF t SLIGHTLY

POINT UNDER EXAMINATION	OBSERVED WAVEFORM	REMARKS

$V_{402}v_a$



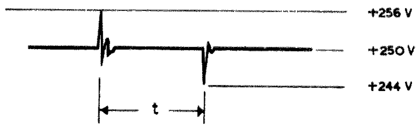
$V_{402}v_a$ (INCREASED T.B. VELOCITY)



VALUES OF t

t	HEIGHT
21 µs	ZERO FT.
60 µs	20000 FT.
100 µs	40000 FT.

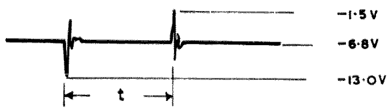
TRANSFORMER TERMINAL 2



VALUES OF t

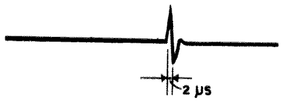
t	HEIGHT
21 µs	ZERO FT.
60 µs	20000 FT.
100 µs	40000 FT.

$V_{403}v_g$



VALUES OF t AS ABOVE

$V_{403}v_k$



HEIGHT MARKER BEFORE DELAY OF 2 µs

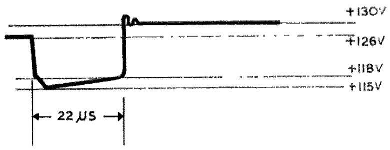
RECEIVER TIMING - R.3515 - WAVEFORMS (2)

FIG. 46

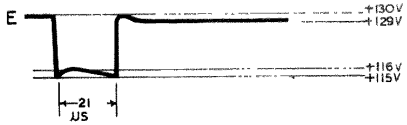
FIG. 46

POINT UNDER EXAMINATION | OBSERVED WAVEFORM | REMARKS

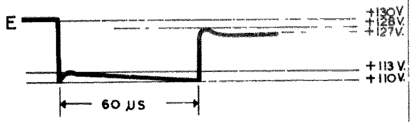
$V_{406}v_k$



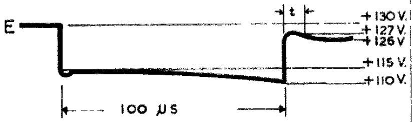
30 AND 100 MILE MARKER RANGES



10/10 RANGE
ZERO RANGE
ZERO HEIGHT



10/10 RANGE
ZERO RANGE
20,000 FT.

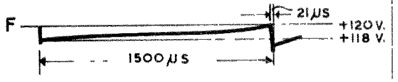


10/10 RANGE
ZERO RANGE
40,000 FT.

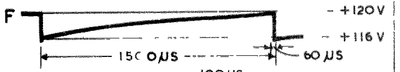
10/10 RANGE
VARIATION OF t AND POT' E WITH RANGE ADJUSTMENT

t	POT' OF E	RANGE
9 μS	130 V.	ZERO
64 μS	82 V.	5 MILES
120 μS	7 V.	10 MILES

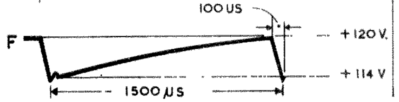
$V_{406}v_g$



10/10 RANGE
ZERO RANGE
ZERO HEIGHT



ZERO RANGE
20,000 FT. HEIGHT



ZERO RANGE
40,000 FT. HEIGHT

POINT OF EXAMINATION | OBSERVED WAVEFORM | REMARKS

$V_{406}v_k$ AS ABOVE

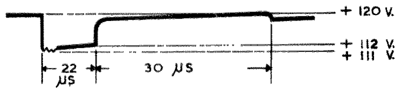
VARIATION OF POT' OF POINT F WITH VARI-ATION OF RANGE SCALE READING
HEIGHT ZERO FT.

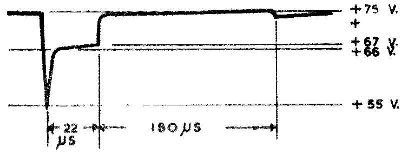
POT' F	RANGE
+120 V.	ZERO
+ 70 V.	5 MILES
− 3 V.	10 MILES

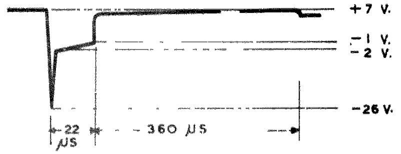
ON 30 AND 100 MILE RANGES CORRESPONDING VOLTAGES OCCUR AS FOLLOWS

POT OF F.	30 MILE	100 MILE
+120 V.	ZERO	ZERO
+ 70 V.	15 MILE	50 MILE
− 30 V.	30 MILE	100 MILE

$V_{406}v_d$







ON 10 MILE RANGE WAVEFORM IS SAME AS $V_{406}v_k$

30 MILE AND 100 MILE SCAN RANGE
RANGE SCALE READINGS

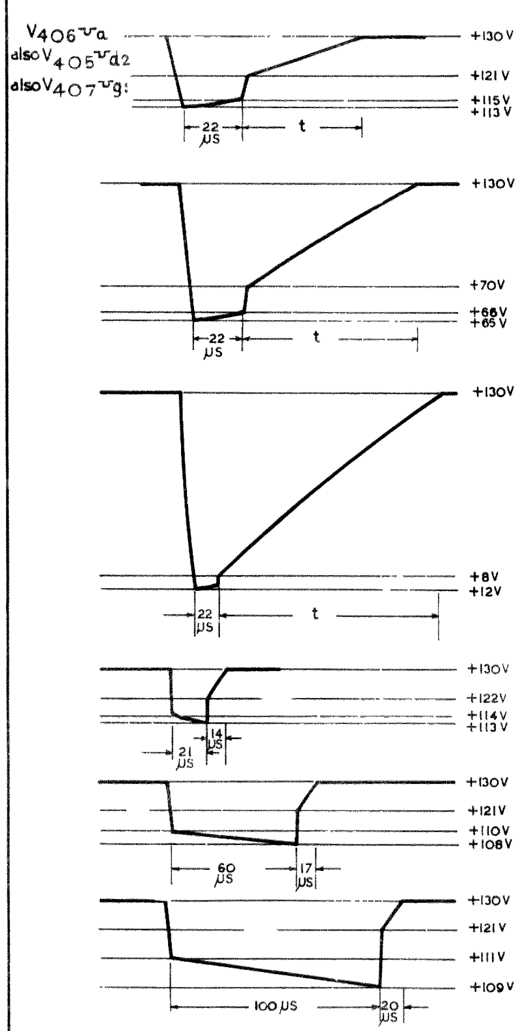
30 MILE SCALE	100 SCALE
ZERO	ZERO
15 MILES	50 MILES
30 MILES	100 MILES

NOTE
10, 30 AND 100 MILE RANGES ABOVE REFER TO 'MARKER' RANGES

RECEIVER TIMING - R 3515 - WAVEFORMS (3)

FIG. 47

POINT UNDER EXAMINATION — OBSERVED WAVEFORM — REMARKS



30 AND 100 MILE RANGES VALUES OF t

30 MILE SCALE AT ZERO
t = 56 µs

100 MILE SCALE AT ZERO
t = 220 µs

30 MILE SCALE AT 15 MILES
t = 300 µs

100 MILE SCALE AT 50 MILES
t = 1,100 µs

30 MILE SCALE AT 30 MILES
t = 520 µs

100 MILE SCALE AT
100 MILES
t = 1500 µs

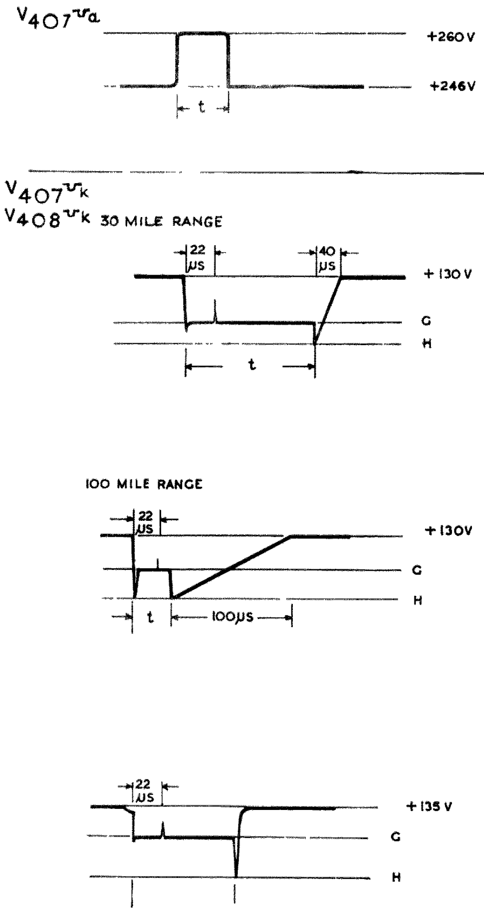
10/10 RANGE
RANGE SCALE AT ZERO
HEIGHT :- ZERO FT.

HEIGHT :- 20,000 FT.

HEIGHT :- 40,000 FT.

NOTE: 10, 30 AND 100 MILE RANGES ABOVE REFER TO "MARKER" RANGES.

POINT UNDER EXAMINATION — OBSERVED WAVEFORM



NOTE
ON ALL RANGES RANGE ZERO PRESET CONTROL VARIES POTENTIAL OF G BY 8V.
TABULATED VALUES OF POTENTIAL OF G WERE TAKEN WITH RANGE ZERO ADJUSTED

30 & 100 MILE RANGE
VALUES OF t
30 MILE SCALES

t	RANGE SCALE READINGS
22 µS 182 µS 342 µS	ZERO 15 MILES 30 MILES

100 MILE SCALES

t	RANGE SCALE READINGS
22 µS 557 µS 1092 µS	ZERO 50 MILES 100 MILES

10 MILE SCALE

t	RANGE SCALE READINGS
22 µS 78 µS 127 µS	ZERO 5 MILES 10 MILES

IN CASE OF 10/10 RANGE
HI SCALE AT ZERO
10 MILE SCALE 10/10 ONLY
RANGE SCALE AT ZERO
HEIGHT SCALE VARIED

t	HEIGHT SCALE READINGS
22 µS 62 µS 103 µS	ZERO 20,000 FT. 40,000 FT.

NOTE: 10 0 & 100 MILE RANGES ABOVE REFER TO "MARKER" RANGES

30 MILE MARKER RANGE

VALUES OF t & POTLS. OF G & H AT VARIOUS RANGE SCALE SETTINGS

SCALE	H	G	t
ZERO	+124 V	126·5V	22 µS
15 MILES	+122 V	125·5V	182 µS
30 MILES	+120V	123V	342 µS

100 MILE MARKER RANGE

VALUES OF t AND POTLS. OF G AND H AT VARIOUS RANGE SCALE SETTINGS

SCALE	G	H	t
ZERO	126·5 V	122·5V	22 µS
50 MILES	122 V	118 V	557 µS
100 MILES	118 V	115 V	1092 µS

10 MILE MARKER RANGE

VALUES OF t AND POTLS. OF G AND H AT VARIOUS RANGE SCALE SETTINGS HEIGHT SCALE SET AT ZERO

SCALE	G	H	t
ZERO	134 V	132 V	22 µS
5 MILES	133·5 V	131·5V	76 µS
10 MILES	133·5 V	131 V	127 µS

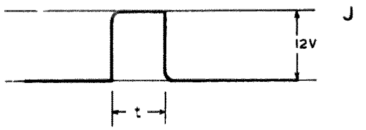
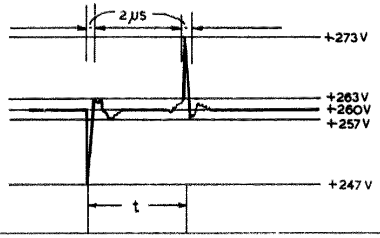
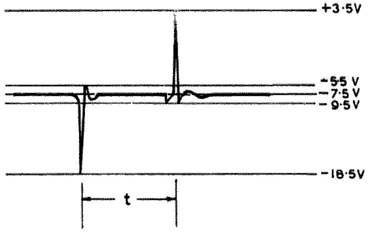
VALUES OF t AND POTLS. OF G AND H AT VARIOUS HEIGHT SCALE SETTINGS RANGE SCALE SET AT ZERO

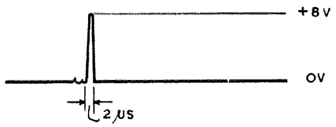
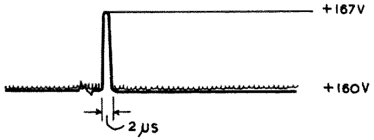
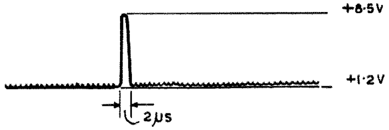
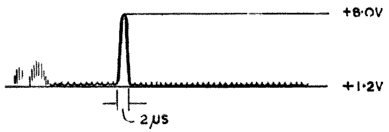
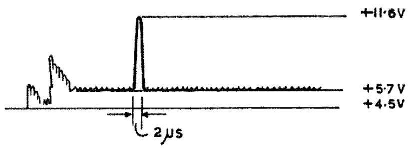
SCALE	G	H	t
ZERO	134 V	132 V	22 µS
20,000 FT.	134 V	131·5V	62·5 µS
40,000 FT.	133·5 V	131·5 V	103 µS

RECEIVER TIMING TYPE R3515 – WAVEFORMS (4)

FIG.48

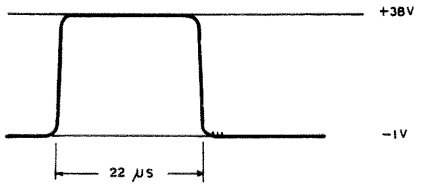
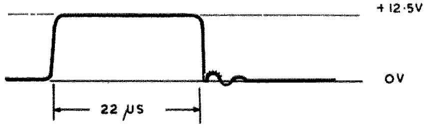
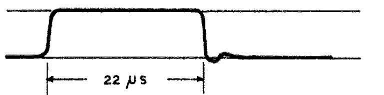
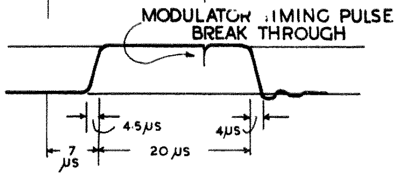
FIG.48

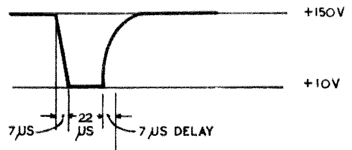
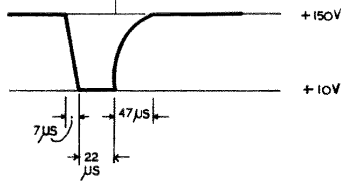
<table>
<tr><th>POINT UNDER EXAMINATION</th><th>OBSERVED WAVEFORM</th><th>REMARKS</th></tr>
<tr><td>V408 ∿ g1</td><td> </td><td>VALUES OF t AS IN V407 ∿ a
VALUES OF D.C. LEVELS J ON VARIOUS MARKER RANGES<table><tr><th>MARKER RANGE</th><th>J</th></tr><tr><td>10 MILE</td><td>125 V.</td></tr><tr><td>30 MILE</td><td>123 V.</td></tr><tr><td>100 MILE</td><td>120 V.</td></tr></table>RANGE OF VARIATION OF D.C. LEVEL J WITH VARIATION OF RANGE ZERO PRESET CONTROL IS 9 V.</td></tr>
<tr><td>V408 ∿ a</td><td> </td><td>VALUES OF t ARE AS THOSE IN V407 ∿ a</td></tr>
<tr><td>V409 ∿ g</td><td> </td><td>VALUES OF t AS IN V407 ∿ a</td></tr>
</table>

<table>
<tr><th>POINT UNDER EXAMINATION</th><th>OBSERVED WAVEFORM
OBSERVED ON 10 MILE RANGE</th><th>REMARKS</th></tr>
<tr><td>V409 ∿ k</td><td> </td><td>PULSE MOVES HORIZONTALLY WHEN RANGE SCALE IS ADJUSTED ON 30 AND 100 MARKER SCALE
ALSO MOVES HORIZONTALLY WHEN EITHER HEIGHT OR RANGE SCALES ARE ADJUSTED ON 10/10 RANGE</td></tr>
<tr><td>TERMINAL REC 8</td><td> </td><td>PULSE MOVES AS IN V409 ∿ k</td></tr>
<tr><td>V410 ∿ k1</td><td> </td><td>PULSE MOVES AS IN V409 ∿ k</td></tr>
<tr><td>V411 ∿ g1</td><td> </td><td>PULSE MOVES AS IN V409 ∿ k</td></tr>
<tr><td>V411 ∿ k</td><td> </td><td>PULSE MOVES AS IN V409 ∿ k
WAVEFORMS V9 ∿ k
REC 8
V410 ∿ k1
V411 ∿ g1
V411 ∿ k
WERE EXAMINED ON 10 MILE RANGE. SLIGHT POTENTIAL CHANGES OCCUR ON OTHER RANGES.</td></tr>
</table>

RECEIVER TIMING R3515 – WAVEFORMS (5)

FIG. 49

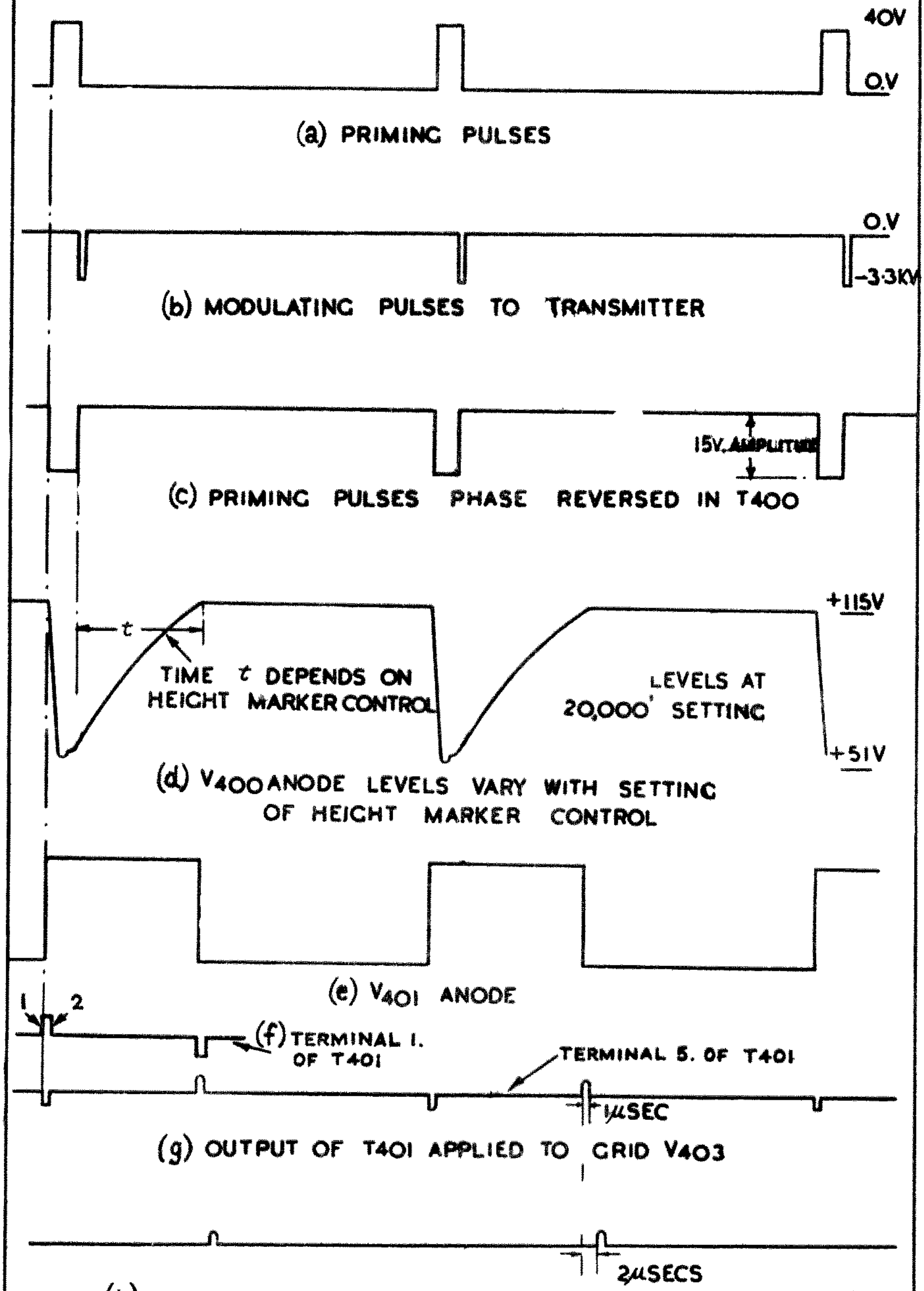
POINT UNDER EXAMINATION	OBSERVED WAVEFORM	REMARKS
T400 TAG I		
BEGINNING OF SUPPRESSION DELAY NETWORK		TRAILING EDGE OFTEN APPEARS JAGGED DUE TO PICK UP FROM SPARK GAP
V412 v_{g1}		SUPPRESSION DELAY CONTROL FULLY COUNTER CLOCKWISE
		SUPPRESSION DELAY CONTROL FULLY CLOCKWISE

POINT UNDER EXAMINATION	OBSERVED WAVEFORMS	REMARKS
V412 v_a		SUPPRESSOR DELAY CONTROL FULLY COUNTER CLOCKWISE
		SUPPRESSION DELAY CONTROL FULLY CLOCKWISE

RECEIVER TIMING – R3515 – WAVEFORMS (6)

FIG. 50

FIG. 50



(a) PRIMING PULSES

(b) MODULATING PULSES TO TRANSMITTER

(c) PRIMING PULSES PHASE REVERSED IN T400

(d) V400 ANODE LEVELS VARY WITH SETTING OF HEIGHT MARKER CONTROL

(e) V401 ANODE

(g) OUTPUT OF T401 APPLIED TO GRID V403

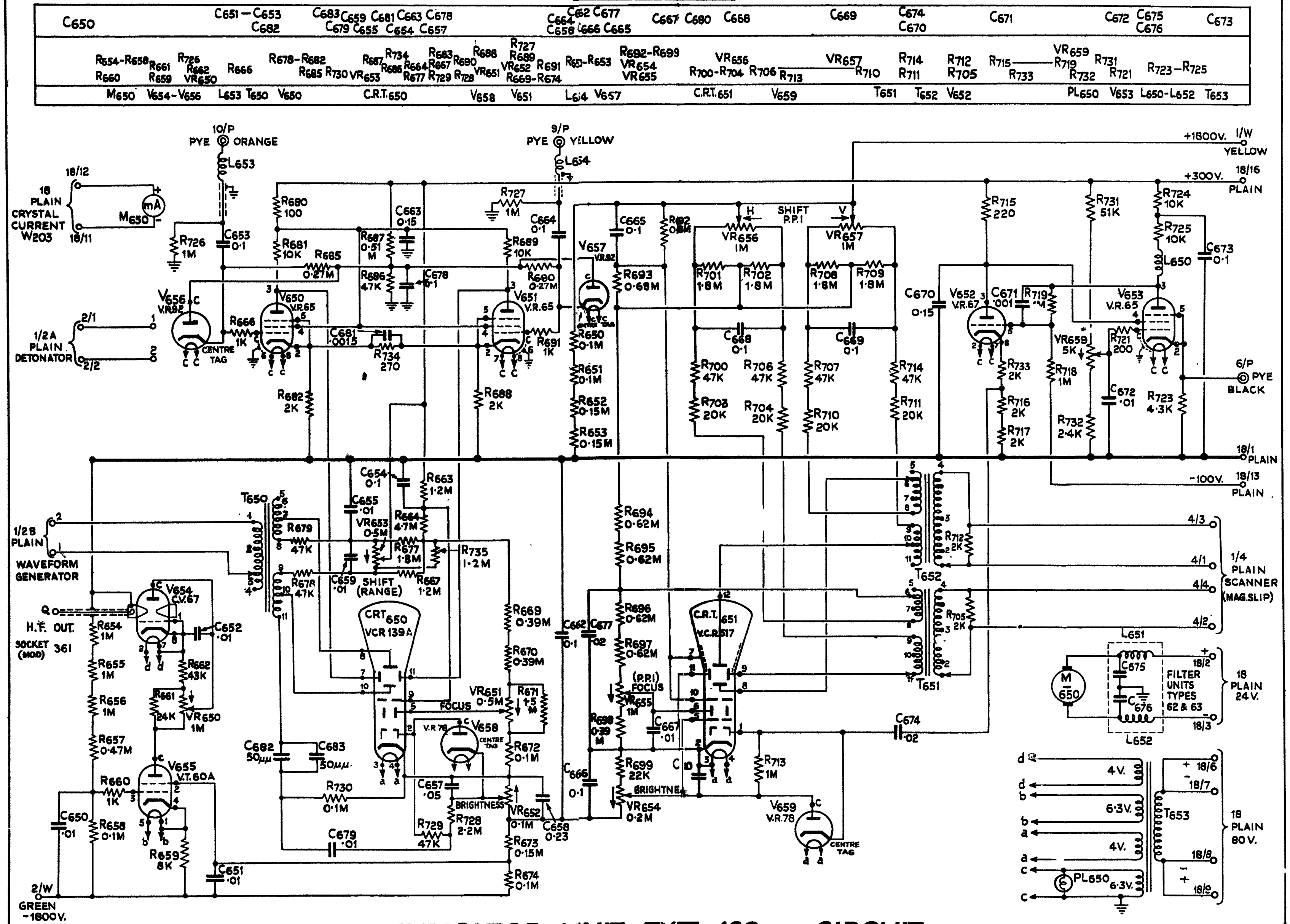
(h) HT MARKER PULSE DELAYED 2μSECS (WHITE PYE PLUG).

FORMATION OF HEIGHT MARKER PULSE

FIG. 51

FIG. 51

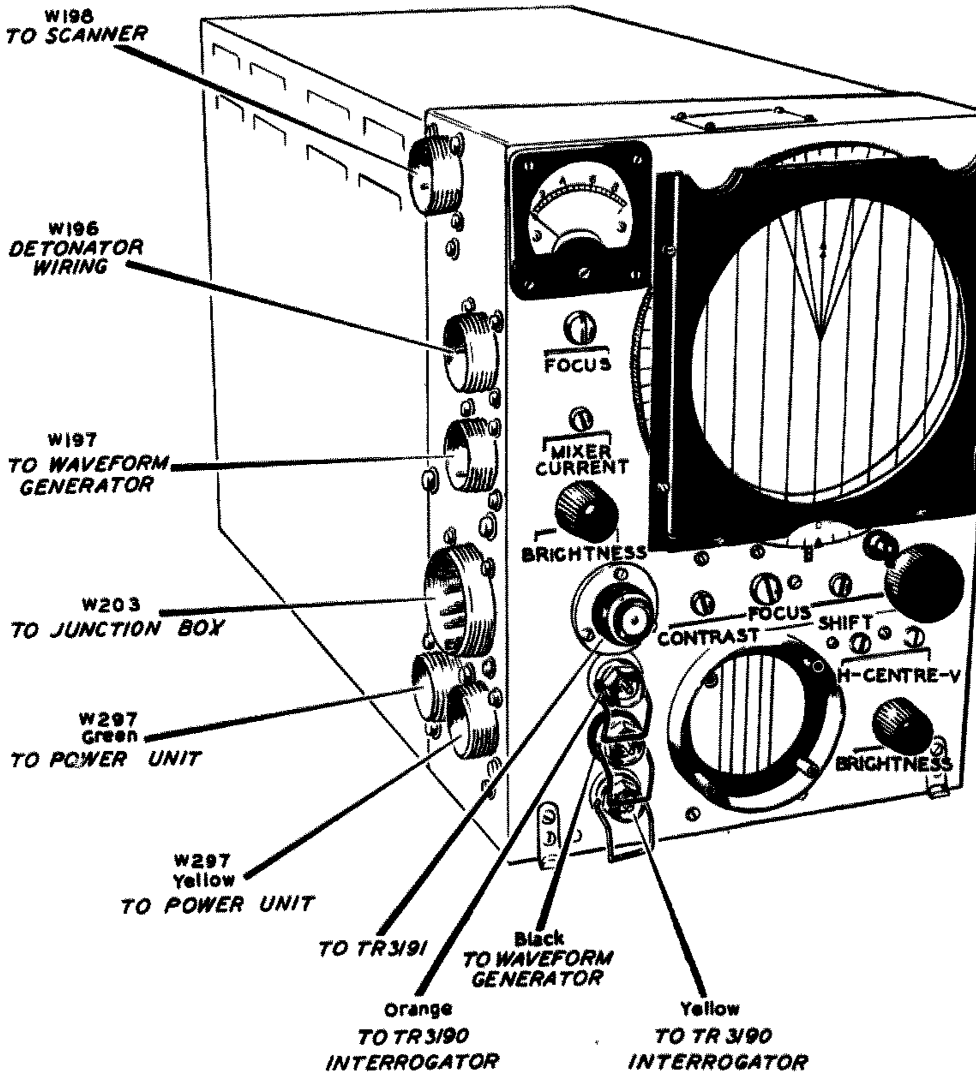
S.D. 0296 (1), CHAP. I



INDICATOR UNIT, TYPE 162—CIRCUIT

FIG. 52

FIG. 52

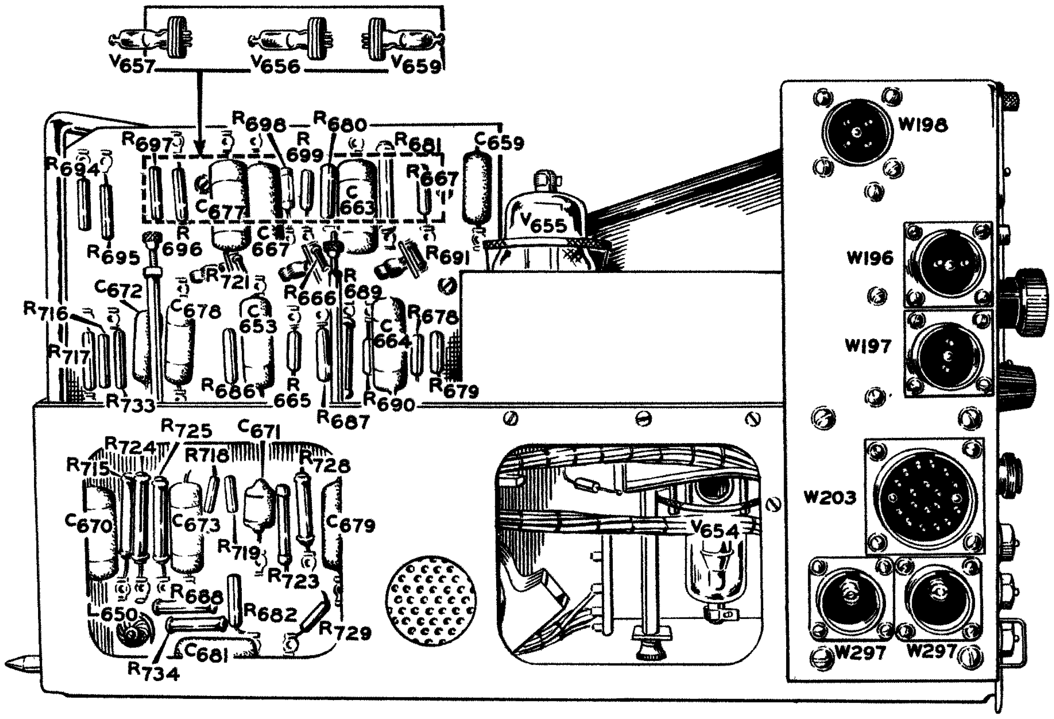


INDICATOR UNIT
TYPE 162

FIG. 53

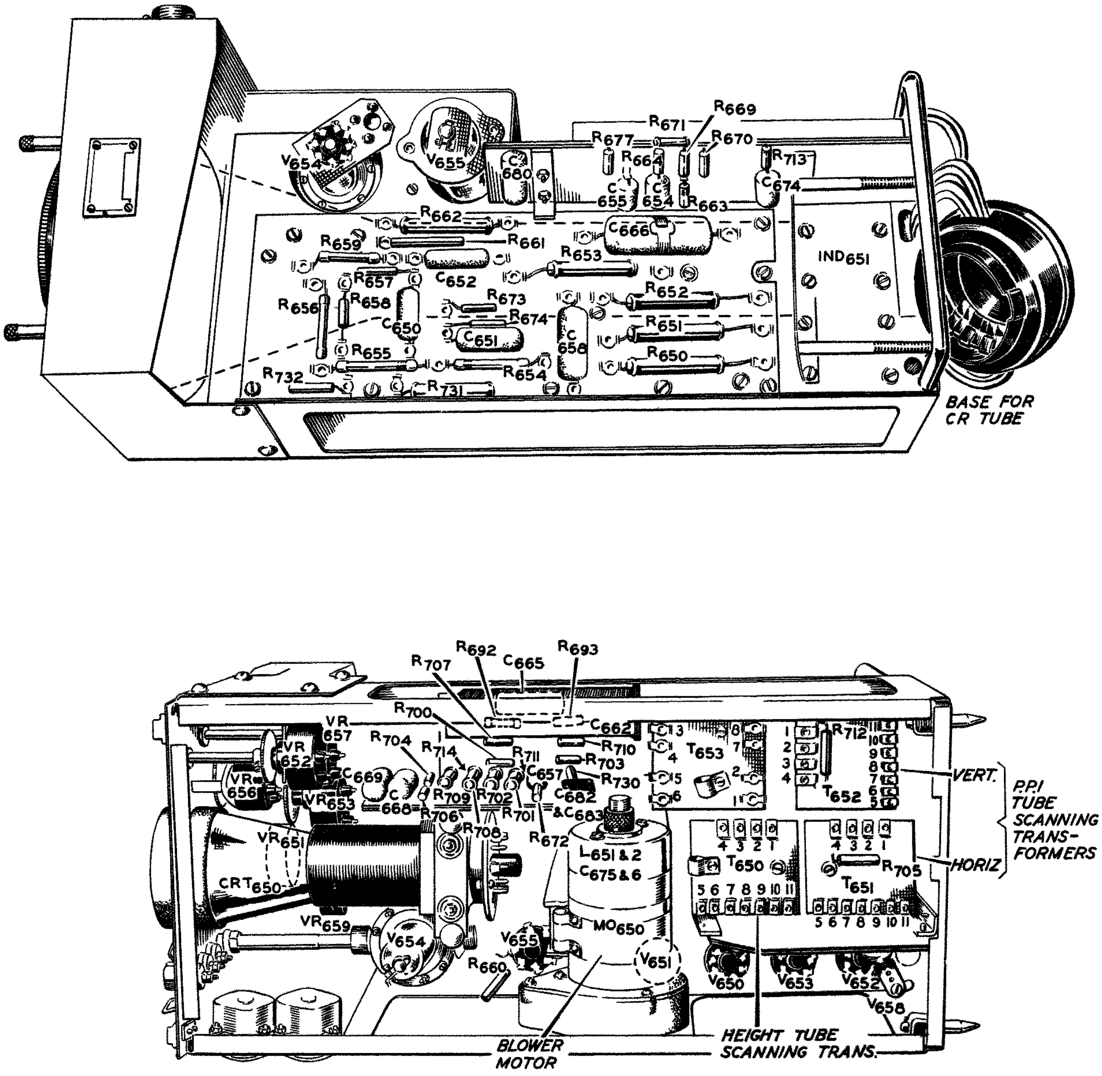
FIG. 53.

FIG.54



INDICATOR UNIT TYPE 162
SIDE VIEW

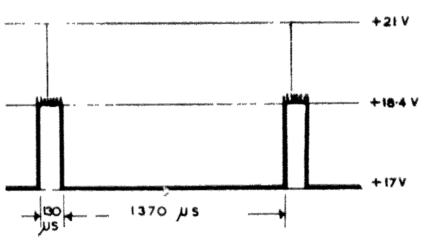
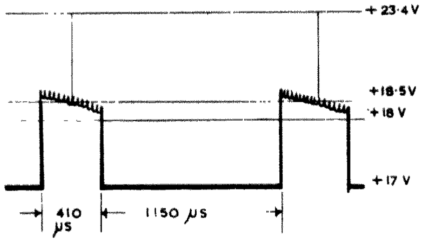
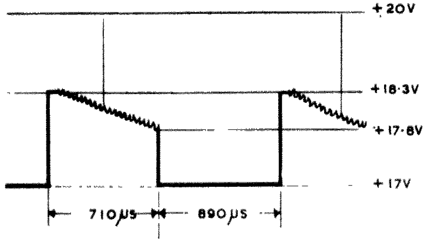
FIG.54

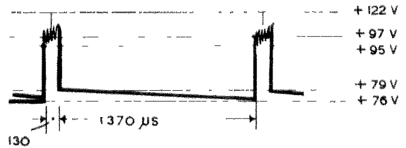
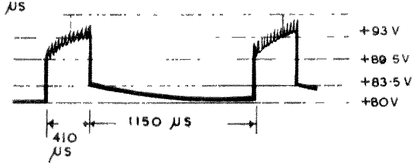
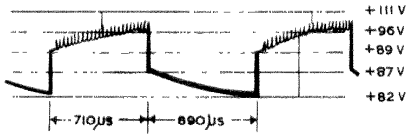
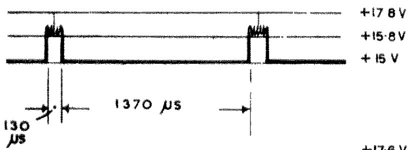
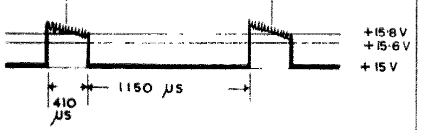
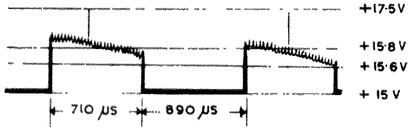


INDICATOR UNIT TYPE 162
TOP AND BOTTOM VIEWS

FIG. 55

FIG. 55

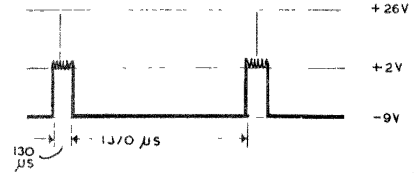
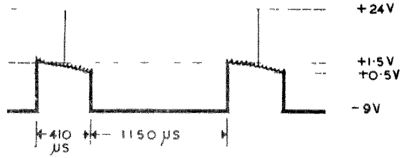
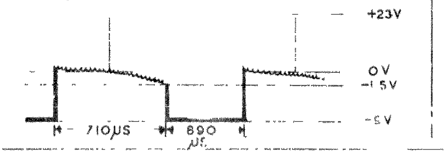
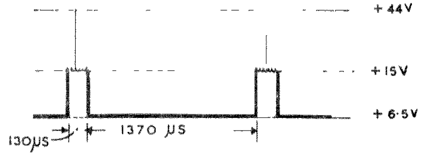
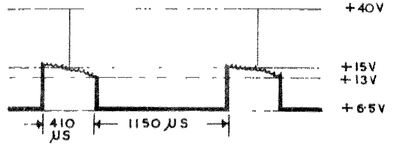
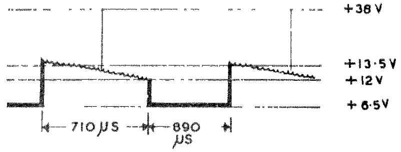
POINT UNDER EXAMINATION	OBSERVED WAVEFORM	REMARKS
$V_{653}v_k$		GAIN CONTROL SET TO JUST SHOW NOISE USING HEAD AMPLIFIER 10 MILE SCAN RANGE
		30 MILE SCAN RANGE
		50 AND 50-100 MILE SCAN RANGES NOTE MARKER PEAK VOLTAGE DEPENDS ON MARKER SCALE READING ALSO ON GAIN SETTING. HENCE ABOVE FIGURES SERVE AS GUIDE ONLY

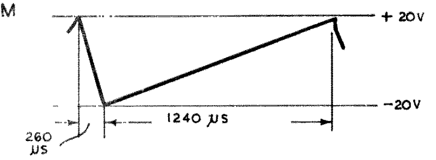
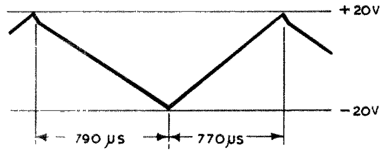
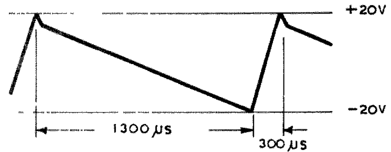
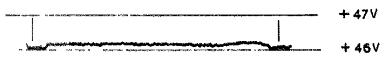
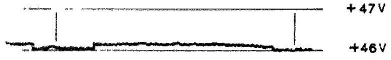
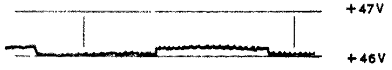
POINT UNDER EXAMINATION	OBSERVED WAVEFORM	REMARKS
$V_{653}v_a$		10 MILE SCAN RANGE
		30 MILE SCAN RANGE
		50 AND 50-100 MILE SCAN RANGES NOTE: GAIN CONTROL AS FOR $V_{653}v_k$
$V_{653}v_{g1}$		10 MILE SCAN RANGE
		30 MILE SCAN RANGE
		50 AND 50-100 MILE SCAN RANGES NOTE GAIN CONTROL SET AS FOR $V_{653}v_k$

INDICATOR UNIT TYPE 162- WAVEFORMS (1)

FIG. 56

FIG.56

POINT UNDER EXAMINATION	OBSERVED WAVEFORM	REMARKS
$V_{652}\ v_{g1}$		10 MILE SCAN RANGE
		30 MILE SCAN RANGE
		50 AND 50-100 MILE SCAN RANGES NOTE GAIN CONTROL SET AS FOR $V_{653}\ v_k$
$V_{652}\ v_k$		10 MILE SCAN
		30 MILE SCAN
		50 AND 50-100 MILE SCAN RANGES GAIN CONTROL AS FOR $V_{653}\ v_k$

POINT UNDER EXAMINATION	OBSERVED WAVEFORM	REMARKS
INPUT FROM MAGSLIP		MAGSLIP ADJUSTED FOR MORE AMPLITUDE ON TEST SET 31 WAVE EXAMINED ON PUSH PULL A.C. 10 MILE SCAN RANGE
		30 MILE SCAN RANGE
		50 AND 50-100 MILE SCAN RANGES
V_{650}		10 MILE SCAN RANGE
		30 MILE SCAN RANGE
		50 AND 50-100 MILE SCAN RANGES NOTE GAIN CONTROL SET AS FOR $V_{653}\ v_k$

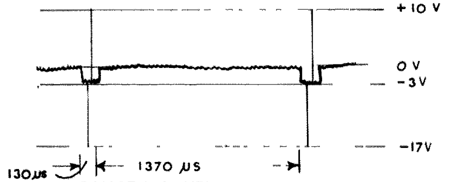
INDICATOR UNIT - TYPE 162- WAVEFORMS (2)

FIG. 57

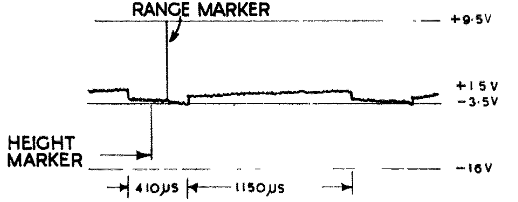
FIG. 57

POINT UNDER EXAMINATION — OBSERVED WAVEFORM — REMARKS

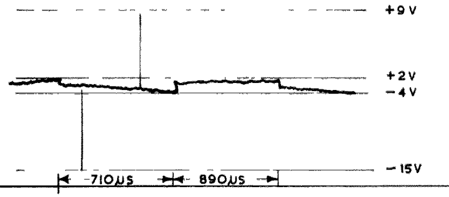
CRT 650
HT. TUBE
Y2 PLATE



GAIN ADJUSTED TO RENDER NOISE JUST VISIBLE USING HEAD AMPLIFIER



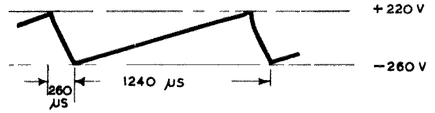
30 MILE SCAN RANGE



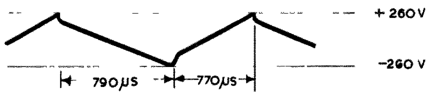
50 AND 50-100 MILE SCAN RANGES

NOTE: GAIN CONTROL SET AS FOR $V_{653}v_k$

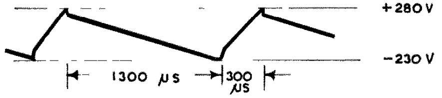
CRT 650
(HEIGHT TUBE)
X PLATE



MEASURED ON PUSH-PULL A.C.
10 MILE SCAN RANGE



30 MILE SCAN RANGE

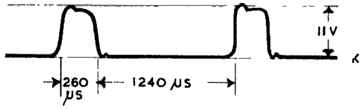


50 AND 50-100 MILE SCAN RANGES

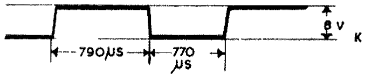
POINT UNDER EXAMINATION — OBSERVED WAVEFORM — REMARKS

CRT 650 v_g
HEIGHT TUBE)

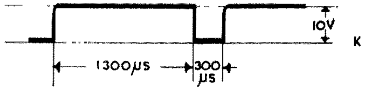
10 MILE SCAN RANGE



REFERENCE POTENTIAL POINT ON TEST SET 31 CONNECTED TO HEIGHT TUBE CATHODE
10 MILE SCAN RANGE



30 MILE SCAN RANGE



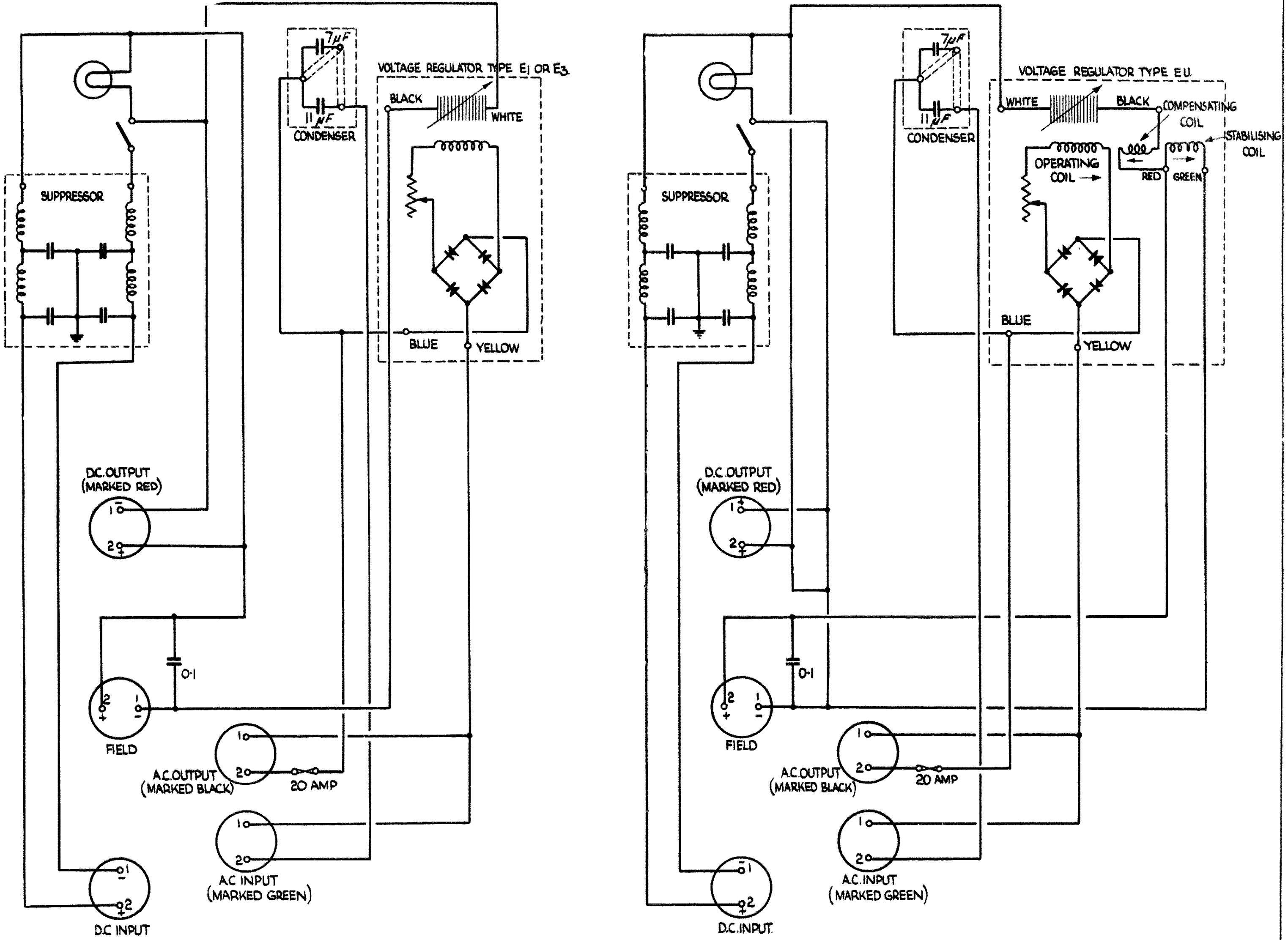
50 AND 50-100 MILE SCAN RANGES

NOTE
WITH BRIGHTNESS CONTROL FULLY CLOCKWISE.
K. LEVEL IS 0V.
WITH CONTROL FULLY ANTI-CLOCKWISE K LEVEL IS - 20V.

INDICATOR UNIT TYPE 162- WAVEFORMS (3)

FIG. 58

FIG. 58



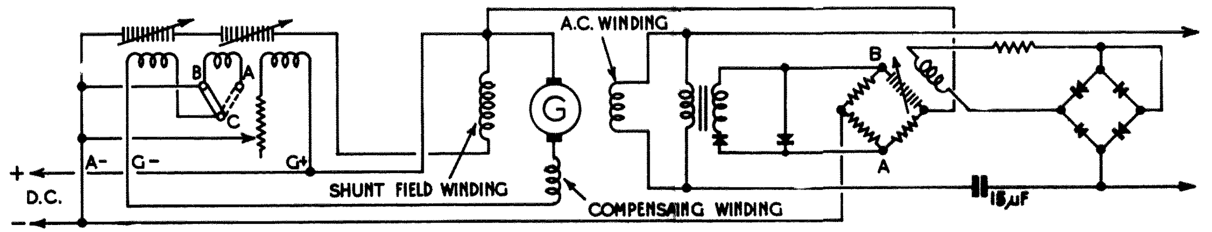
FITTED WITH REGULATOR TYPE E.1 OR E3

FITTED WITH REGULATOR TYPE E.U.

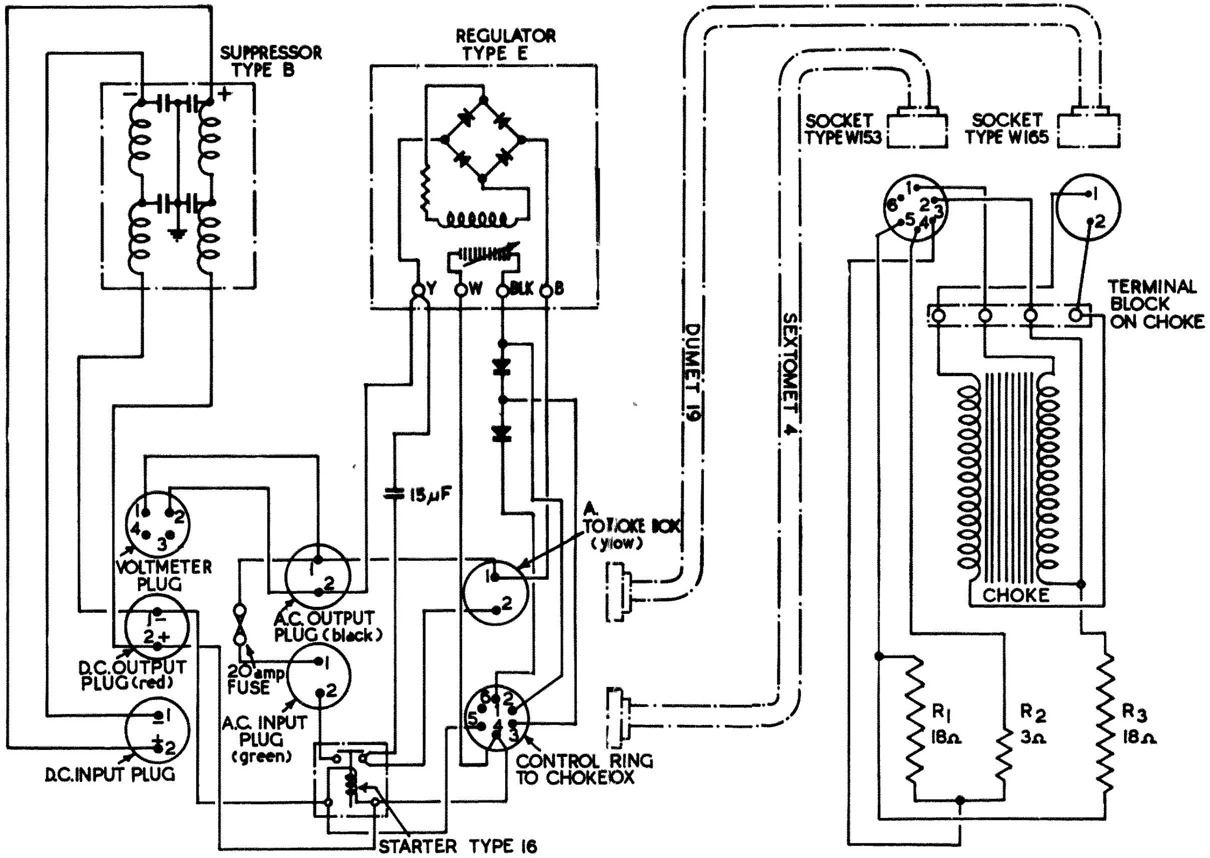
FIG.61.

CONTROL PANEL TYPE 5

FIG.61.



(a) THEORETICAL CIRCUIT - GENERATOR TYPE UKX AND CONTROL EQUIPMENT

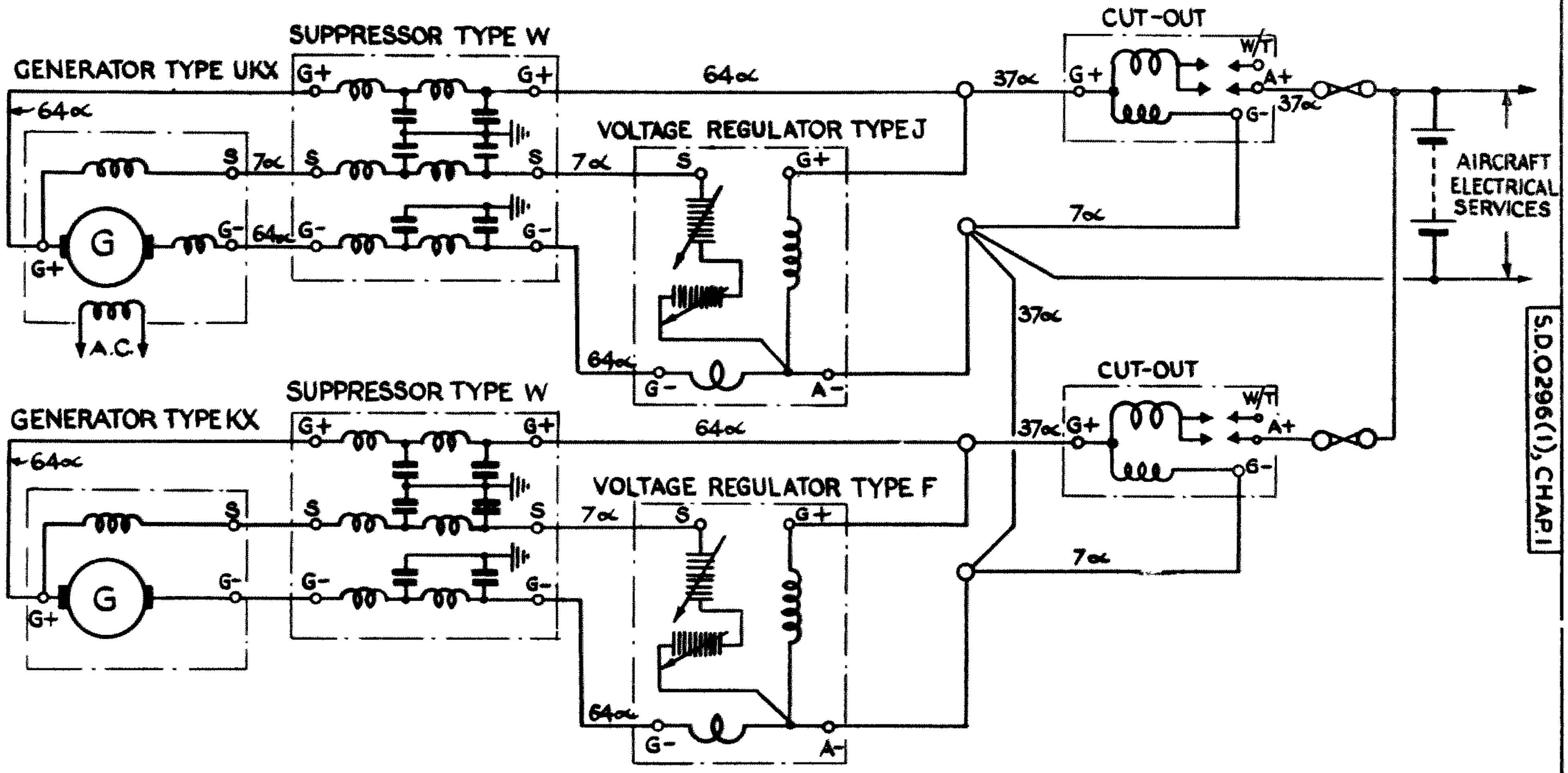


(b) INTERNAL WIRING OF CONTROL PANEL TYPE 6 AND CHOKE BOX TYPE 1

FIG. 62

FIG. 62

FIG.63



CIRCUIT DIAGRAM UKX AND KX GENERATORS IN PARALLEL

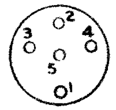
FIG.63

BRITISH STANDARD BASES

S.D. 0296 (I) CHAP. 1

X . . INDICATES NO PIN EXCEPT IN C.R.T TUBES
— INDICATES PIN BUT NO CONNECTION

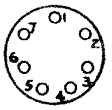
B4 = BRITISH STANDARD 4-PIN
B5 = " " 5-PIN



CENTRE PIN NOT FITTED ON B4

PIN Nº	VU120	CV54	VU133
1	BLANK	BLAN	BLANK
2	BLANK	BLANK	BLANK
3	CATH. Htr	Htr.	CATH. Htr
4	Htr.	Htr.	Htr
(5)			
TOP CAP(S)	ANODE	ANODE	ANODE

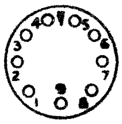
B7 = BRITISH STANDARD 7-PIN



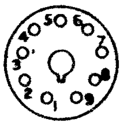
PIN Nº	CV73
1	BLANK
2	G1
3	CATH.
4	Htr.
5	Htr.
6	CATH.
7	G_2
TOP CAP(S)	ANODE

B9 = BRITISH STANDARD 9-PIN
B9G = " " 9-PIN (GLASS)

B9

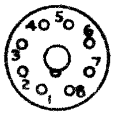


B9G



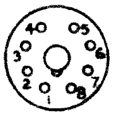
PIN Nº	VR91	VR136
1	H	H
2	G_2	A
3	A	G_2
4	G_3	S
5	S	S
6	C	G_1
7	G_1	S
8	S	S
9	H	H
TOP CAP(S)		

IO-INTERNATIONAL OCTAL



PIN Nº	VR53	VR54	VR55	VR56	VR67	VU71	524G	CV63	CV67
1	M	MS	M	M		—	—	—	G
2	H	H	H	H	H	H	H	H	H
3	A	A_2	A	A	A	—	—	—	—
4	G_2	C_2	D_1	G_2		A	A_1	—	—
5	G_3	A_1	D_2	G_3	G	—	—	—	—
6	BLANK	BLANK	BLANK	BLANK		A	A_2	—	—
7	H	H	H	H	H	—	—	H	H
8	CATH.	C_1	C	C	C	H·C	HC	C	C
TOP CAP(S)	G_1		G	G_1				A,G.	Reg‡

MO = MAZDA OCTAL

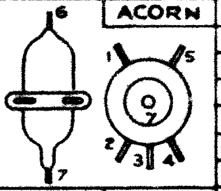


Pin	VR65	VR116
1	H	H
2	C	C
3	A	A
4	G_2	G_2
5	G_3	G_3
6	M	M
7		
8	H	H
T.C.	G_1	G_1

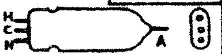
EUROPEAN 8 SIDE CONTACT

Pin
1
2
3
4
5
6
7
8
T.C.

ACORN VALVE



DIODE VALVE VR92

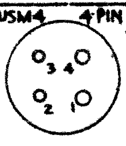


AMERICAN (SMALL) AMERICAN (MEDIUM) BASES AMERICAN (LARGE)

USS4 4-PIN

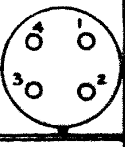
Pin
1
2
3
4
T.C.

USM4 4-PIN



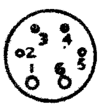
Pin
1
2
3
4
T.C.

USL4 4-PIN



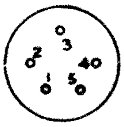
Pin
1
2
3
4
T.C.

USS6 6-PIN



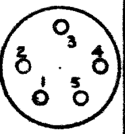
Pin
1
2
3
4
5
6
T.C.

USM5 5-PIN



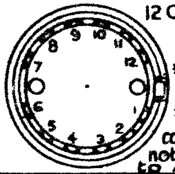
Pin	VT60A
1	Htr.
2	G_2
3	G_1
4	CATH.
5	Htr.
T.C.	A.

GIANT 5-PIN



Pin
1
2
3
4
5

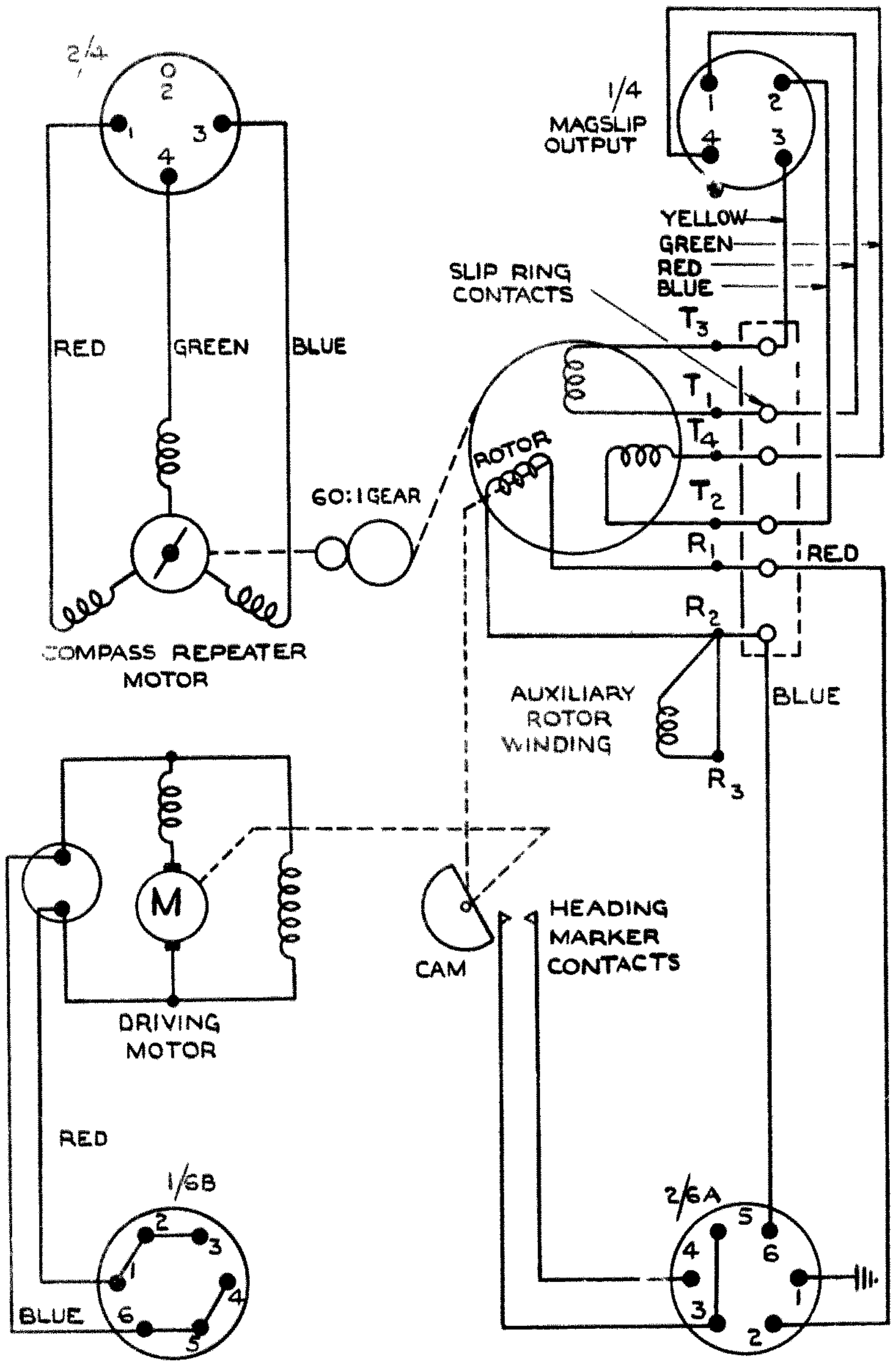
C.R.T. STANDARD 12 CONTACT BASE



* A1 if not strapped to A3
† Internal coating if not strapped to A3

Con	V.C.R	V.C.R. 97	V.C.R. 139A+X
1	G		
2	C		
3	H		
4	H		
5	A1 *	*	*
6	A2		
7	Int. Coatg †		
8	Y2		
9	X2		
10	A3		
11	X1		
12	Y1		

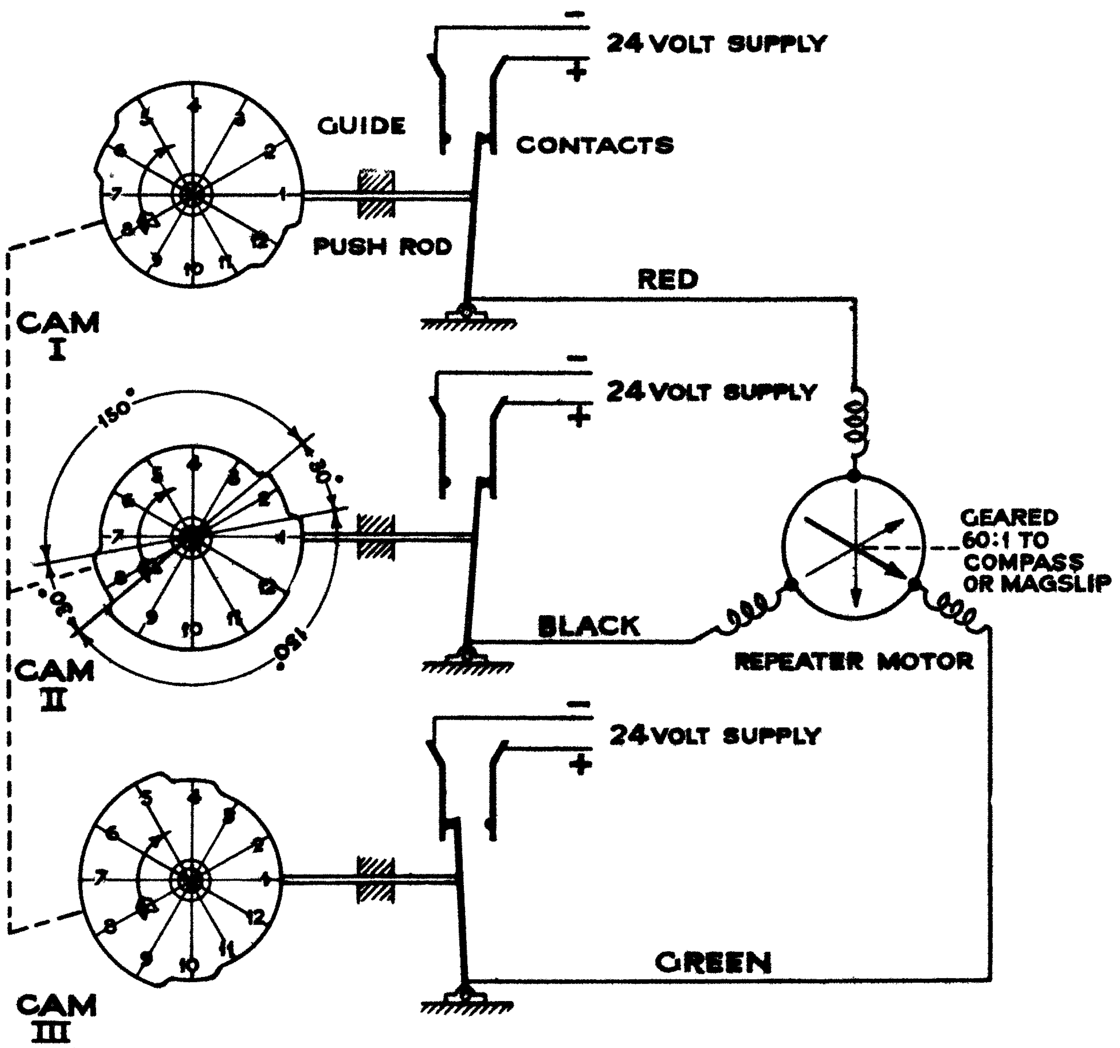
FIG. 64 VALVE BASE CONNECTIONS FIG. 64



SCANNER, TYPE 3 CIRCUIT

FIG. 65

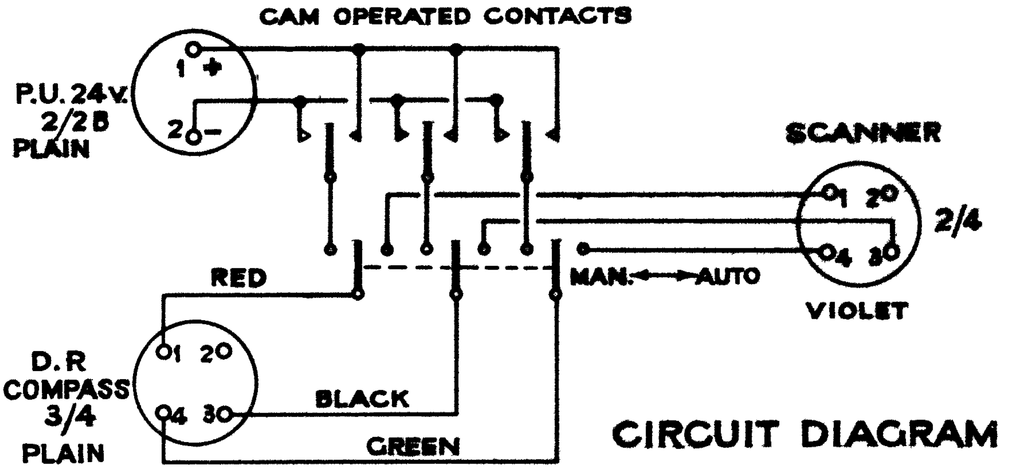
FIG. 65



CAM POSITION OR ARRANGEMENT	1	2	3	4	5	6	7	8	9	10	11	12		1	2	3
RED	+	+	+	+	+	0	−	−	−	−	−	0		+	+	+
BLACK	+	0	−	−	−	−	−	0	+	+	+	+		+	0	−
GREEN	−	−	−	0	+	+	+	+	+	0	−	−		−	−	−

IMPULSES FORMED BY TRANS.

SCHEMATIC DIAGRAM



CIRCUIT DIAGRAM

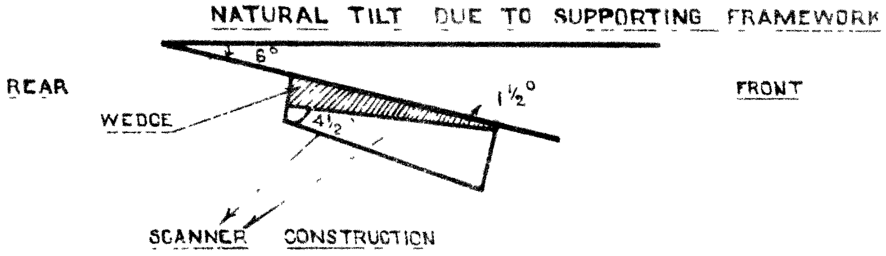
HEADING CONTROL UNIT, TYPE 218 CIRCUIT

FIG. 67

FIG. 67

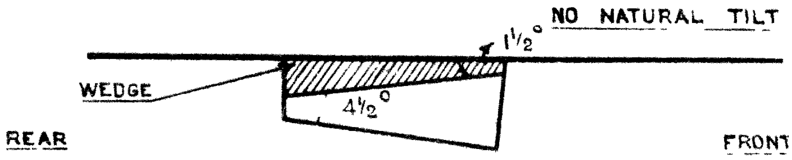
SCANNER TILT

HALIFAX BOMBER



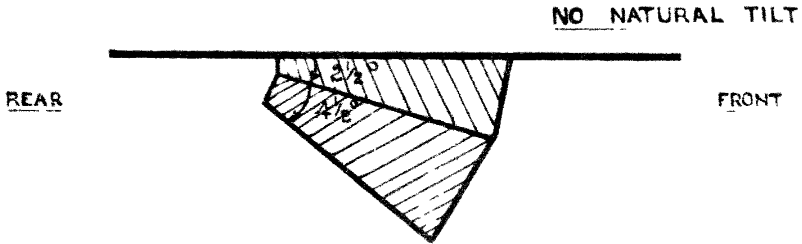
TOTAL TILT DOWNWARD - 9°

STIRLING BOMBER



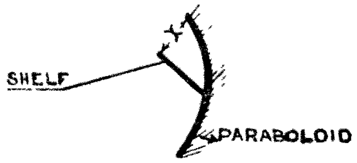
TOTAL TILT DOWNWARD - 3°

LANCASTER BOMBER



TOTAL TILT DOWNWARD 7°

SHELF SETTINGS



HALIFAX - x = 3·25 CMS
STIRLING - x = 2·9 CMS
LANCASTER - x = 4· CMS

SCANNER SETTINGS

FIG.69

FIG.69