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June, 1944.

SECRET.

ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH.

German Ground Radar Equipment
Transmitter of G.E.M.A. Coast Watcher Installation ("Seetakt")

by

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R.A.E. Reference : RAD S4761/166

SUMMARY

This note describes the construction and operation of the 80 cm. (375 Mcs/sec) transmitter of the G.E.M.A. Coast Watcher installation ("seetakt"). The transmitter is housed in a weatherproof box measuring about 4 feet high by 20 inches wide by 15 inches deep and is normally mounted adjacent to the array it serves. The transmitter and built-in modulator are simple in design and derive their H.T. supplies from another unit. The pulses generated are 2 microseconds wide with a recurrence frequency of 500 per second but the output power is only of the order of 15 KW.

CONTENTS.

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C.R.B. 17/1/1955.

1. Introduction.

The work on this transmitter formed part of a programme of the reconstruction and installation at a suitable site, of a complete G.E.M.A. Coast Watcher Installation, (See reference 6.1.) Unlike many other items, the transmitter had almost completely escaped injury and was found with its two oscillator valves intact. The only part missing was the air cooler or "Kühlgerät", which was of the closed circuit type. A conventional fan blower, drawing direct from outside air, has been substituted.

One of the valves found in the oscillator section proved to be soft on test and was submitted to Messrs. Standard Telephones and Cables Valve Section, who have produced six copies of it, which do not greatly differ in characteristics from the remaining sound valve and these have been used in the tests and in the final installation of the apparatus as part of a complete station. Apart from this, the transmitter is in exactly the same state as that in which it was used by the enemy prior to capture.

2. Description of Transmitter (Fig.1)

The transmitter is contained in a weather-proof box intended to be fixed to the supports of the transmitting aerial and consists of modulator and oscillator sections only, being fed from the main power pack of the station. A closed circuit air cooler, "Kühlgerät" is mounted on top of the case.

The transmitter works on a frequency of 375 megacycles giving approx. 15 K.W. pulses about 2 micro seconds long at a recurrence frequency of 500 per second and drawing 5 to 6 mA at 8000 volts H.T. supply and 2000 volts bias.

The top portion of the case is devoted to the oscillator unit T.U. 106 which slides on insulated runners and plugs into the sockets "U" (Fig.7) Its aerial connections also plug into straight rods passing through a porcelain diaphragm in the back of the box, (Fig 4) thus avoiding impedance discontinuities due to complicated wiring, in fact the T.U. 106 is situated less than a foot from the aerial array it serves. The upper right hand corner of this compartment bears plug sockets and fixing means for a unit which has not come to hand and which is not referred to in any available documents. As the front cover is fitted with a glass window and a control spindle at this place, it is thought that the missing unit may have been a wavemeter. The safety resistance 175 (Fig.7) of 50000 ohms is mounted at the top of the compartment at the back so as to be cooled by the air blast provided by the "Kühlgerät" mounted on the top of the unit. This is all the apparatus found in the top compartment. The bottom compartment contains the modulator unit T.S. 103 (Fig 2) and the filament transformer unit T.N. 103, both of which are removable and also the filament rheostat 182 (mounted below T.S. 103) and the E.H.T. bleeder chain 176 to 181 mounted below the upper compartment. All connections from both compartments are collected onto a sixteen way terminal strip of substantial construction and a pair of porcelain insulators in the bottom of this compartment.

The whole apparatus stands on a hollow sub-base also provided with a terminal strip and insulators, which are connected straight through to those in the lower compartments of the transmitter itself and also to the three plugs, H,E,F on the right hand side of the sub-base. It is difficult to see the object of this, as the mechanical fixing of sub-base to transmitter does not correspond to the division of the wiring by the tag boards.

A comprehensive interlocking circuit between point 3, plug H and point 8, plug E, is provided and is not completed until all the three plugs are in place and both top and bottom doors are shut.

2.1. Modulator Unit, T.S. 103 (Fig.2.)

This is an extremely compact unit, almost in the shape of a cube and plugs into the cabinet on the right hand side of the lower compartment. When it is in place, only the two valves and the edgewise reading milliameter 143 and its control switch are seen. The push button at bottom left, is a catch which must be pressed to free the unit to pull it out. Inside, the most noteworthy features are the anode inductance coils 122 and 123 (Fig 8) which are self contained units, whose anode ends come through the tops of the aluminium cans via a porcelain bushing adequate to bear the very high voltage developed in operation. Coil 122 is wound on a sectioned bobbin with an ordinary transformed lamination core while coil 123 is wound on an open porcelain core of many sections which stands vertically in the middle of the can.

The unit produces its own grid bias and filament current, but is fed with 580 volt H.T. current from the main power pack of the station. It does not consume any H.T. current unless the 500 cycle input is present.

Principle of operation (see Figs. 8 and 11)

The grid bias is stabilised at 210 volts which does not permit the flow of current in either valve in the absence of 500 cycle input. This input is a balanced 17 volts, applied to terminals S10 and S11,, the input impedance between which was designed to be 150 ohms. Transformer 121, whose secondary is loaded by condensers 145, and 146, and resistance 147, raises the 500 cycle voltage to 450 volts R.M.S. which is sufficient to overcome the bias on valve 124 for about half of a cycle, excessive grid current being prevented by the grid stopper 132 of 50000 ohms. At the end of the conducting regime, the valve 124 is cut off somewhat rapidly and a sharp voltage peak developed across the coil 122 (Fig.8). This peak, which is positive going, passes the condenser 129 of 0.005 MF capacity and, raising the potential of the grid of valve 125, allows the gradual growth of a current in coil 123. Owing to the short time constant of condenser 129 and the 20000 ohm resistance, the grid of valve 125 rapidly recovers its steady potential and the energy stored in coil 123 during the time that the valve was conducting now expends itself in the production of a short peak whose length and amplitude depend on the constants of the anode circuit of valve 125 (and on the load imposed by the transmitter when this is in use).

It will be seen that the flow of H.T. current is entirely dependent on the existence of adequate 500 cycle input and the milliameter 143 can be switched either into the anode of the first valve or the screen of the second, to observe suitable conditions. The permissible variation is marked on the scale, but no adjustments to the circuit other than valve replacement is possible.

The outstanding feature in this design is the simplicity of the circuit allowing the pulse to be produced from a sine wave by the employment of only two valves, but it has many disadvantages. Perhaps the worst of these is that there is no shaping of the pulse or control of its width, the pulse shape being determined once for all by the components in the anode circuit of the last valve and being of more or less triangular shape. This last consideration cannot fail to influence the design of the transmitter which must be such as to start oscillating at a grid voltage considerably below that of the modulation peak and preferably such as to drive a heavy grid current in opposition to the modulation pulse and keep within limits the further rise in oscillator grid voltage which the sharp peak might occasion (a safety spark gap is fitted in the oscillator).

The whole feasibility of this scheme of obtaining short pulses at high voltage depends absolutely on the use of pentodes with a high magnification combined with a substantial independence of anode current with anode voltage, for if the rise of anode voltage brought about by the action of the circuit tended to increase the anode current, no practicable grid swing would be able to produce cut-off and the scheme would fail. One bad effect of operating under these conditions is that the anode voltage when the valve is conducting cannot be very low and consequently the first valves anode, which has to carry appreciable current during nearly half the cycle, gets extremely hot. The same trouble is not encountered in the second valve, which is only active for a very small fraction of the cycle and may, besides, have a fair anode efficiency.

One interesting feature brought out during tests was the liability of the output valve to cause flash over, both inside the valve and at the leads from coil 123 and this may have led to the decision to place the milliameter in the screen rather than the anode of this valve in order to reduce the risk of injury to the meter.

British type V.T. 60 valves have been successfully used in this unit, the only modification needed being to raise the screen voltage of the first valve from 70 volts (stabilised) to 120 volts. Waveforms were obtained identical with those from the Telefunken LS 50 valves in the original equipment, (see reference) but the first anode showed faint signs of redness.

2.2. Oscillator Unit T.U. 106 (Figs. 3, 4, and 9)

This unit is a simple push pull oscillator using a larger version of the well known "door knob tubes", namely G.E.M.A. T.S.6 valves. (The left hand valve in Fig 3 is a type TS 6. The right hand one is a British copy).The type of oscillator circuit is that in which the grids are connected by a conductor of the least possible inductance, while the filament leads are approximately tuned to the working frequency. It will be seen from the photographs and circuit diagram that the filament leads are in the form of the letter J and spring from capacity plates separated from the chassis by thin presspahn and therefore at R.F. earth potential. The two filaments are in series and consume 31 amps at 2 volts each. Small choke coils are found between the capacity plates mentioned and the LJ. input plugs.

The anode circuit inductance consists of an arch of silver plated metal to which is variably coupled a short circuited loop, which is the frequency control and the only tuning control in the whole transmitter.

A short wire loop, coupled to the anode inductance, ends directly on two plugs carried in a porcelain disc, which corresponds with a similar arrangement passing through the back of the cabinet thus forming an ideal means of connecting to the aerial. However there is no means of tuning or varying its coupling. The anode, aerial and tuning loops constitute between them the main R.F. circuits of the transmitter and are mounted between and above the two G.E.M.A. T.S.6. valves. The cooling air current from the "Kuhlgerät" is split by this structure and divided between the two valves, whence it circulates round the top compartment of the transmitter before being again drawn into the "Kuhlgerat" and recooled. This arrangement is necessary because the transmitter is intended for outdoor operation and in some situations, e.g. deserts, an open cooling system would result in the introduction of sand, insects, etc.

The chassis of the oscillator unit runs on insulated rails and the single securing screw is also insulated, so that the only connection to earth is via the plug U5. This plug is directly connected to the chassis by being supported on a metal pillar but the socket in which it plugs is only connected to the general earth of the cabinet by a long lead going right down to the tag strips at the very bottom of the cabinet. The reason for this is not known.

Matching the transmitter into a small strip lamp with the aid of a stub, a mean power of about 15 watts was obtained with 5 to 6 mA consumption at 8000 volts, giving approx. 15 K.W. peak power with a recurrence of 500 per second and pulse width of about 2 microseconds.

2.3 <u>"Netzteil" Unit, T.N. 103</u> (Figs. 5, 6 and 10)

Unit T.N.103 is called by the enemy "Netzteil" (literally "feed unit") and carries the filament transformer and the two E.H.T. smoothing condensers. An ammeter marked at 31 A, the correct filament current is provided on the face of this unit, but the filament rheostat, in the mains supply to the unit, is mounted in the cabinet itself, just out of sight, beneath the modulator unit and to the right of unit T.N.103. The purpose of the small 0.02 condenser together with the 50000 ohm resistance in the cabinet seems to be to limit the destructive effect of any flash over in the valves of the oscillator unit, an accident very likely to happen owing to the poor shape of the modulator pulse. It is in this unit that the oscillator H.T. circuit is completed to earth via terminal N6 and the cabinet wiring.

3. Performance of Transmitter

The transmitter as a whole appears to give a fairly good pulse shape. The mean power is about 15 watts for an H.T. consumption of 5 to 6 mA at 8000 volts giving an efficiency of about 35%. With regard to the valves, as there is only one good enemy valve extant, no tests have been made upon it, but it may be said that the British copies, which were exhausted by means of a "getter", while the originals were pumped hard, were able to dissipate 200 watts each on the anode without distress. The "Kuhlgerät" cooling system appears to be intended to allow the transmitter to be hermetically sealed rather than to form an air cooling system for the valves, whose anodes in any case it cannot reach.

4. Comparison with Freya (see Reference 6.2.)

This apparatus presents many points of similarity with the Freya transmitter, especially as regards Modulator and "Netzteil" units, but there is no interchangeability of any of the parts. Externally the most striking change consists in the provision of a sub-base to the whole structure, instead of mounting the three supply sockets on the side of the cabinet itself.

In the oscillator section, the most important change is that the filaments are connected in series instead of in parallel and their tuning is fixed. (The Freya had variable tuning of the filaments). In consequence of this, the filaments are run at constant current instead of constant voltage and an ammeter has had to be added to the "Netzteil".

The variable condenser across the aerial feeders has been omitted in the present transmitter thus leaving only a single RF control, namely inductance of anode lines.

In the modulator unit, smaller valves have been adopted (LS50 instead of RS391) but the circuit and even the component values remain the same except that the screen voltage of the first valve is now stabilised at 70 volts by means of the spare Stabilovolt section, and the milliameter swamp resistance (141) has been reduced to cope with the smaller current involved.

5. Conclusions.

This transmitter is chiefly remarkable for its simplicity of operation and absence of adjustments, but the output is very low compared to British practices. The modulator, producing the final modulating pulse from the master sine wave in only two stages, is especially worthy of notice, but the form of the output pulse of this modulation is far from ideal and it must be remembered that the R.F. pulse controlled by it is only of the order of 15 K.W. The working conditions of at least the first valve are also somewhat arduous.

The only tuning adjustment in the whole transmitter is that of the tuning loop in the oscillator chassis and no other adjustment is possible as the filament current, having to be preset to a mark on the ammeter scale, cannot be considered as an adjustment. It appears that the transmitter is intended for a single fixed wavelength and the adjustment provided is merely to enable it to be kept to this frequency after change of valves. This would account for the absence of coupling and tuning adjustment for the aerial, as all aerials would be made to dimensions in the hope that their electrical values would be sufficiently alike to render adjustment unnecessary. A gratifying feature of the test so far made is the fact that British valves can be substitued for the original German ones without change in performance and the apparatus can thus be kept in use indefinitely. The H.T. and G.B. supplies now in use are derived from a power pack constructed at R.A.E. for this purpose.

6. References.

6.1 Recognition of German Ground Radar Air Scientific Intelligence Report No. 24 Air Ministry (ADI Sc)

6.2 Freya Transmitter T 106 R.A.E. Technical Note No RAD 156

7. Other Relevant Reports.

7.01 German Ground Radar Characteristics Air Scientific Intelligence Report No. 20 Air Ministry (ADI Sc)

7.02 FuSE 62 Mechanical Aspects and Turning Gear
R.A.E. Technical Note No. RAD 151

7.03 FuSE 62 Display Unit OSZ 62
R.A.E. Technical Note No. RAD 178

7.04 FuSE 62 Low Tension Circuits
R.A.E. Technical Note No. RAD 189

7.05 FuSE 62 Pulse Generators IG62 & IG62.A.
R.A.E. Technical Note No. RAD 196

7.06 FuSE 62 Monitoring Receiver Units KD62
R.A.E. Technical Note No. RAD 202

7.07. Coast Watcher and Freya Installations - Main Display Unit NB 110
R.A.E. Technical Note No. RAD 204

7.08. Examination of German Valves manufactures between 1938 and 1943
R.A.E. Technical Note No. RAD 114

7.09. German Valve type LD2
R.A.E. Technical Note No. RAD 127.

7.10. German Valve type LG 1
R.A.E. Technical Note No. RAD 149

7.11. Examination of Enemy Valves and C.R.T.s
R.A.E. Technical Note No. RAD 155

7.12. FuSE 62 D type Display System
7.13 FuSE 62 Examination of Aerial Feeder System and RF Circuits
7.14 Telefunken Valve type LS50

(7.12–7.14: R.A.E. Tech. Note in preparation)

Distribution:-

Air Min. A.D.I.Sc (80 copies)
D.C.D. /D.D.C.D.2.
D.C.D./R.D.C.7.
D.C.D./R.D.C.13 b
T.R.E. (Dr. Taylor.)

Appendix. Part List.

Transmitter Unit T (including units T.S. 103, T.U. 106 and T.N. 103)

No.	Components	Description.
182	Variable Resistance	30 ohm. 2.5 amp.
175	Vitreous Resistance	50K ± 5% 100 watt
176	Resistance	.05M + 5%; 6 watt
177	Resistance	.05M ± 5%; 6 watt
178	Resistance	.05M ± 5%; 6 watt
179	Resistance	.05M ± 5%; 6 watt
180	Resistance	.05M ± 5%; 6 watt
181	Resistance	.05M ± 5%; 6 watt

Unit T.S. 103.

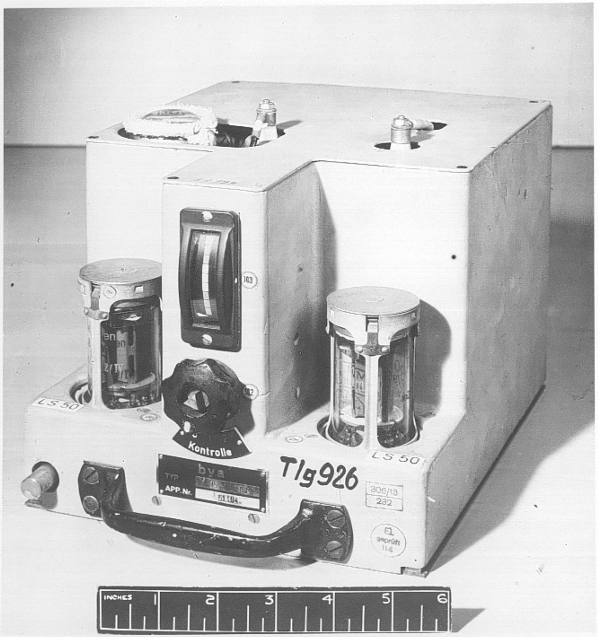
120	Mains Transformer	43 V.A. 220 to 330/2 x 6.3V
121	Resonance Transformer	1 to 27
122	Choke coil	52 mH ± 3%
123	Choke coil	8.5m ± 10%
124	Pentode valve	LS.50 (Telefunken)
125	Pentode valve	LS.50 (Telefunken)
126	Metal Rectifier	140V. 2.5 m.a.
127	Metal Rectifier	140V. 2.5 m.a.
128	Multiple Condenser	4 x 2 µF. ± 10%; 450/650V.D.C.
129	Condenser	5000 pF. ± 5%; 2 K.V.
130	High Tension Condenser	0.1 µF. ± 10%; 2.7 K.V.
131	High Tension Condenser	0.1 µF. ± 10%; 2.7 K.V.
132	Resistance	50K. ± 5%; 1 watt
133	Vitreous Resistance	20K. ± 5% 25 watt
134	Vitreous Resistance	50 ohm ± 5%; 1 watt
136	Vitreous Resistance	5K. ± 10% 12 watt
137	Vitreous Resistance	10K. ± 5%; 6 watt
138	Vitreous Resistance	10K ± 10%; 12 watt
139	Resistance	200K. ± 5%; .05 watt
140	Resistance	500K. ± 5%; 2 watt
141	Resistance	2K. ± 5%; 0.5 watt
142	3 way switch	
143	Milliammeter	2 m.a.
144	Condenser	2 µF. ± 10%; 550V. D.C.
145	Condenser	20,000 pF. ± 20%; 500V. D.C.
146	Condenser	20,000 pF. ± 20%; 500V. D.C.
147	Resistance	1M ± 5%; 0.5 watt
148	Vitreous Resistance	20K. ± 5%; 25 watt
149	Vitreous Resistance	20K. ± 5%; 25 watt
150	Resistance	3K. ± 5%; 0.5 watt
151	Vitreous Resistance	1K. ± 10%; 12 watt
152	Resistance	200K. ± 5%; 0.5 watt
153	Resistance	200K. ± 5%; 0.5 watt
154	Stabilovolt	S.T.V. 280/40 (Telefunken)
155	Resistance	5M. ± 5%; 2 watt
156	Vitreous Resistance	5K. ± 10%; 12 watt
157	Condenser	.1 µF. ± 10%; 350V. D.C.
158	Condenser	40,000 pF. ± 10%; 500V. D.C.

Unit T.U. 106.

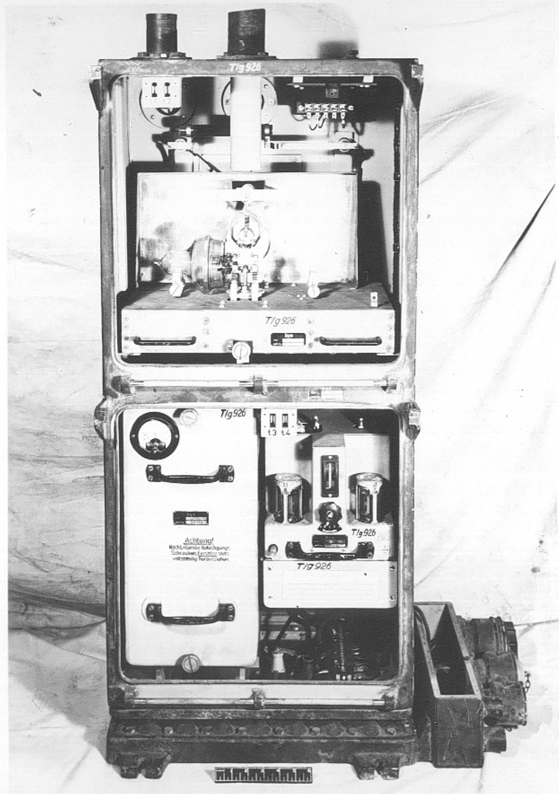
No.	Components	Description
161	Triode Valve	T.S. 6 (GEMA)
162	Triode Valve	T.S. 6 (GEMA)
164	Vitreous Resistance	1K. ± 10%; 35 watt
167	Spark Gap	

Unit T.N. 103.

100	Filament Transformed	375 V.A.; 220/2X2
101	Condenser	.02 μF. ± 10%; 12 K.V.
102	Condenser	0.25 μF. ± 10%; 12 K.V.
103	Ammeter	50A.

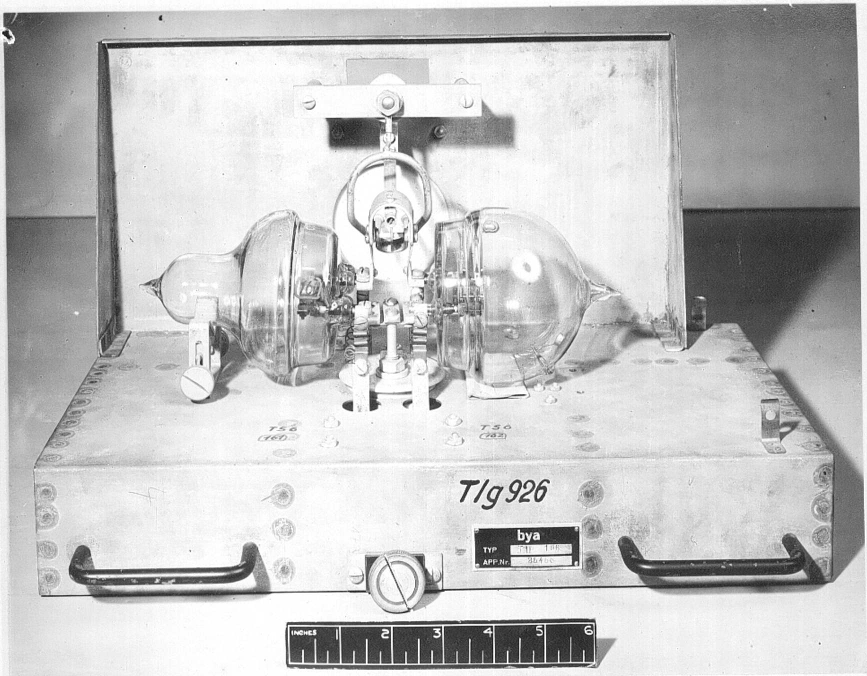


MODULATOR. FIG. 2.

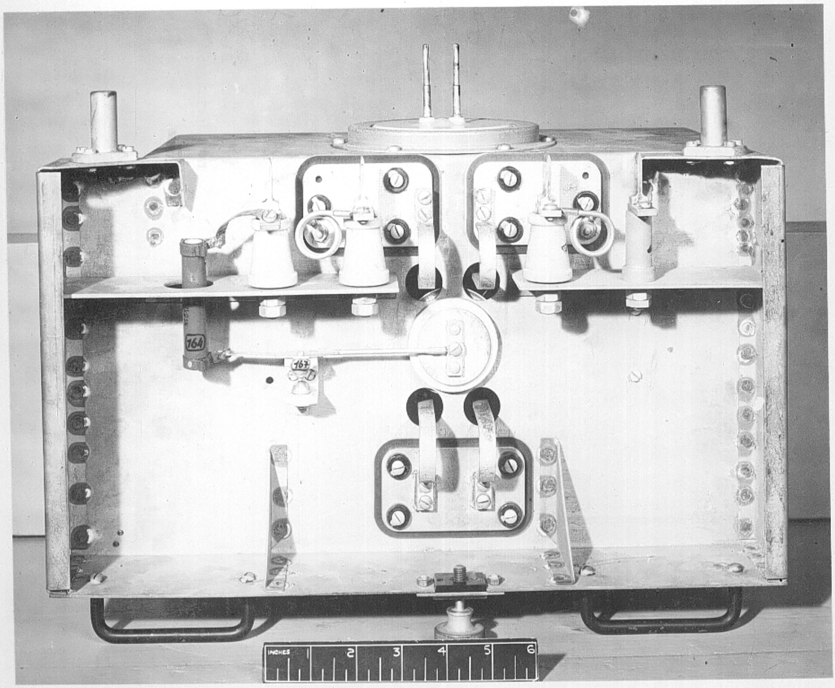


COMPLETE TRANSMITTER. FIG. 1.

FIGS. 1 & 2.

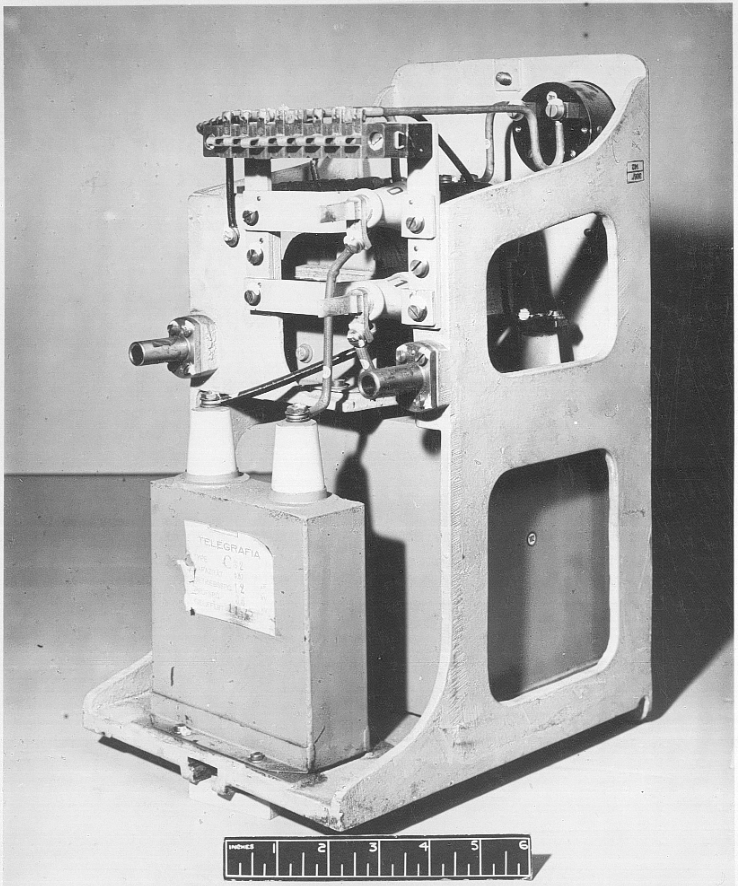


OSCILLATOR - TOP VIEW. FIG.3.



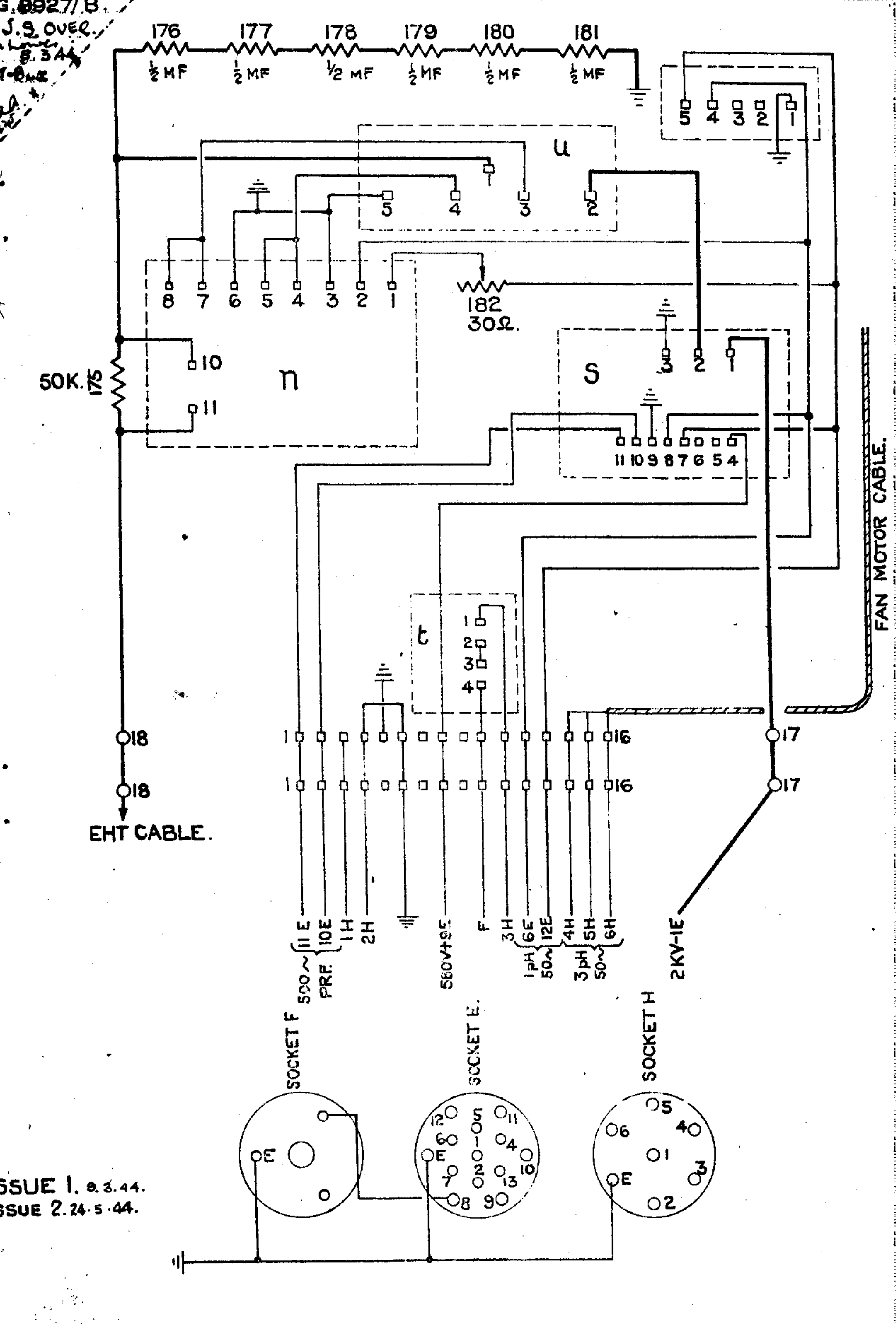
OSCILLATOR - BOTTOM VIEW. FIG.4.

FIGS 3 &

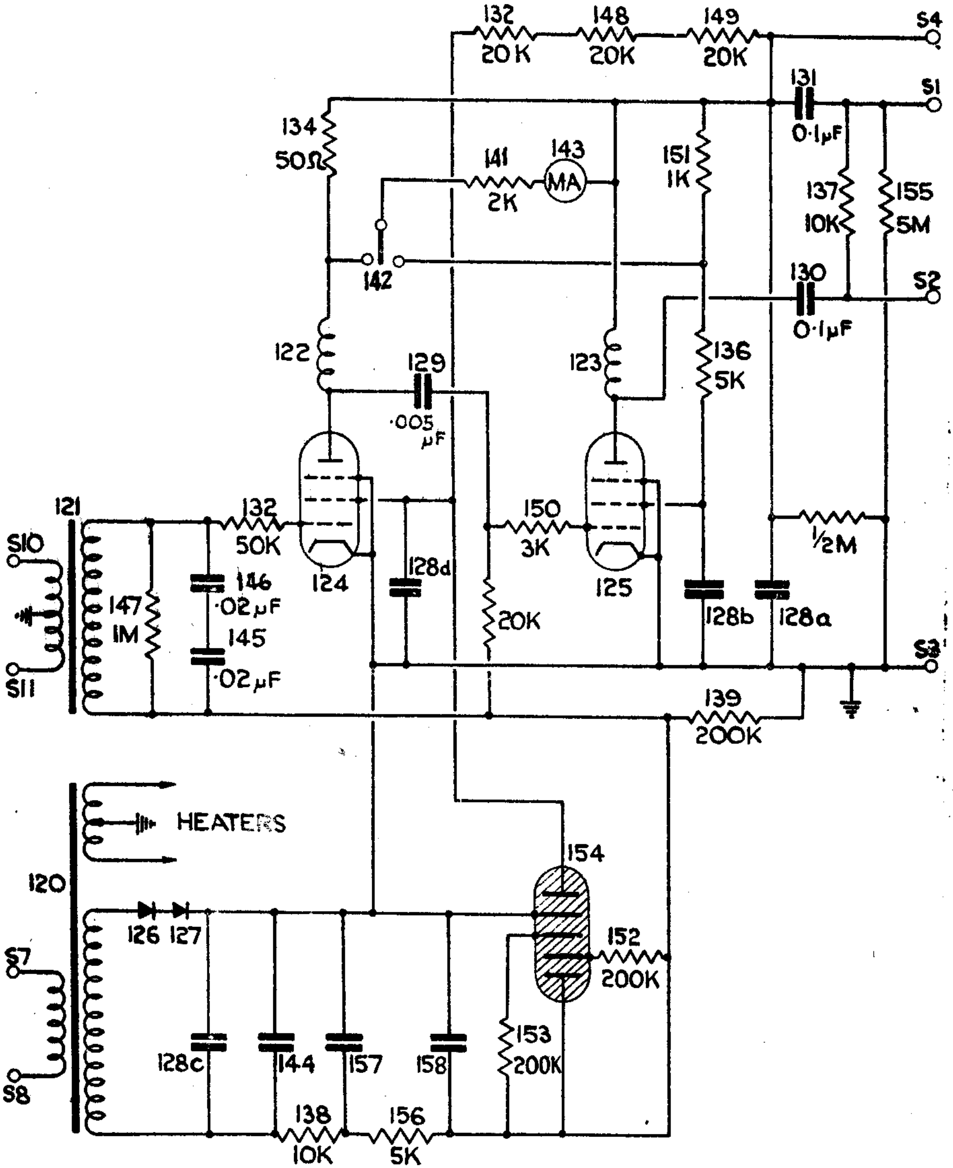


"NETZTEIL" REAR VIEW. FIG. 6.

"NETZTEIL" FRONT VIEW. FIG. 5.



WIRING OF TRANSMITTER CABINET
GERMAN GROUND RADAR EQUIPT



SUE 1.
E 8·3·44
UE. 2
D.Nº 5768 A/o
E 28/3/44
UE 3. 26·5·44.

MODULATOR UNIT T.S 103.

GERMAN GROUND RADAR EQUIPMENT.

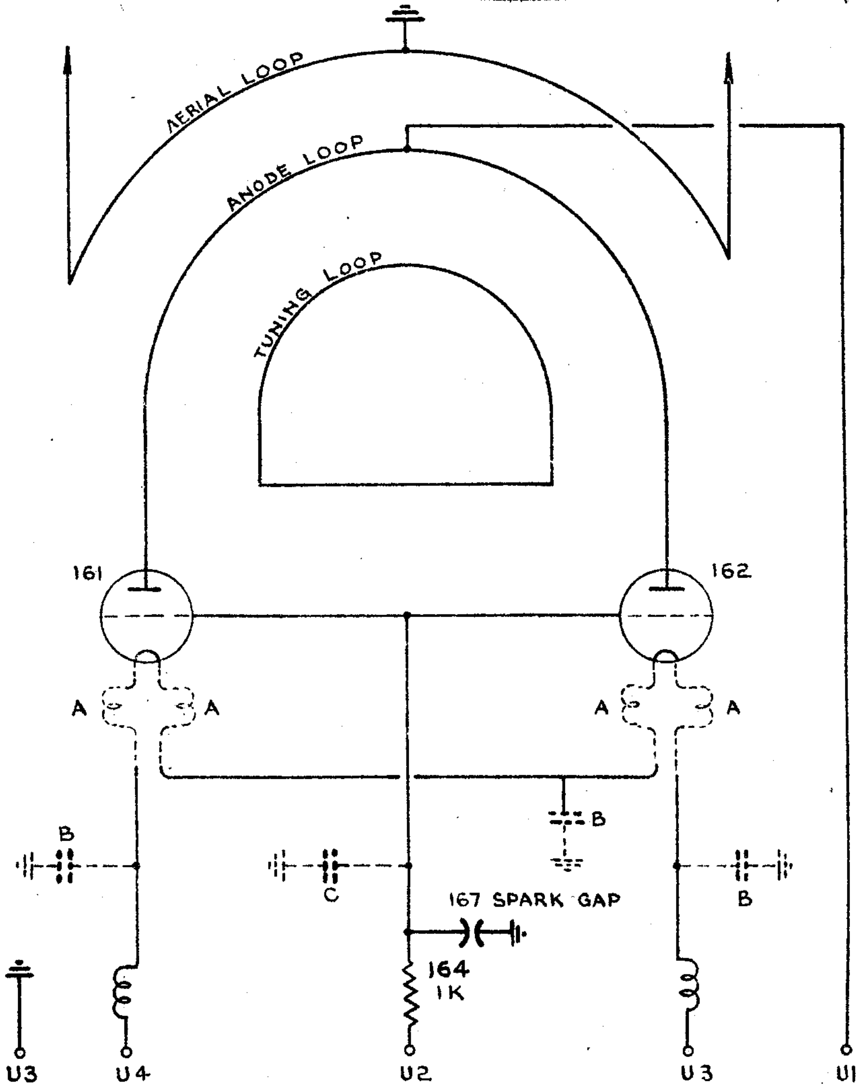
COAST WATCHER.

FIG. 8.

DIAG. Nº 9907/B

957/B.

18-3-44



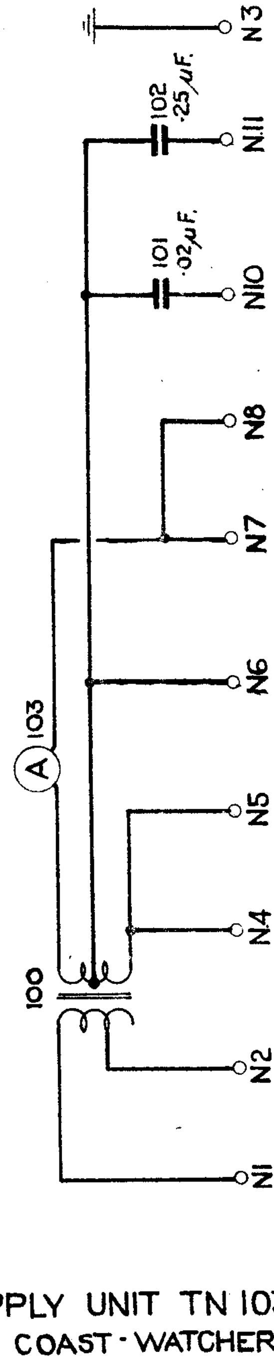
A. FILAMENT INDUCTIVE LEADS
B. " CAPACITY PLATE
C GRID " "

OSCILLATOR UNIT TU 106
GERMAN GROUND RADAR EQPT.
COAST - WATCHER.
FIG. 9.

DIAG 9957/B.

EI. 9.3.44.
2.24.5.44.

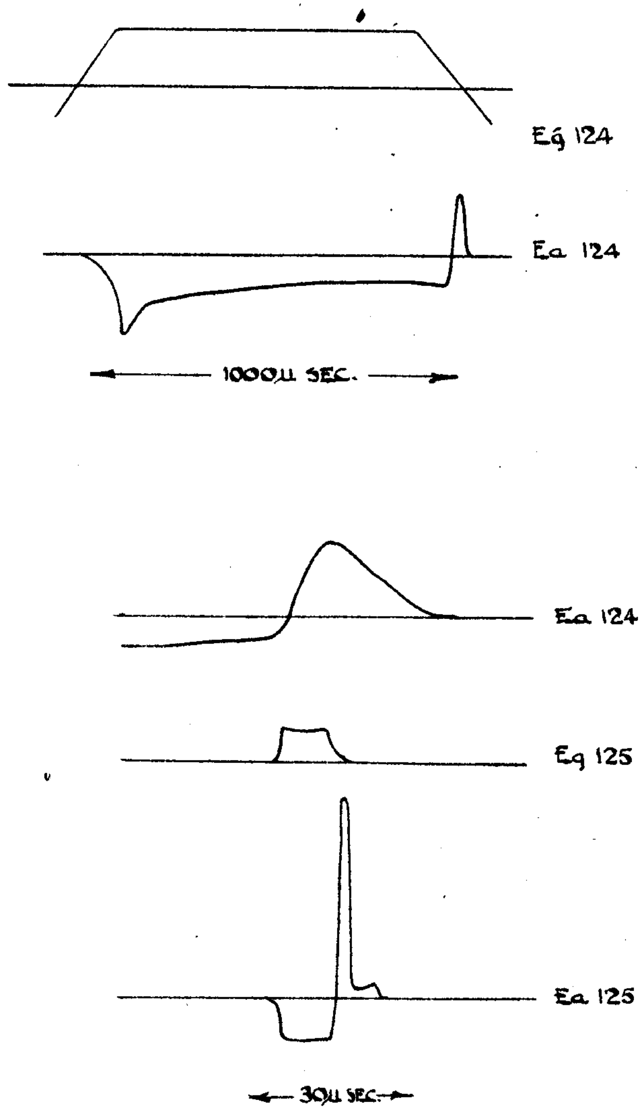
9.3.44.



SUPPLY UNIT TN 103
COAST - WATCHER.
TRANSMITTER TYPE T.112.
FIG. 10.

ISSUE. 1. 9.3.44.
ISSUE. 2. 24.5.44.

DIAG. Nº 9970. B.



German Ground Radar Equipment

Coast Watcher

Modulator Waveforms

FIG. 11.

SUE Nº 1.
ATE 6/4/44
SUE Nº 2 24-5-44

Diag. Nº 10073/8