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R. A. E.

RADIO DEPARTMENT

TECHNICAL NOTE

No RAD 223

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Tech. Note No. Rad. 223,
July, 1944.

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~~S E C R E T.~~

ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH.

German Ground Radar Equipment.
Receivers for Freya and Coastwatcher Stations

- by -

G. Dawson.

S U M M A R Y.

The Freya Receiver has a frequency coverage of 120 to 128 Mc/s with one signal frequency stage, two 15 Mc/s I.F. stages, two 7 Mc/s I.F. stages, detector and video amplifier. In the Coast Watcher Receiver, the signal frequency of 375 Mc/s is converted to 15 Mc/s without prior amplification and the subsequent stages are exactly similar to those of the Freya Receiver.

The receivers present no new electrical ideas and their employment of two intermediate frequencies is criticised. The units are sturdy in construction; workmanship, connections and screening are of a high standard.

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1. Introduction

This Note is one of a series (see para. 7) prepared at the request of Air Ministry (A.D.I.Sc.) and intended to deal with all the features of the Freya and Coast Watcher equipment.

The two receivers described were captured in the Mediterranean theatre and brought to this country for reconstruction and testing. The case of the Freya receiver was partially buckled by blast but most of the components were intact and the remainder were easily replaced or repaired. The Coast-Watcher receiver was undamaged.

Figs. 1 and 2 show the assembly of the Coast Watcher Receiver and its front panel. The whole unit is plugged into the Display Unit housing, connections being made automatically between fixed sockets on the latter and the plugs at the rear of the receiver. The same mechanical arrangements apply to the Freya receiver.

Two I.F. units have been examined, namely:-

Type NZ102 Serial 57859 and Type GNZ102 Serial 18850 illustrated in Figs. 6 and 7 respectively. The two units are exactly similar electrically and are mechanically interchangeable. Either type may be used in either receiver.

Only one complete set of I.F. valves was available and these valves were interchanged as required.

2. Description of Freya Receiver

2.1 General

The complete receiver, somewhat similar to that illustrated in Figs. 1 and 2, consists of an R.F. unit and an I.F. unit. Fig. 1 shows the stabilivolt for the power supply, the tuning controls of the R.F. unit and the gain control, in the front panel. Fig. 2 shows the power supply plugs and the input and output sockets on the rear of the unit, together with the positioning sockets. The R.F. and I.F. units are connected by means of a screened lead behind the front panel.

The two chassis and front panel are strong, light alloy castings. The components and valves are well protected and firmly fixed.

The receiver characteristics are:-

Normal receiving frequency	125 Mc/s
Frequency coverage	120 - 128 Mc/s
Gain (max.)	124 db
Bandwidth	900 Kc/s at 6 db down
Noise Factor	9.5 db
Saturation output pulse	50 volts

The frequency response curves appear in Fig. 10 and a block schematic is given in Fig. 17.

2.2 R.F. Unit

The unit is shown in Figs. 3, 4 and 5 and the circuit in Fig. 14.

The 125 Mc/s input from the aerial is inductively coupled to a tuned circuit in the grid of the R.F. amplifier valve (105) and the output from the tuned circuit in its anode is mixed with the 110 Mc/s output from the local oscillator (107) on the grid of the output valve (106). The 15 Mc/s beat frequency is fed to the output socket from the tuned circuit in the anode of valve 106.

Stabilised 280V. and 140V H.T. supplies are obtained via the stabilivolt (108).

Fig. 3 shows the circuit layout. The top right hand compartment contains the input tuned circuit and the grid side of the R.F. amplifier valve. The bottom left hand compartment contains the output tuned circuit and socket. The same view with the amplifier valves removed is shown in Fig. 4. The reverse side view of the unit showing heater and H.T. supply wires is given in Fig. 5.

The input and output valves are enclosed in ceramic holders which slide into position and engage with the circuit and supply terminals (Figs. 3 and 4). The ceramic plate which fits into the grooves is sprayed on one side with copper and ensures that the screening of the compartment is complete. The decoupling condensers for the valves are built in the ceramic holders (the latter are shown in Fig. 14 by the dotted squares).

2.3 I.F. Unit

The I.F. unit has a 15 Mc/s input followed by 7 Mc/s stages and a video output to the display unit.

The detailed layout of the unit is shown in Fig. 6 and the reverse side can be seen in the lower half of Fig. 2.

Fig. 16 gives the circuit of the I.F. unit.

The 15 Mc/s output from the R.F. unit is fed via a screened lead mounted on the front panel to the input socket of the I.F. unit on the grid of the first amplifying valve (177). The tuned circuit in the anode of the valve is damped by the 1K resistor in the grid of valve 178 and the amplification obtained is approximately unity. The potentiometer in the cathode of valve 178 is the gain control for the receiver and varies the gain of the valve by altering the cathode bias over a range of 2 - 30 volts. The 22 Mc/s output of the crystal controlled oscillator (183) is mixed with the output from the tuned circuit in the anode of valve 178, and fed into the grid of valve 179 which has a 2K bias resistor to ground. The amplified output from valve 179 is resistance-capacity coupled through a 12 Mc/s low-pass filter to the grid of valve 180. The 7 Mc/s tuned circuit in its anode is inductively coupled (less than critical) to the tuned circuit in the grid of valve 181, and the output from this valve is R.C. coupled into a tuned circuit in the effective anode of the diode detector (182). The diode output is fed through a small grid stopper into the video amplifier (185). The output from that valve is D.C. restored in valve 184 and is fed to the video output socket and on to the display unit.

The response curves of the two units at different gain settings are shown in Figs. 11 and 12. The maximum gain is approximately 100 db and the bandwidth at 6 db down is 1 Mc/s. The shape of the response curve is discussed in paragraph 4.3 below.

The gain of the RL12P10 video output valve (185) is approximately 20. The frequency response of this stage is shown in Fig. 13.

3. Description of Coast Watcher Receiver

3.1 General

Two views of the receiver are shown in Figs.1 and 2. In Fig. 1 the top control is the mixer H.T., the second one down is the oscillator tuning, the third one the input tuning and the bottom one the gain control.

The I.F. valves and R.F. acorns are shown in Fig. 2 and the block schematic in Fig. 17.

The receiver has not been tested in detail as no signal generator at present available will cover the required frequencies, but the following details are known:-

Normal receiving frequency	375 Mc/s
Local oscillator frequency	390 Mc/s
Noise factor	14 db

3.2 R.F. Unit

Detailed views of the Coast Watcher R.F. unit are shown in Figs. 8 and 9, and the circuit diagram will be found in Fig. 15.

The twin feeder input at 375 Mc/s is fed into a coupling loop (with earthed centre tap) loosely coupled to the tuned circuit of the regenerative mixer acorn valve 111, and the H.T. supply to the acorn is adjusted by means of a potentiometer to prevent oscillation. The 390 Mc/s triode oscillator (110) is coupled by a wire to the tuned circuit of the mixer and the 15 Mc/s beat frequency is passed through two under-coupled tuned circuits to the output socket.

A stabilised 210V. H.T. supply is obtained via the stabilivolt. The stabilivolt has non-linear resistors in its anode to prevent heavy current surge. The acorns are mounted on a flat ceramic plate which is supported on insulator rods and the loop for the tuned circuit is copper sprayed on to the plate as shown in Fig. 8.

3.3 I.F. Unit

The Coast Watcher employs the same type of I.F. unit as the Freya.

4. Critical Notes and Comments

Great care has been taken in all units to reduce the number of valve types to a minimum, e.g. pentodes are used as diodes in the I.F. units.

4.1 Freya R.F. Unit

An interesting feature of this unit is the special ceramic holders and mountings for the R.F. valves (see Figs. 3 and 4). The glass envelope of the valve is well protected and stout contacts are brought out to close with the external circuit and supply terminals. The valve holders are sprayed with copper on one surface to complete the screening and they are easily withdrawn from the unit.

The interstage screening is very thorough, the circuit and layout are straightforward.

4.2 Coast Watcher R.F. Unit

The use of ceramic mountings and sprayed copper has enabled a very neat R.F. valve circuit to be constructed. Fig. 15 shows that the circuit for the mixer valve and oscillator valve is the same except for bias values and therefore only one type of ceramic mounting is used. However, the use of a regenerative circuit for a mixer amplifier valve has very little to recommend it. The adjustment of the H.T. voltage to prevent oscillation and achieve maximum sensitivity is critical, and since the amount of feedback and hence the Q of the circuit is determined by the H.T. voltage, the band-width of the receiver varies with this setting. The S/N ratio with this arrangement tends to be high and better results could be achieved with a grounded grid amplifier and a diode mixer.

The lay-out of this unit is determined by the requirement of interchangeability with the Freya R.F. unit in the display cabinet, and is not as neat as most German radio equipment. The construction is sound and the screening thorough.

4.3 Freya and Coast Watcher I.F. Units

The enemy's descriptive document claims that very high gain and stability are obtained by the use of two I.F. frequencies (15 and 7 Mc/s) in the I.F. unit. This complication is unnecessary as a straight chain of 15 Mc/s I.F. amplifiers followed by a detector and a video amplifier would give equal amplification and adequately narrow bandwidth.

The first I.F. valve has no amplifying action on account of the heavy damping across its anode load, and serves only as a buffer valve between the R.F. unit and the rest of the I.F. unit. It could be omitted without altering the performance of the unit. The response curve of the I.F. unit (Fig. 11 or 12) shows the peculiar effects obtained by using I.F. frequencies of 15 Mc/s and 7 Mc/s and a local oscillator at 22 Mc/s. All three frequencies are nearly multiples of 7 Mc/s. An input of 11 Mc/s beats with the beat produced by it and the 22 Mc/s oscillator. A signal of 18.5 Mc/s produces a beat of 3.5 Mc/s with the 22 Mc/s oscillator and the second harmonic of this is amplified by the 7 Mc/s chain giving a peaking effect at 18.5 Mc/s input frequency. Similar effects are produced with large inputs at 14.65 Mc/s and 19.7 Mc/s.

The bandwidth of each R.F. unit is narrow enough to eliminate these effects on its response curve, but it would be better to remove the second I.F. chain and use only one I.F.

The use of pentode valves for the detector and D.C. restorer diodes (182 and 184) has been mentioned above and it is interesting to note that only the first two electrodes are used and the remainder effectively removed by earthing them.

The I.F. units captured with each receiver are shown in detail in Figs. 6 and 7. The unit in Fig. 6 has a much cleaner appearance and better finish than that in Fig. 7 which seems to have been wired up without any attention to the positioning of the leads. The I.F. unit in Fig. 7 has a very large ripple on its output (about 20% of output) but that shown in Fig. 6 has no detectable ripple. In Fig. 6 the heater and H.T. supply leads are carefully separated and the heater leads are made as short as possible by passing them through specially drilled holes in the screening.

With the gain high enough to give saturation noise level the I.F. unit oscillates. This does not affect the operational working of the set as it occurs beyond the normal working condition.

5. Further work required

A detailed investigation of response curve, gain, S/N ratio, frequency coverage and stability of the Coast Watcher R.F. unit is required.

6. Conclusions

The units present no new electrical ideas and, as indicated in paras. 4.2 and 4.3 above, the best solution has not been achieved in one or two circuits.

The mechanical construction, compactness and screening of the units are very good and worthy of study by British designers, although it must be remembered that it is very difficult to modify units when this type of construction is used. The extensive use of complicated ceramic structures for variable condensers and valve mountings is notable.

7. List of Relevant Reports

Freya Transmitter T106 — R.A.E. Tech. Note Rad. 156

Coast Watcher and Freya Installations, Main Display Unit MB 110. — R.A.E. Tech. Note Rad. 204.

Coast Watcher Transmitter (See takt). — R.A.E. Tech. Note Rad. 210.

Other reports in preparation.

Attached:- Appendix.

Distribution:- A.D.I.Sc. (80 copies)
D.D.C.D.2.
R.D.C.7.
R.D.C.13B.
T.R.E. (Dr. Taylor).

File S4761.

APPENDIX.

Parts List for Freya Receiver.

This list is copied from the German Secret Document "Dete-Gerät II Fu.M.G. (Flum) 40G(FD)" for the Freya Installation.

R.F. Unit NZ 100

No.	COMPONENT	DESCRIPTION
100	H.F. Coil	Construction Part.
101	" "	" "
102	" "	" "
103	" "	2.4 µH.
104	" "	Construction Part.
105	Ceramic Holder	Construction No.H26015.
106	" "	" " "
107	Valve	RL 12 P 4.
108	Stabilivolt	STV 280/80.
110	Trimmer Condenser	1.5 pF (+ 20%) + 6 pF; 500 V.
111	" "	4 pF (+ 20%) + 17 pF; 500 V.
112	" "	1.5 pF (+ 20%) + 6 pF; 500 V.
113	Variable Condenser	2.6 pF + 4.0 pF; 350 V.
114	" "	" " "
115	" "	" " "
116	Condenser	50 pF ± 10%; 500 V.
117	"	200 pF ± 10%; 500 V.
118	"	2 pF ± 10%; 500 V.
119	"	50 000 pF ± 20%; 500 V.
120	"	50 000 pF ± 20%; 500 V.
121	"	300 pF ± 10%; 500 V.
122	"	50 000 pF ± 20%; 500 V.
123	"	200 pF ± 10%; 500 V.
124	"	200 pF ± 10%; 500 V.
125	"	2 pF ± 10%; 500 V.
126	"	50 000 pF ± 20%; 500 V.
127	"	200 pF ± 10%; 500 V.
128	"	10 pF ± 5%; 500 V.
129	"	200 pF ± 10%; 500 V.
130	"	200 pF ± 10%; 500 V.
131	"	50 000 pF ± 20%; 500 V.
132	Resistance	1K ± 5%; 0.25 watt.
133	"	200K ± 5%; 0.25 watt.
134	"	50K ± 5%; 0.25 watt.
135	"	2K ± 5%; 0.25 watt.
136	"	200K ± 5%; 0.25 watt.
137	"	3K ± 5%; 0.25 watt.
138	"	50K ± 5%; 0.25 watt.
139	"	100 ohms ± 5%; 0.25 watt.
140	"	8K ± 5%; 0.25 watt.
142	"	10K ± 5%; 0.25 watt.
143	"	2K ± 10%; 30 watt.
144	"	500K ± 5%; 0.25 watt.
146	"	500K ± 5%; 0.25 watt.
147	"	2.5K ± 10%; 30 watt.
148	Thermal Resistance	1500 ohms ± 15%; 4 watt.
149	Transformer	42 VA; 220/2 x6.3/2x2V.
150	Thermal Resistance	1500 ohms ± 15%; 4 watt.

I.F. Unit NZ 102

No.	COMPONENT	DESCRIPTION
170	Inductive Coupling	26 µH/21.5 µH.
171	Tuning Coil	3.8 µH.
172	" "	3.6 µH.
173	" "	2.7 µH.
174	" "	50 µH.
175	" "	40 µH.
176	" "	15.7 µH.
177	Valve	AF 100.
178	"	"
179	"	"
180	"	"
181	"	"
182	"	"
183	"	"
184	"	"
185	Valve	RL 12 P 10.
186	Quartz Crystal	Construction Part.
187	Trimmer Condenser	1.5 pF (+ 20%) + 6 pF; 500 V.
188	" "	1.5 pF (+ 20%) + 6 pF; 500 V.
189	" "	" " " "
190	" "	" " " "
191	" "	" " " "
192	Double Trimmer Condenser	2 x 4 pF (+ 20%) + 2 x 17 pF;500 V
194	Trimmer Condenser	1.5 pF (+ 20%) + 6 pF; 500 V.
196	Condenser	50 000 pF. ± 20%; 500 V.
197	"	" " "
198	"	200 pF ± 10%; 500 V.
199	"	50 000 pF ± 20%; 500 V.
200	"	" " "
201	"	2 pF ± 10%; 500 V.
202	"	200 pF ± 10%; 500 V.
203	"	2 pF ± 10%; 500 V.
204	"	50 000 pF ± 20%; 500 V.
205	"	" " "
206	"	50 000 pF ± 20%; 500 V.
207	"	" " "
208	"	200 pF ± 10%; 500 V.
209	"	25 pF ± 10%; 500 V.
210	"	50 000 pF ± 20%; 500 V.
211	"	" " "
212	"	" " "
213	"	" " "
214	"	200 pF ± 10%; 500 V.
215	Electrolytic Condenser	60 µF + 30 - 20%; 10 V.
216	Condenser	0.45 µF ± 20%; 500 V.
217	"	" " "
218	"	10 000 pF ± 20%; 500 V.
219	Resistance	100 K ± 5%; 0.25 watt.
220	"	125 ohms ± 5%; 0.25 watt.
221	"	3K ± 5%; 2 watt.
222	"	1K ± 5%; 0.25 watt.
223	"	125 ohms ± 5%; 0.25 watt.
224	"	3K ± 5%; 2 watt.
225	"	2K ± 5%; 0.25 watt.
226	"	100K ± 5%; 0.25 watt.
227	"	20K ± 5%; 2 watt.
228	"	300 ohms ± 5%; 0.25 watt.
229	"	70K ± 5%; 0.25 watt.
230	"	10K ± 5%; 2 watt.

(continued overleaf).

I.F. Unit NZ 102 (continued)

No.	COMPONENT	DESCRIPTION
231	Resistance	1K ± 5%; 0.25 watt.
232	"	50K ± 5%; 0.25 watt.
233	"	1.5K ± 5%; 0.25 watt.
234	"	125 ohms ± 5%; 0.25 watt.
235	"	20K ± 5%; 0.25 watt.
236	"	3K ± 5%; 2 watt.
237	"	8K ± 5%; 0.25 watt.
238	"	150 ohms ± 5%; 0.25 watt.
239	"	3K ± 5%; 2 watt.
240	"	3K ± 5%; 2 watt.
241	"	6K ± 5%; 0.25 watt.
242	"	1K ± 5%; 0.25 watt.
243	"	300 ohms ± 5%; 1 watt.
244	"	7K ± 5%; 1 watt.
245	"	3K ± 10%; 12 watt.
246	"	2 Meg. ± 5%; 0.25 watt.
247	"	100K ± 5%; 1 watt.
248	Potentiometer	10K ± 20%; 3.5 watt.

Unclassified

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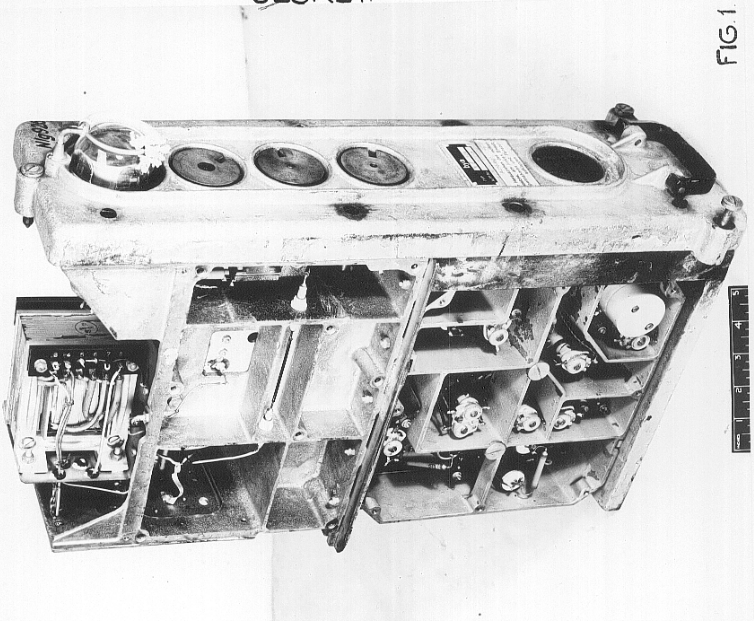

FIG.1.

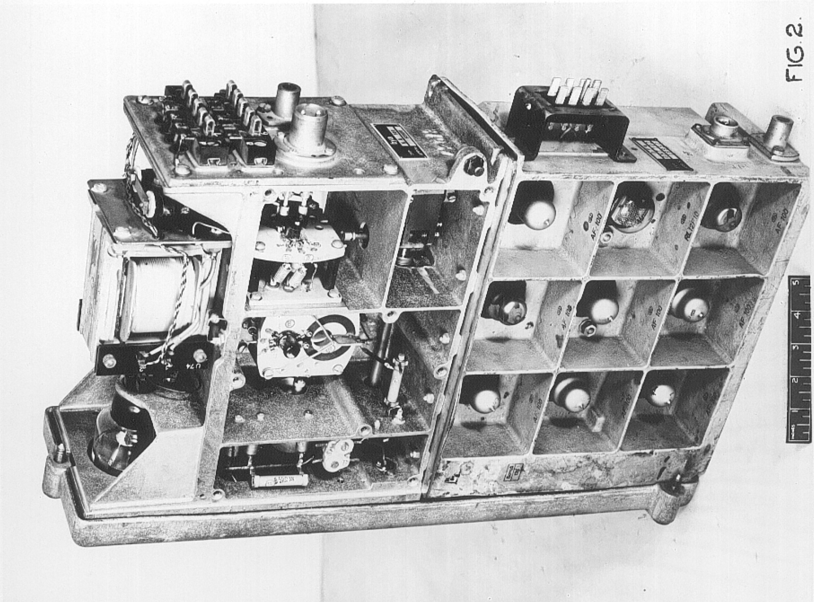

FIG.2.

COAST WATCHER RECEIVER WITH SIDE COVERS REMOVED.

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FIGS. 1 & 2.

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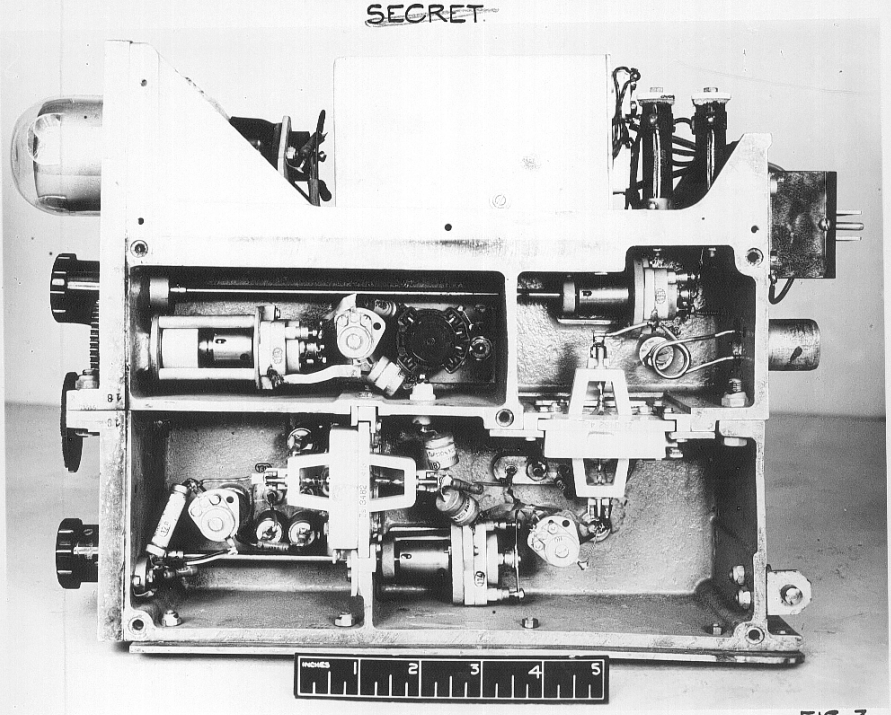

FIG. 3.

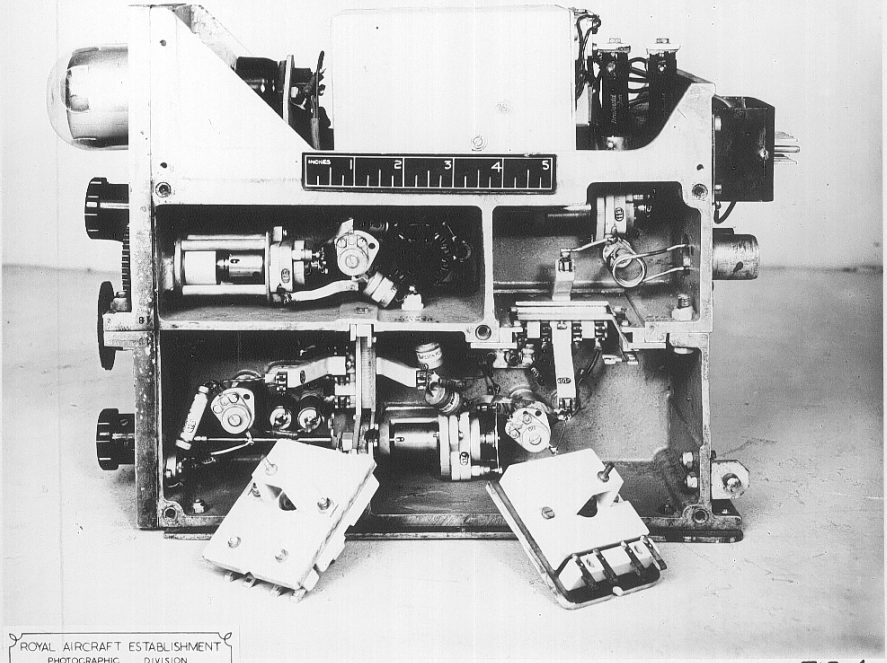

FIG. 4.

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FREYA R.F. UNIT.

FIGS. 3 & 4.

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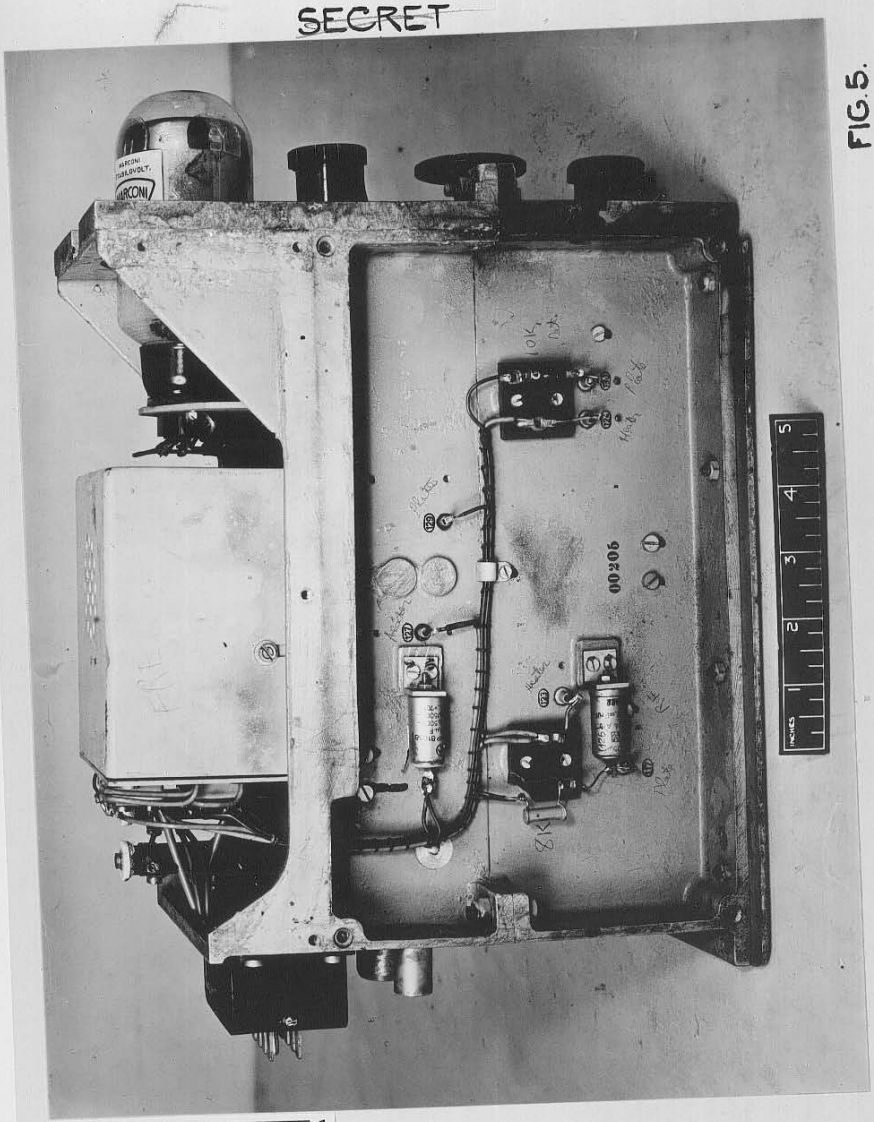

FIG. 5.

FREYA R.F. UNIT.

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FIG. 5.

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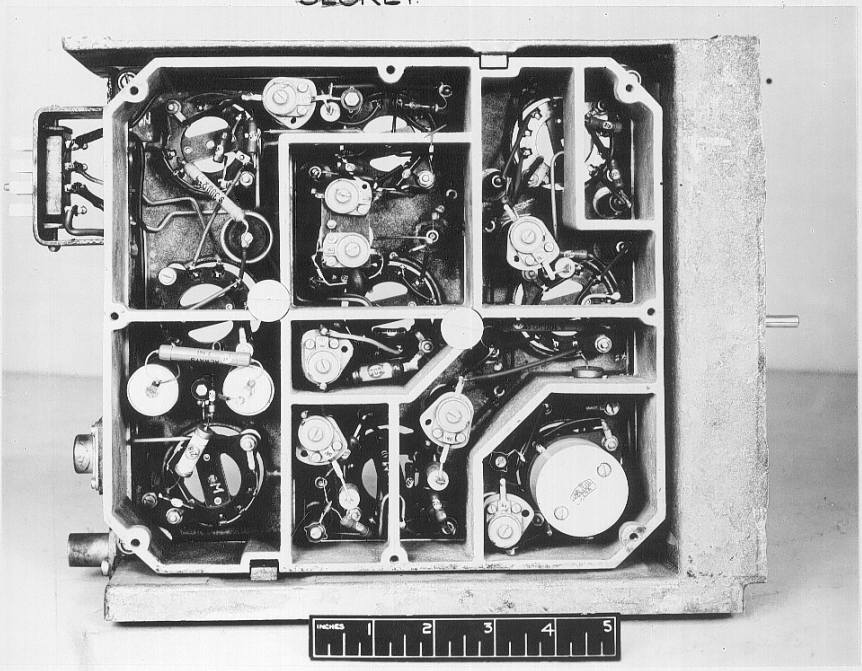
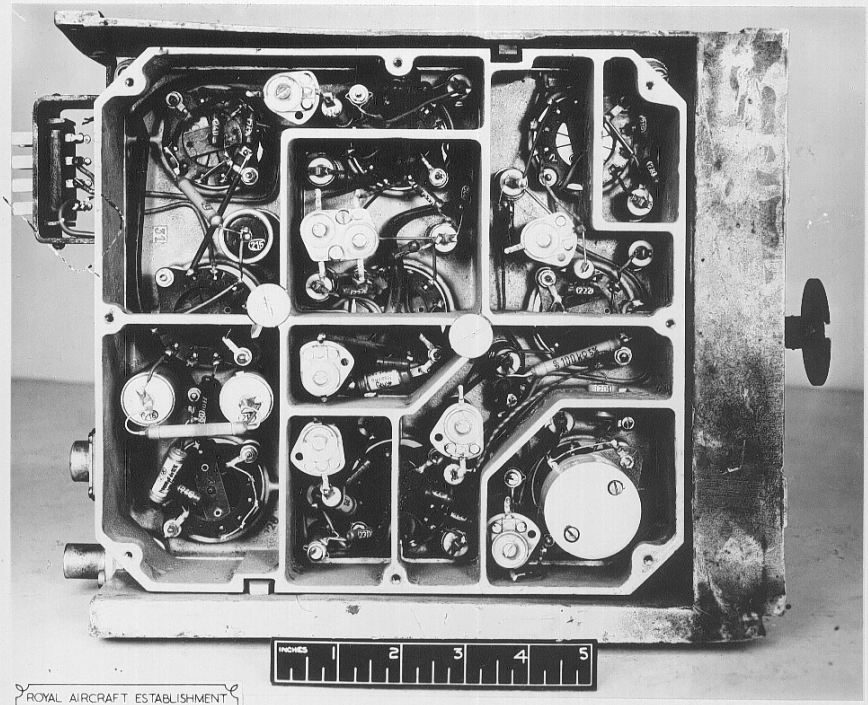


TYPE NZ 102. FIG.6.



TYPE GNZ. 102. FIG. 7.

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I.F. UNITS.

FIGS. 6 & 7.

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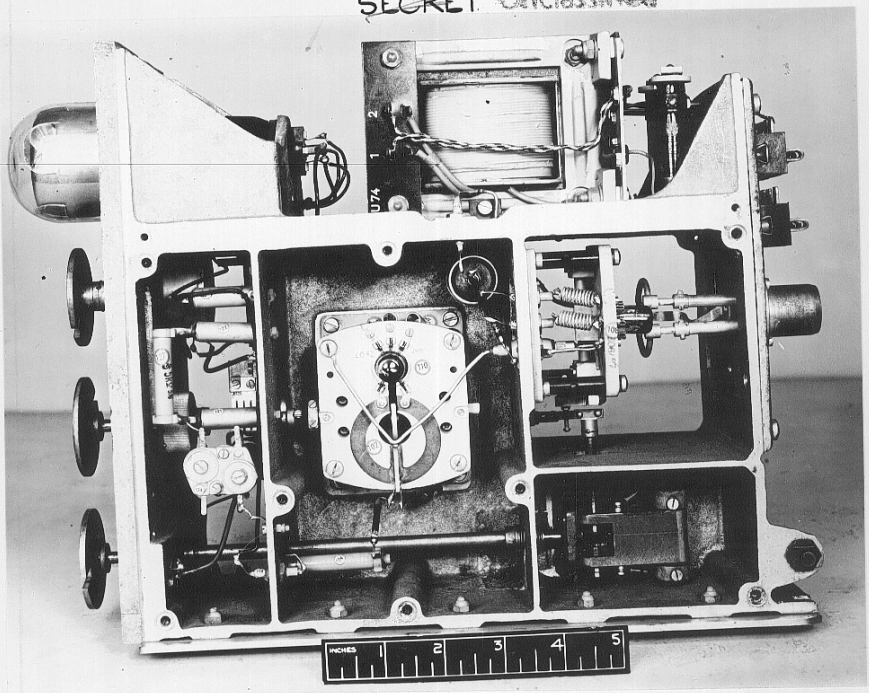

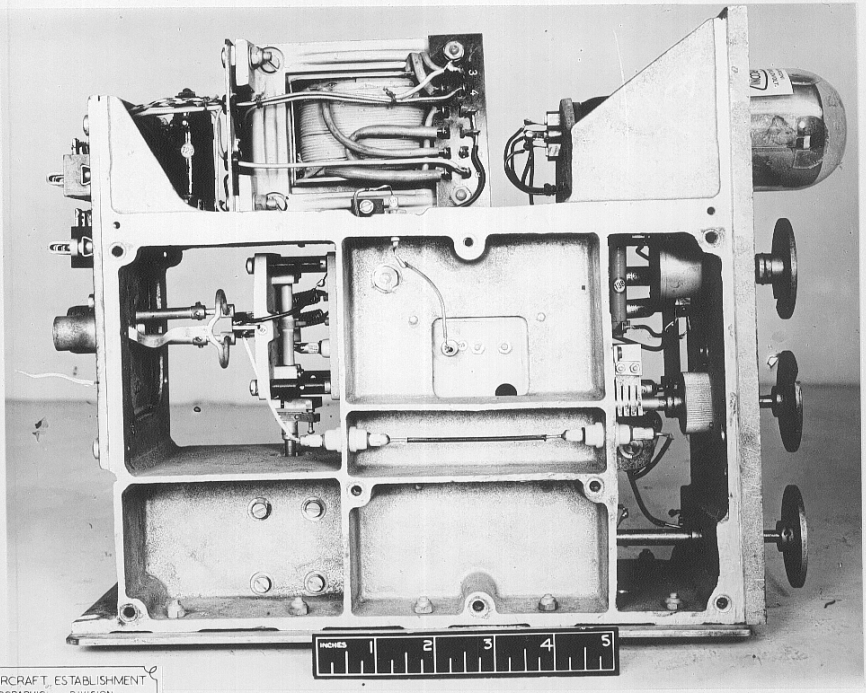

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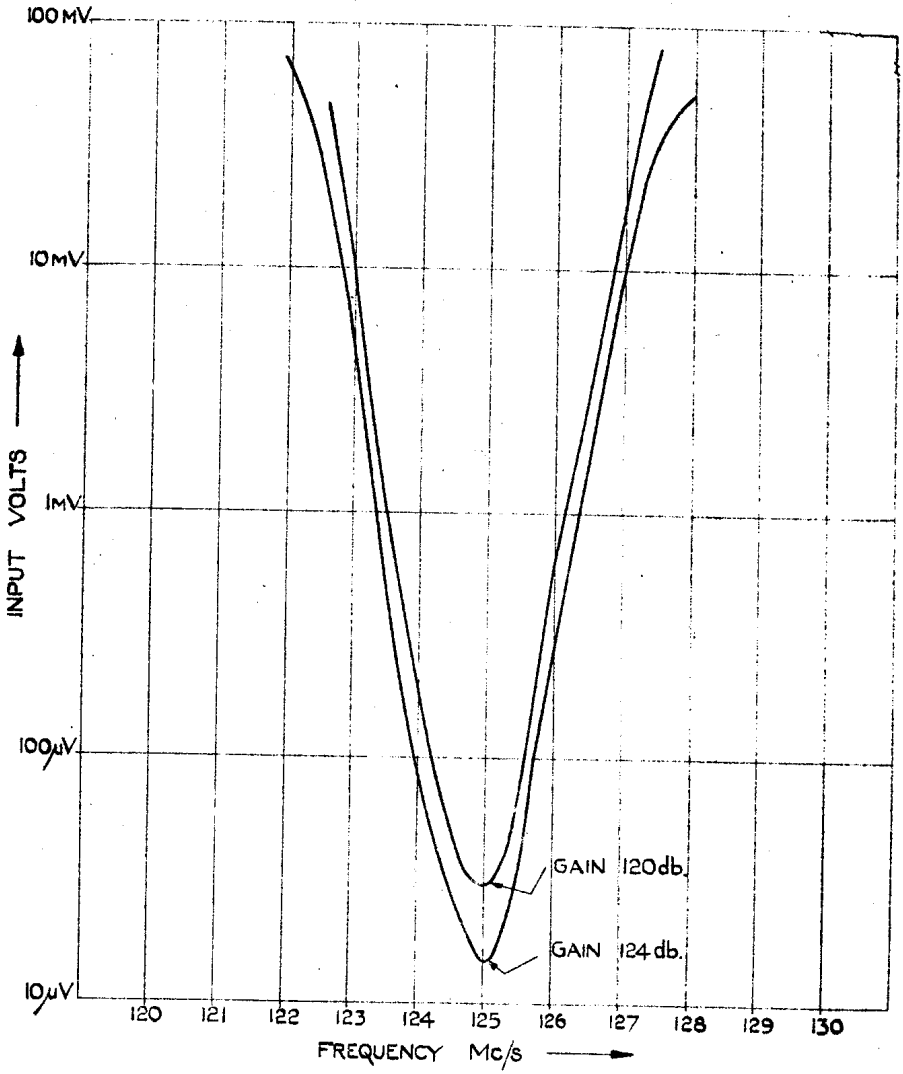
COAST WATCHER R.F. UNIT.

FIGS. 8 & 9.



CONSTANT OUTPUT = .26 V.

FREQUENCY RESPONSE OF FREYA RECEIVER.

FIG. 10.

ISSUE 1 9-6-44.

DIAG. No 10295/B

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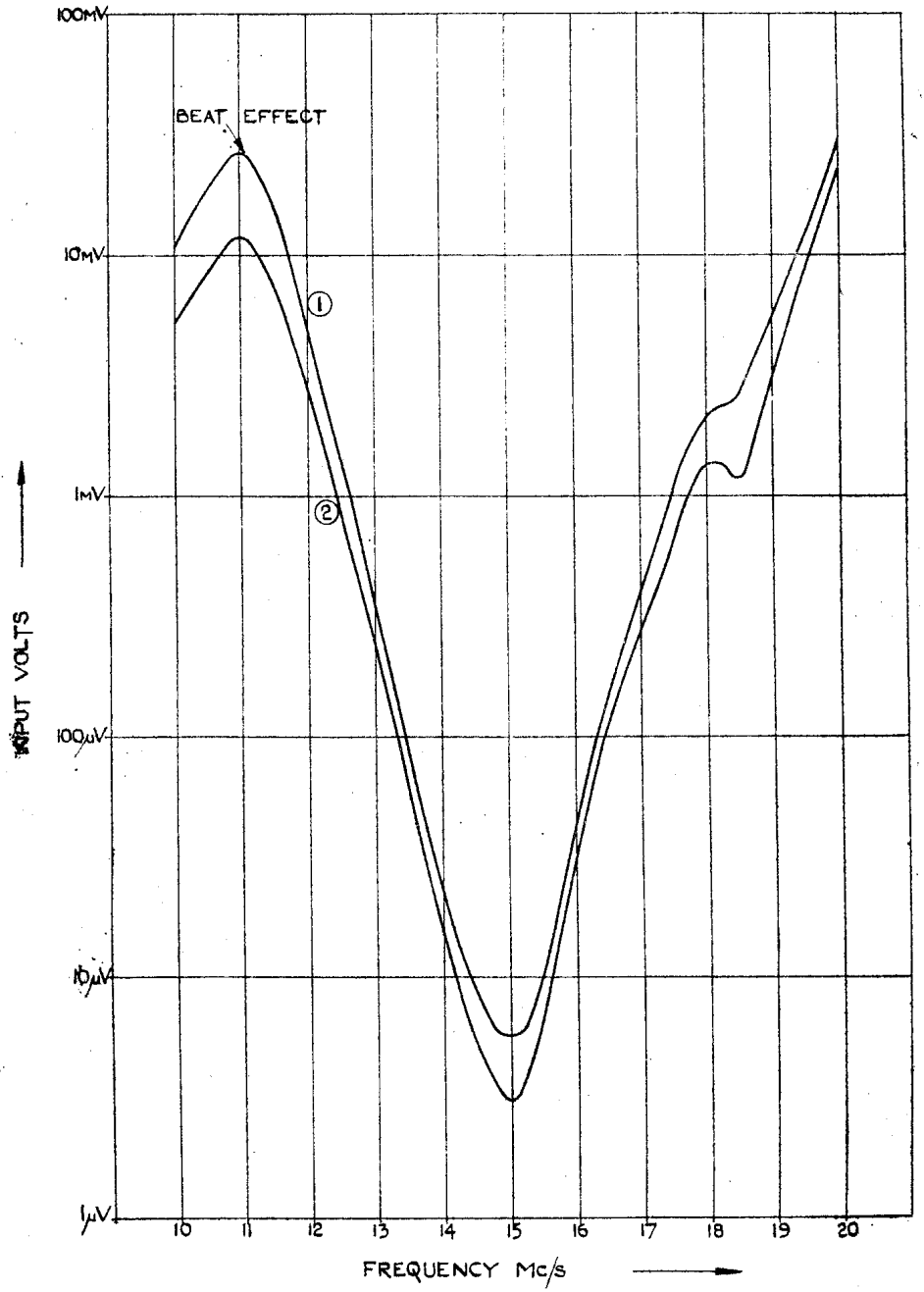
① RESISTANCE OF GAIN POT = 400 Ω

② RESISTANCE OF GAIN POT = ZERO

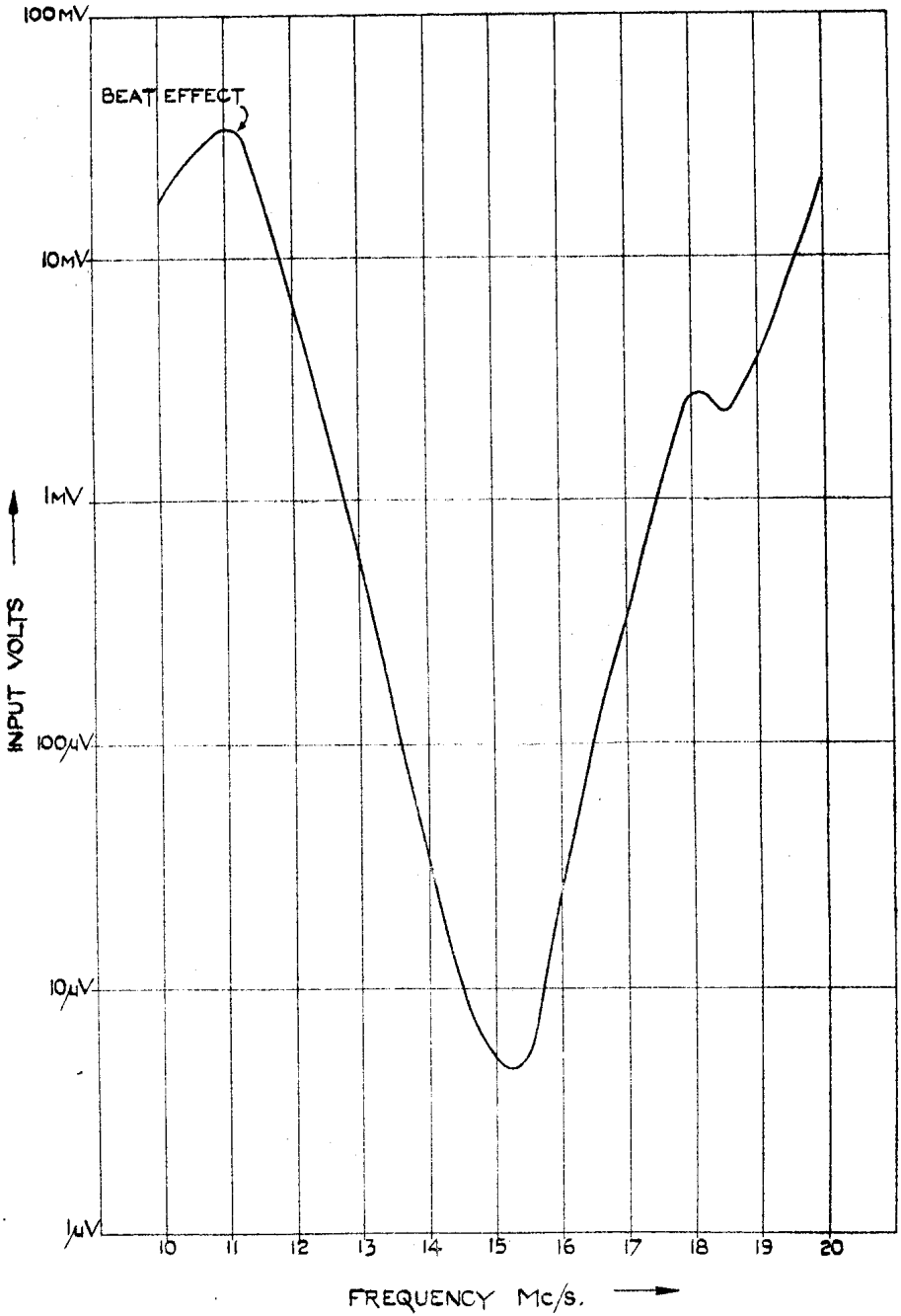
CONSTANT OUTPUT AT DETECTOR = 240 MV.



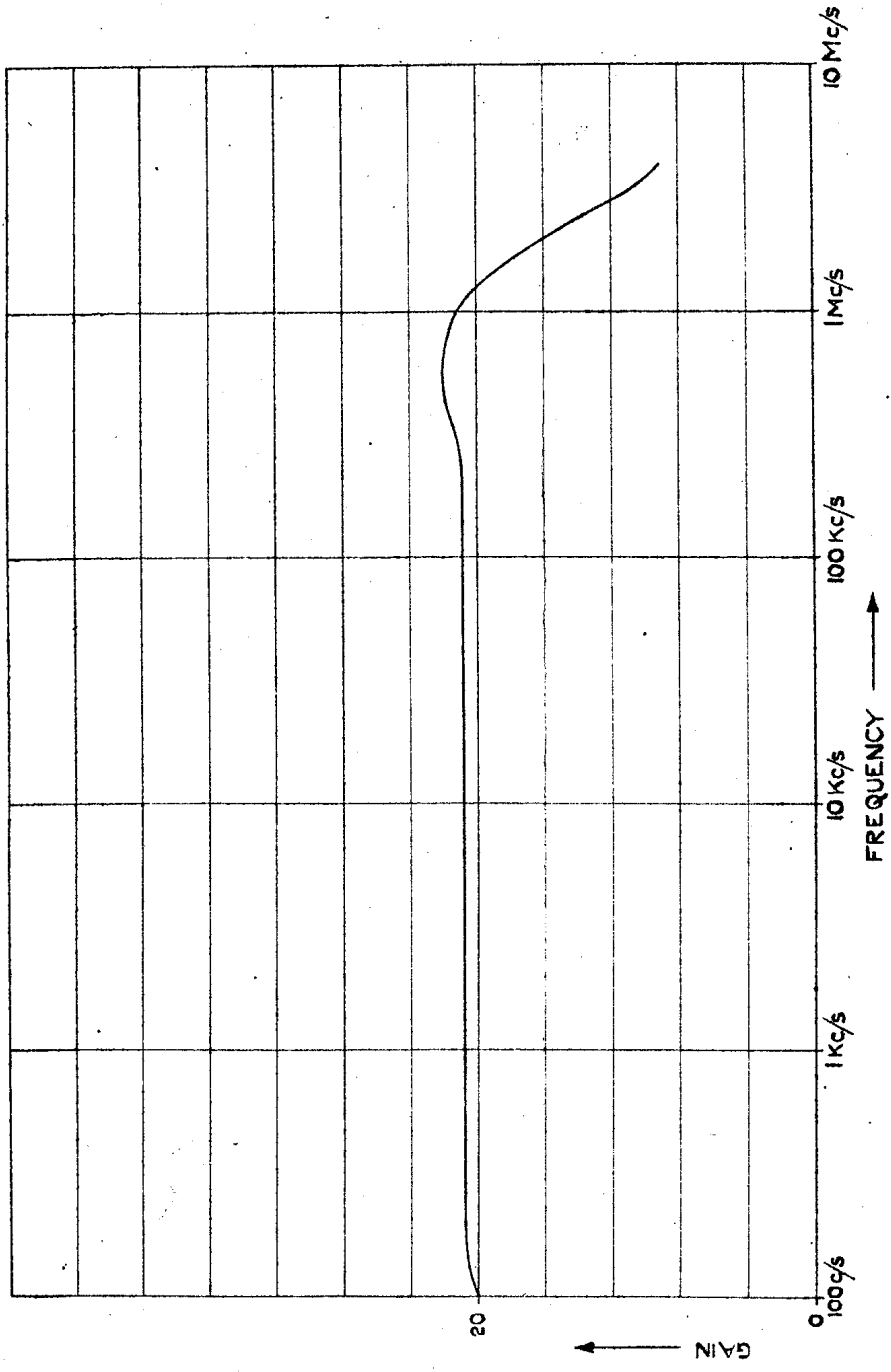
RESPONSE OF I.F. UNIT N.Z 102, 57859.

FIG. 11

RESISTANCE OF GAIN POT = 900 Ω
CONSTANT OUTPUT AT DETECTOR = 240 mV.

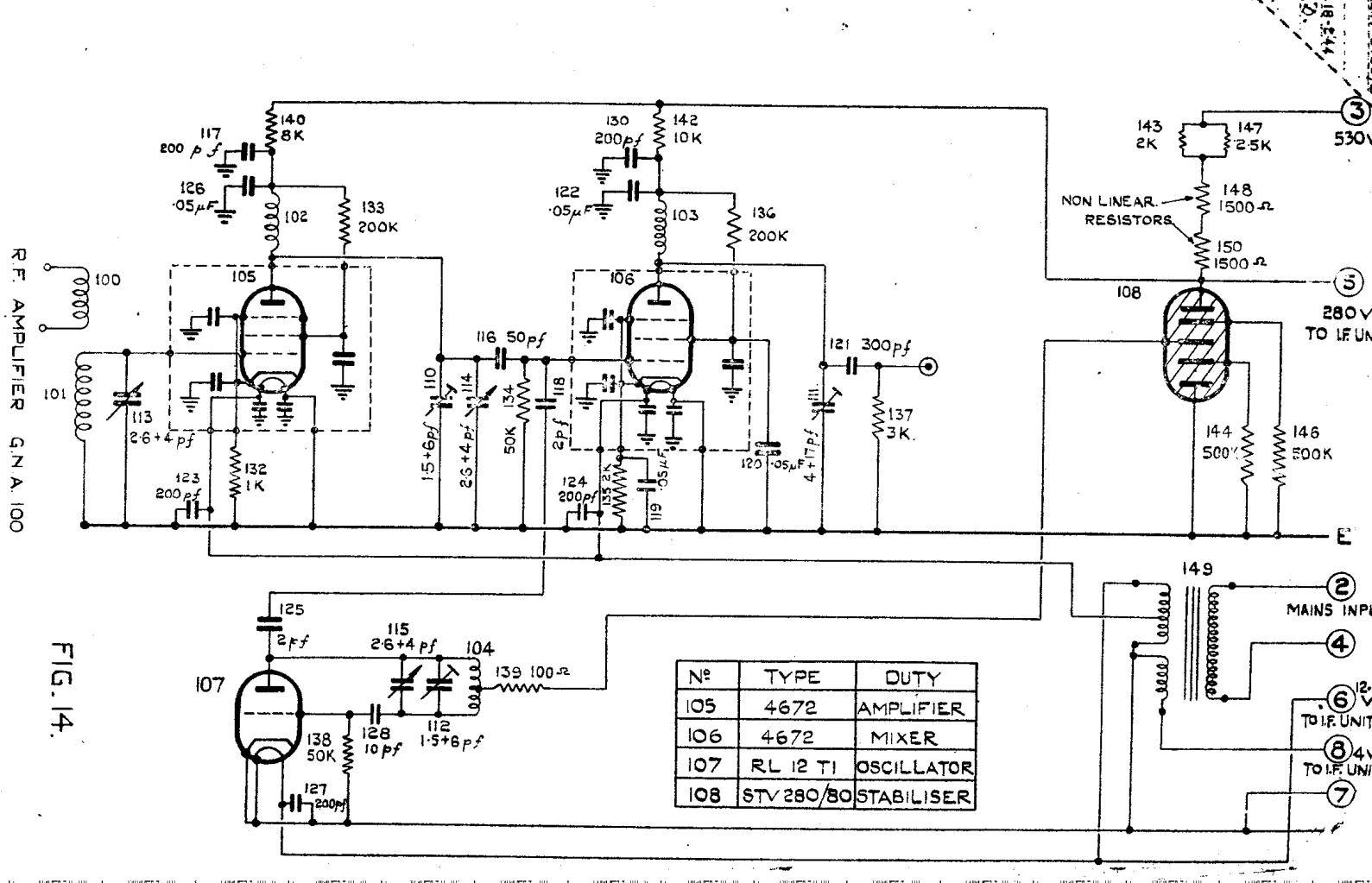


RESPONSE OF I.F. UNIT G.N.Z. 102, 18850.
FIG. 12.



FREQUENCY RESPONSE OF R.L.12 P.10. STAGE. IN I.F. UNIT.

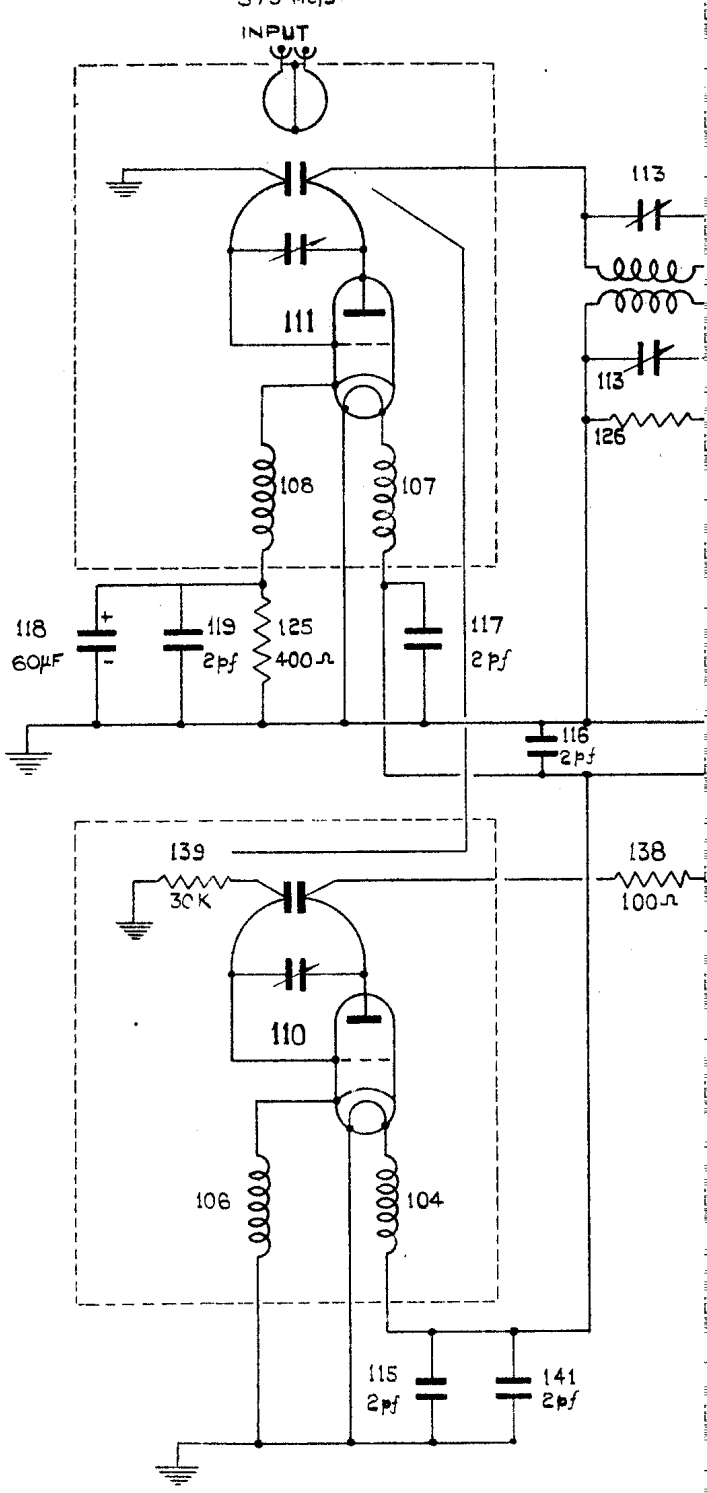
FIG. 13



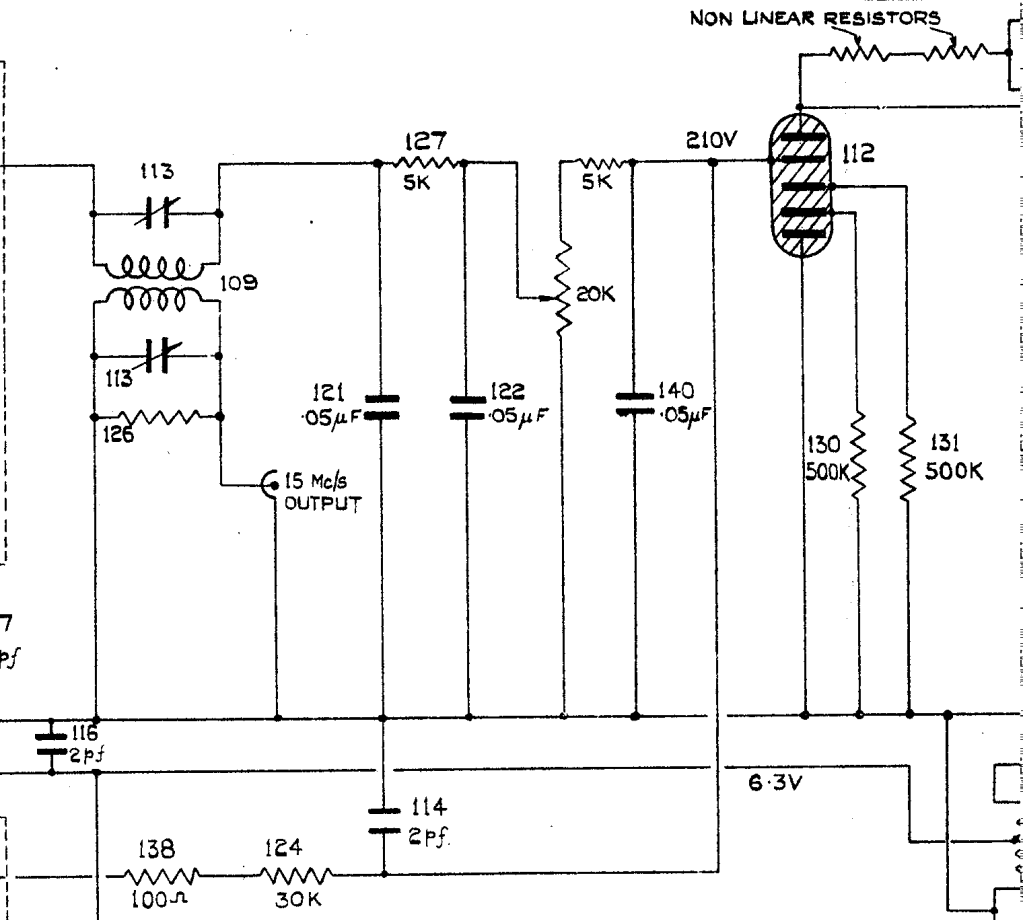
Nº	TYPE	DUTY
105	4672	AMPLIFIER
106	4672	MIXER
107	RL 12 T1	OSCILLATOR
108	STV 280/80	STABILISER

FIG. 14.

DIAG. N: 9523 B
DR. G.E.G.
TR. S.T.S. 3-44
CH. R.L.
APP. A.J.O.
W.S.



ISSUE 1
DATE 4-3-44
ISSUE 2. 22-6-44



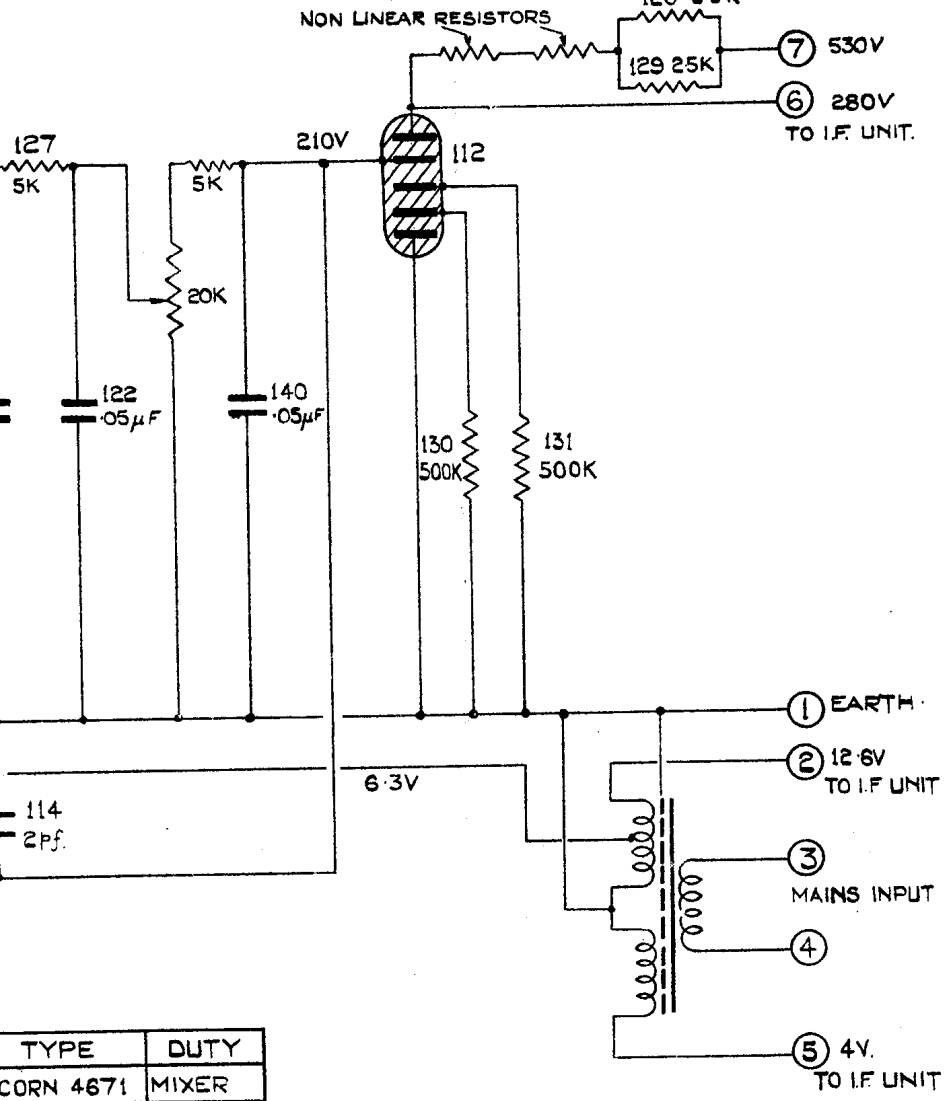
Nº	TYPE	DUTY
111	ACORN 4671	MIXER
110	ACORN 4671	OSCILLATOR
112	S.T.V. 280/80	STABILISER

R.F. UNIT N.A. 101

GERMAN GROUND RADAR EQUIPMENT. COAST WATCH

F

DIAG.



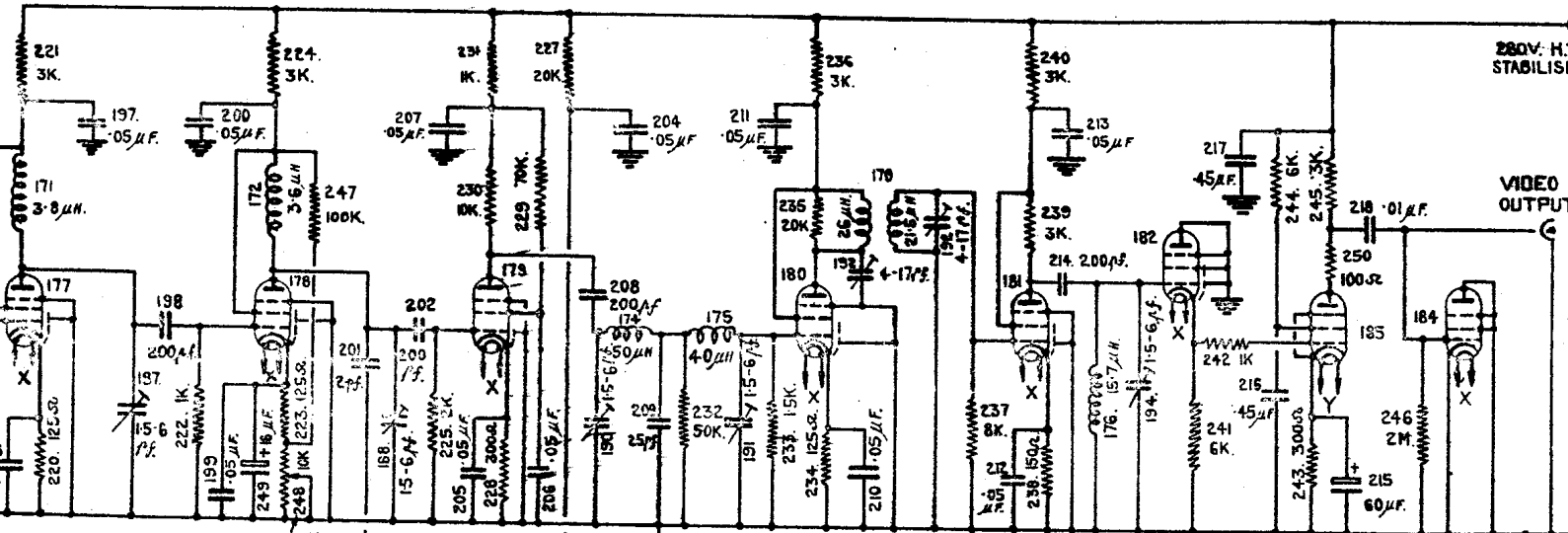
TYPE	DUTY
CORN 4671	MIXER
CORN 4671	OSCILLATOR
T.V. 280/80	STABILISER

R.F. UNIT N.A. 101

N GROUND RADAR EQUIPMENT. COAST WATCHER.

FIG.15.

DIAG. Nº 9923/B.



VALVE LIST.

TYPE	DUTY
·100.	15 MC/S AMPLIFIER
100.	" "
100	MIXER
100	7 MC/S AMPLIFIER
100	" "
100	DETECTOR
100	22 MC/S OSCILLATOR
100	D.C. RESTORER
12. P.10.	VIDEO AMPLIFIER

H.T. AND L.T. SUPPLIED FROM R.F. UNIT NA.100.

X 4V. AC.

Y 12·6V. AC.

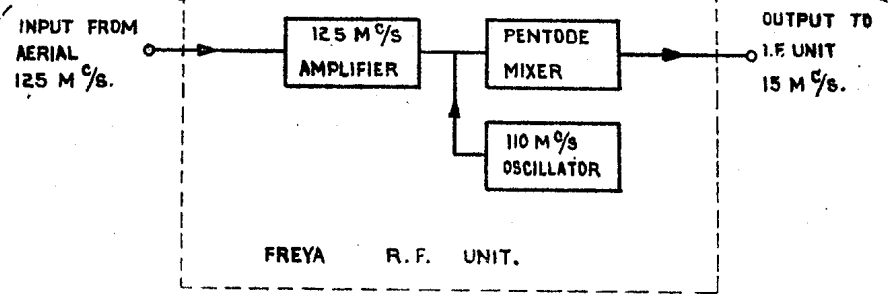
TERMINALS ON JONES PLUG.

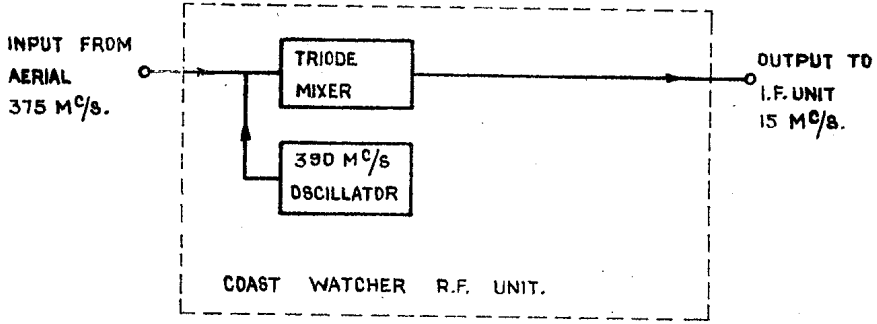
I.F. AMPLIFIER UNIT NZ.102.

GERMAN GROUND RADAR EQUIPMENT. FU.MG. (FLUM) 40G. (FB.)

(FREYA.)

DIAG. Nº 9900/B.





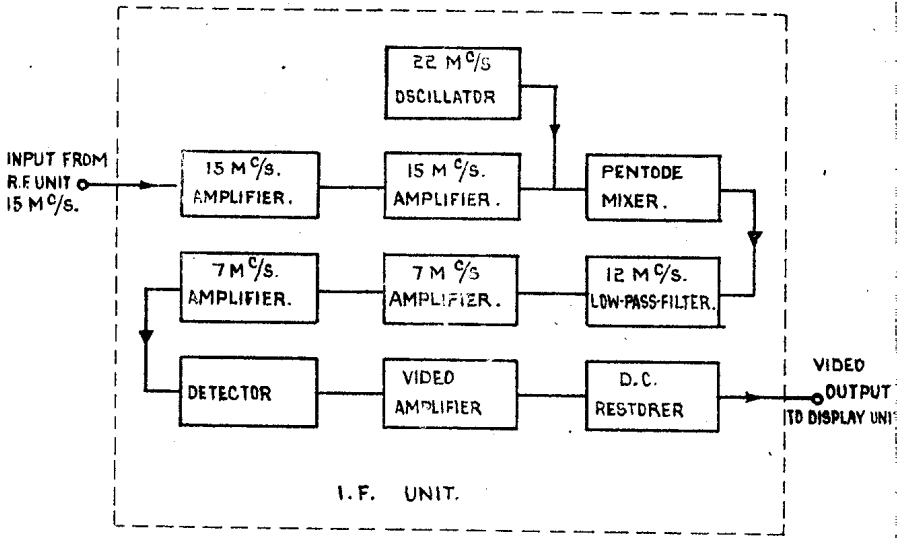


FIG.17.

BLOCK DIAGRAMS OF FREYA AND COAST WATCHER RECEIVERS