H.M. SIGNAL SCHOOL. STAFF MINUTE SHEE

SUBJECT :— ~~The~~ German Bernhard Navigational System —

Date 16 MAR 1946

No.

S.S. No. ~~1613~~/ 409/2

Referred to—

~~Sec~~ 2 18/3

~~W2~~ ~~O1~~ 19/3

~~W1~~

~~W2~~

~~M(E)~~ 19.3.46

~~Y1~~ ~~Radar~~

Fort Southwick

~~SSO~~

~~Cdr(C)~~

~~Sec~~

Former—

409/1

9

By W2

For Aircraft. Uses Hellschreiber principle to give bearing of aircraft to within ½ to 1° from any ground station or pass messages of up to 12 words.

Freq. 30-33.5 Mc/s. Range limited.

No application for British forces.

W2 1/4

After action—

Bring up—

Disposal

A general view of the station is given at Fig. 1 with an explanatory diagram in Fig.2. The overall dimensions are 106 ft. high x 132 ft. broad and the structure is based on a strong girder framework supported at four points by electric trollies running on a single circular rail, 65 ft. in diameter, on which the whole structure rotates about its vertical axis in a clockwise direction (North, East, South and West) twice per minute.

3.2. Referring to the diagram at Fig.2, it will be seen that the cabin portion running across the face of the rotating frame carries two 5 KW transmitters, each of which transmits a separate beam from a separate aerial array. The upper, three-element array is fed from transmitter "B" and transmits the Azimuth writing beam and recognition letter, while the lower array provides the marker indication. Both transmissions are MCW, transmitter "A" being modulated at 2600, and "B" 1800 cycles per second. The AF modulation of 1800 c.p.s. is applied to transmitter "B" via the device producing the teleprinter characteristics, the carrier wave being continuous. Transmitter "A" is continuously modulated and depends for its function on the split beam pattern produced by the aerial array. A sketch of the shape of the beams (superimposed on one another) is given at Fig.3, and Fig.4 shows a graph of the field strength plotted against bearing.

K/

4091/(9)

CAPTAIN
16 MAR 1946
H.M.S. "MERCURY"

CONFIDENTIAL

A.I.2(g) ~~Report No. 1834~~ 1813/46

THE GERMAN BERNHARD AIRCRAFT NAVIGATIONAL SYSTEM.

1. INTRODUCTION.

The following report gives details of a German aircraft navigational system which employs large ground stations, of the rotating beacon type, transmitting a double beam to teleprinter receiving apparatus in the aircraft, where a printed tape is produced that shows the bearing of the aircraft from the ground station. The original plan was to provide sufficient ground stations throughout Germany and the occupied countries to enable any aircraft flying in this region to be within the range of at least one, and probably two, stations. Each station is on a different frequency in the range of 30-33.5 Mc/s. and is identified by a single recognition letter, thus, by tuning in to two stations in succession and knowing their location, a D/F fix is obtained by drawing on a map the bearings printed on the tape. The stations are referred to by the code term "Bernhard" and the aircraft apparatus as "Bernhardine" or Funkgerat 120. A light weight version (FuG 120A) is also described in the report and it is this type that is used on jet aircraft. If desired, transmission of a short message of not more than 12 letters (or figures) can be made instead of transmitting the bearin s.

1.2. The report is based on the examination of two ground stations captured intact and on an examination of the aircraft equipment, in addition to a study of documents relating to the subject. Particular attention is given to the details of the method of frequency separation between the two beams, the photo-electric generation of the teleprinter characteristics, the control of rotation of the ground station, and the operation of the aircraft printer, as these features are somewhat unusual.

2. PERFORMANCE.

The range of the system depends on the height of the aircraft and is about 200 miles at 6000 ft. The accuracy is from a ½ to 1 deg., and automatic control of the airborne receiver sensitivity is provided. Thus, although the apparatus is not entirely fool-proof, it avoides the production of a major error due to mishandling and forms a simple and reliable navigational aid which calls for little skill or attention to operate and which can be used by any number of aircraft simultaneously.

3. THE BERNHARD GROUND STATION.

A general view of the station is given at Fig. 1 with an explanatory diagram in Fig.2. The overall dimensions are 106 ft. high x 132 ft. broad and the structure is based on a strong girder framework supported at four points by electric trollies running on a single circular rail, 65 ft. in diameter, on which the whole structure rotates about its vertical axis in a clockwise direction (North, East, South and West) twice per minute.

3.2. Referring to the diagram at Fig.2, it will be seen that the cabin portion running across the face of the rotating frame carries two 5 KW transmitters, each of which transmits a separate beam from a separate aerial array. The upper, three-element array is fed from transmitter "B" and transmits the Azimuth writing beam and recognition letter, while the lower array provides the marker indication. Both transmissions are MCW, transmitter "A" being modulated at 2600, and "B" 1800 cycles per second. The AF modulation of 1800 c.p.s. is applied to transmitter "B" via the device producing the teleprinter characteristics, the carrier wave being continuous. Transmitter "A" is continuously modulated and depends for its function on the split beam pattern produced by the aerial array. A sketch of the shape of the beams (superimposed on one another) is given at Fig.3, and Fig.4 shows a graph of the field strength plotted against bearing.

3.3. The teleprinter strip is shown at Fig. 5 and it will be seen that the bearing is given by the position of the gap in the broad line above the Azimuth scale. This gap is obtained from the pattern of the indicating beam. Fig. 6 shows the message tape that may be transmitted instead of the Azimuth scale. The teleprinter method used for the production of the Azimuth scale and recognition letter is the German "Hellschrieber" system in which each symbol is built up of separately printed vertical lines spaced about the width of a line apart and all or part of each line is included, as required, to define the character. This method of printing is used for both the Azimuth scale obtained from Transmitter "B" and the bearing indication from Transmitter "A".

3.4. The normal power supply for the station is taken from the local AC mains, even if an accurate 50 c.p.s. is not maintained, as an accurately controlled 50 cycle AC can be produced on the station. There is also a complete stand-by power station operated by Diesel engine. Apart from the power supply the apparatus is contained either in the rotating cabin or the control hut directly beneath it and details of each section of the structure are given in the following paragraphs.

4. CONTROL ROOM

This is shown diagramatically in Fig. 2 and can be sub-divided into four sections -

(a) Control and test panel for power supplies
(b) Photo cell pick-up and modulating arrangements.
(c) Modulation amplifier supplying transmitters.
(d) Special message desk for production of short messages.

In addition slip-ring arrangements are included for feeding the output of the control room and the power supplies to the rotating cabin above.

4.2. The control room is a circular concrete hut standing on the ground in the centre of the track just clear of the rotating cabin. The modulation of transmitter "B" is produced by a photo electric method in which three photo electric cells are used, illuminated by three light rays passing through a large glass disc that is carried round by a steel shaft, projecting into the centre of the control cabin from the rotating frame above. This glass disc is common to all Bernhard stations and is engraved with 20 "tracks" in the form of concentric rings. The first track is for the production of the Azimuth writing scale (Fig.7). The next 18 tracks are for station recognition letters and a different one of these is allotted to each station. The twentieth track is used for checking the speed of rotation of the structure.

4.3. Figure 7 illustrates how the modulation is effected, the beam of light to the photo electric cell scans the track and is interrupted by the lines engraved thereon. The output of the cell therefore produces the characteristics required. A similar effect is obtained mechanically by the use of discs carrying cams to produce the special messages that may replace the azimuth scale. Each symbol has a separate disc and one revolution of the disc produces the letter. One such letter disc is illustrated in Fig.8. A switchboard is provided in the control room in which plugs may be pushed into sockets that are connected to the contacts operated by the cams on the letter disc (Figure 8). Thus in both cases the actual printing is produced by on-off operation. In one case of a P.E.cell of which the light source is interrupted, in the other by the mechanical opening and closing of a contact by cams. It should be noted that it is the "off" position (contacts open) which is the operating period as the output of either system is taken to an amplifying circuit which includes a valve normally biassed beyond cut-off by the application of a voltage from the P.E. cell, or via the contacts of the letter disc. This amplifier carries the A.F. modulation of 1800 c.p.s. to transmitter "B". Hence the out going transmission is A.F. modulated in accordance with the spacing required to operate the printer in the aircraft.

4.4. The rotation frequency is maintained by comparison of the 50 cycle A.C. supply mains with an output obtained from track No. 20 on the glass disc. This track is engraved with 1500 evenly spaced lines so that at the correct speed of rotation a frequency of 50 c.p.s. is produced, which is normally compared to the mains frequency by means of two loudspeakers but may also be applied to a frequency meter or an oscillograph.

5. TRANSMITTERS

Two transmitters type KVC 15L/27 are provided (a) for the transmission of the direction indication and (b) for the azimuth writing (or special message) and recognition letter. One is shown in Fig. 9. In view of the fact that both transmitters are received on one receiver, and then separated by their A.F. frequency characteristics, the frequency control of the transmitters is treated with great care and comes from a common unit which provides for the frequency separation of 10 Kc/s. The dual installation is known as Type BRA 30/20.

5.1. The special arrangement by means of which the transmitters are maintained 10 Kc/s apart consists of a separate rack, set up between the transmitters, which carries the initial drive of each transmitter. The first stage of transmitter "B" is crystal controlled at one sixth of the output frequency in the conventional manner, but the transmitter "A" is excited from a master oscillator circuit that is connected to the same crystal by a frequency separating arrangement. In effect, therefore, both transmitters are crystal controlled from the same crystal. The operation of the frequency separating device is illustrated in the block diagram (Fig.10) from which it will be seen that a buffer stage is connected to each of the amplifiers and feeds into a hepto-triode mixer where the beat-frequency difference is extracted and fed into the frequency separation unit. Into this unit is also fed the output of a tuning fork oscillator working at the frequency of separation, i.e. 10/6 Kc/s. The beat frequency, representing the difference of the two exciting stages, is amplified by a pentode valve and applied in the form of an anode voltage (varying from almost zero to a positive value) to condenser C.1. (Fig.11). The effect of this is to build up a charge on C.3. as follows; the top condenser plate on C.1 becomes positively charged and the bottom plate charges up negatively due to a stream of electrons passing via R1 and parallel thereto via R2 and the diode valve V1. The cathode is then at a positive potential and C.2 charges up to this value. When the top plate of C.1 is not charged, valve V1 is blocked, C.1 discharges through R1 and C.2 commences to discharge through R2, but R2 is too large for the condenser to discharge appreciably before the next cycle, when C.2 is charged up again. Hence a pulsating D.C. voltage is produced across C.2 which is smoothed and applied to condenser C.3.

A similar circuit (not shown) produces a voltage from the tuning fork supply in the same manner, which appears at C.4 and which is therefore at a steady D.C. potential. The algebraic difference of the charges on the two condensers is now obtained by applying first one and then the other condenser to the control grid of a pentode valve, via C.5 by means of a vibrator. The difference in voltage obtained across C.3 and C.4 is a direct measure of the out of balance frequency. Thus if the frequency difference between the two exciting stages is 10/6 Kc/s. no voltage is applied to the grid of the pentode, as alternative contacts made by the vibrator apply equal and opposite charges, and no mean voltage results. If, however, the frequency of the master oscillator stage is incorrect a voltage as applied to the pentode V2 which is amplified through V3 and used to control the grid of the Heptode part of the ECH4 master oscillator valve V4. The heptode is arranged as a reactance across the L.C. circuit of the master oscillator which uses the triode portion of the same ECH4 and this, according to the requirements of the moment, the reactance is varied to produce the required balance of frequency. The specification requires an accuracy of 1% and in practice this method is found to work successfully. The two transmitters are identical from the control stage onwards and five stages and the H.T. supplies are included. Fig.11 shows one of the transmitters.

5.2. The HF energy from the separate exciting stage is applied via HF cable to a transmitting pentode PE/06/40 in Section "F" (Fig.9) also tuned to the same frequency as the exciting stage. From here the output goes to the next HF stage (E) where two similar pentodes act as frequency doublers for application to the next stage (C) two PB2/200 Pentodes in push-pull, where frequency tripling occurs to give the output frequency. HF stage (H) has twp PB3/800 pentodes in push-pull and it is in this stage that the audio-frequency modulation is applied via a transformer operating on the anode and screened grids of the PB3/800 pentodes. The transmitter output Section "J" has two air-cooled pentodes type PAK12/30 in push-pull and delivers 4 KW. unmodulated carrier wave or, with a modulated signal, has a 15 Kv. overload rating. The valves in this section are air cooled by an electric compressor and ventilator (K) automatic regulation of the pressure and temperature being provided.

5.3. The rectifiers for the various stages of the transmitter are included in the assembly (Fig.9) and are operated on a 380 volt supply. Referring to Fig.11, Section "A" contains a 2000 volt and 1500 volt rectifier, Section "B" a 150 volt and 500-1000 volt rectifier while Section "H" has a 10 Kv. rectifier for the output valves that is provided with a quick make and break to provide instantaneous disconnection in case of an overload.

6. AERIAL ARRAYS

The upper aerial system consists of three full-wave vertical dipoles spaced ½ wave length apart and mounted ¼ wave length from a reflector net. All three are centre fed from a 2 wire feeder which runs across the centre of the system and connects to a concentric tube H.F. supply and tuned Lecher line.

6.2. The lower aerial array is more complex, and consists of eight full wave dipoles centre fed in two groups of four. Only the two inner dipoles in each group are provided with reflectors and the spacing of the elements is arranged to produce the field pattern shown in Fig.3.

7. ROTATION.

The rotation of the installation is effected by four motors, each of which drives two wheels resting on a single circular rail. Three of the motors are 220 v. D.C. type which provide the main motive power, while the fourth is a 380 v. 3 phase synchronous motor which is responsible for maintaining the speed of rotation at the required figure. The driving mechanism is started and controlled from the centre of the transmitting room. The synchronous motor is fed at precisely 50 cycles/sec; if the supply is not sufficiently accurate from the local mains, a special converter is provided which, operating on the 220 v. supply, provides the necessary 3-phase 50 cycle output and incorporates an elaborate stabilising arrangement. In addition, the frequency of this supply is measured in the control station by a frequency meter which registers simultaneously the frequency generated by the photo-electric recorder in the control room. An auxiliary drive consisting of four small reversible D.C. motors, considerably geared down to move the array very slowly, is available for testing and setting up the apparatus. These motors are uncoupled when the station is operating normally.

8. POWER SUPPLY

The station is intended for normal operation from outside A.C. mains providing 380 volts at an accurately stabilised 50 cycles/sec., but is also able to operate in areas where the mains supply is unreliable. Where this is so, the feed to the 220 v. D.C. motors and the 50 cycle supply to the synchronous motor are both controlled from a spring contact governor, operating on the shaft of the 220 v. D.C. 380 v. A.C. convertor, which serves to increase or decrease the resistance of the power line to the D.C. motors, or (for major variations) to operate a rheostat on the 220 v. D.C. supply. This rheostat is normally operated by a motor driven from the supply and operates to nullify any fluctuations. An alternative standby generating set is provided which consists of a 200 h.p. diesel engine which drives a 3-phase 380 v. generator with a 160 KVA output. This power supply is accurately controlled at 50 cycles. The switchboard for these supplies is in the control cabin and all loads are fed through overload switches.

9. CONTROL RECEIVING STATION AND TEST PANEL

A monitoring station is provided in which a simple receiver is mounted about 1800 ms. (½ mile) from the transmitter on a known bearing. The A.F. output from this receiver is fed by means of a 5 pair telephone cable to the control room (and the necessary H.T. and L.T. supply to the receiver is also carried by this cable). The receiver consists of a diode circuit with a single-stage of L.F. amplification and serves to provide monitoring of the signals transmitted. The output may be connected alternatively to FuG 120 instruments, as used in the aircraft, or to a current recorder for showing the radiation pattern of the beams at the receiving station. Within the control room, therefore, during normal operation, the FuG 120 apparatus will print a succession of bearings every 30 seconds, showing the direction to the monitoring station, and the recognition letter of the transmitter, which serves to establish that the station is functioning correctly. Alternatively, the current recorder may be switched in, instead of the FuG 120 and the beam pattern (Fig.3) drawn as a further check on the output of the station. All supplies and modulation frequencies can be tested on an oscillograph, mounted in the transmitting station, which is permanently wired to a multiple selector switch connected to the appropriate circuits, it is here that the speed of rotation and mains supply frequency may be checked alternatively to the loud-speaker or frequency meter comparisons.

10. FUG 120 (BERNHARDINE)

There are two models of airborne equipment used for the reception and printing of the Bernhard beams, FuG 120 (the original type) and a later model, FuG 120a, in which a different type of printing unit is used and in which some extra units are incorporated (Fig.12). The installation consists of detachable units plugging in to mounting frames to which the fixed inter-unit wiring is permanently attached. In both FuG 120 and 120a, the receiver used for the reception of the Bernhard signals is employed alternatively to its normal function of receiving the main beacon for Lorenz blind approach apparatus. The block diagram (Fig.12) shows the layout of the apparatus and of the connection of this receiver to the blind approach equipment or the FuG 120, and a list of the units comprising FuG 120 and FuG 120a appears at Appendix A. The two instruments are illustrated together in Fig.13 on a test panel, which is designed to test either installation, and again (with covers removed) in Fig.14. On the aircraft the units are not arranged together in this compact manner; the printer unit is the only one available to the operator and is installed in the cockpit. It also carries the controls required by the remainder of the units, which are placed in any convenient location in the fuselage.

10.2. Referring to Fig.12, to briefly outline the operation of the system, the signals are received on the EBb.3 receiver where they are amplified and detected and passed to the junction box ZLk8, from whence they pass to the service switch UG 120. If this switch is set to "FuG 120", they pass to the connection box VD 120 for connection to the amplifier SV 120, in which they are first amplified by one valve (on which the volume control operates) before being passed to the filter unit SG 120, where the two audio frequency notes of 2600 and 1800 are discriminator and returned separately to the SV 120 for separate amplification. Two separate 2-valve LF amplifiers are provided for this purpose from which, in each case a signal is obtained that is applied to a double diode valve operating the printer mechanisms in the printer unit HS 120, or PSch 120a, one for the azimuth scale (or special message) and the other for the bearing indication.

10.3. The H.T. supply for all the FuG 120 units comes from the motor generator U 120, but the receiver EBl.3 normally operates on the H.T. supply for the blind-approach system from the motor-generator U8, which forms part of the blind approach system FUBl.2.

11. R.F. RECEIVER EBL.3.-H or F.

The receiver appears in two forms, with manual tuning (EBl3.H) or with remote control of the 4 gang condenser in 34 positions over the frequency range of 30.0 to 33.3 Mc/s. The receiver uses seven RV12P2000 miniature GP valves (nominally R.F. pentodes) as R.F., Osc., mixer, 3 x IF, and det. The total band width at 6 db down is 45 Kc/s. which is only adequate to receive both beams simultaneously if the set has been carefully tuned to the correct frequency, due to the fact that the over-all band width of the two beams is about 15 Kc/s. (10 Kc/s. separation of carrier wave plus 2.6 and 1.8 AF and 4 Kc/s. keying spectrum).

11.2. The receiver is fed from a one metre rod aerial via a matching unit and it's sensitivity is about 1 mw for 6 mv signal voltage.

12. SELECTOR SWITCH UG 120

The output from the EBl.3 goes via the coupling connection to the changeover switch UG 120, which is relay operated from a 2-way lever in the cockpit and serves to apply the output of the EBl.3 to either the SV 120 teleprinter or EBl.2 blind approach amplifier, and to connect the EBl.3 to the automatic gain control of the set in operation.

13. TELEPRINTER AMPLIFIER SV 120

The Amplifier SV 120 is shown in figures 13, 14 and 19 and the wiring diagram is shown in Fig. 17. It consists of 3 separate amplifiers in one case, comprising

(a) One valve (V1) for general amplification and manual volume control and the combined AF signal is received prior to the separation in the filter unit of the two audio frequencies. The volume control for this valve is situated in the printer unit in the cockpit and serves to establish the general overall amplification as required by the distance of the aircraft from the Bernhard station.

(b) The amplifier for the indicator signal consisting of V2 and V3 for IF amplification, followed by three valves (V4, 5 and 6) for applying the signal to the teleprinter unit and for AVC.

(c) The amplifier for the azimuth scale, similar to (b) above (valves V7 - V12).

13.2. The indicator signal from the filter unit SG 120 applied to (b) above, is an AF of 1800 c/s, varying in amplitude in step with the incoming field strength (Fig.7). It is amplified in V2 and V3 and applied to the double output transformer U4 for application to the rectifiers V4 and V6 for separate treatement. The recording mechanism transcribes the signal in the form of up strokes, the length of which are directly related to the amplitude of the signal. This is effected by the condenser (C6 Fig.17) having been charged at the commencement of each stroke by a cam contact operated in the printer unit. C6 then discharges slowly through the choke, D2, and a saw-tooth voltage is obtained. This is applied to the grid of V5, together with the indicator signal from V4 and a large bias voltage. The bias is so adjusted in relation to the AGC that the saw-tooth voltage is insufficient to causse anode current in V5 in the absence of an indicator signal. When, on receipt of the signal, V4 produces a DC voltage, that overcomes the bias, the saw-tooth voltage causes anode current to flow, the duration of which depends on the

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magnitude of the DC voltage and full length lines are drawn if the two lobes of the indicator beam pass the receiver at sufficient field strength to produce an effective signal. The AGC (which operates on the R.F. receiver) is held at the requisite level to produce this effect between indicator beam signals by the signal received from the side lobes and back beam of transmitter "A" (Fig.3) which, although weaker than the main beam, nevertheless serve to maintain the AGC at such a level that the printer commences to write when the indicator signal is received within the limits of range. A press stud is also provided on the printer unit which eliminates the operation of the AGC valve by means of a relay R2 and puts the receiver on full gain to permit the reception of signals at maximum range.

13.3. The azimuth scale signal is led to valve V7 (Section (c) above) from the SG 120 and is amplified in the LF amplifiers V7 and V8, from whence the output goes to the multiple output transformer U7, which supplies three seperate outputs to valves 9, 11 and 13.

13.4. Valve No. 9 controls the printer valve (No.10), the anode current of which passes through the solenoid operating the printer magnet (Fig.15). The bias voltage is taken from W.39/W.40 and the rectified signal voltage is impressed on C.26/W.25. The time constant of C.26 must be small (1 millisec.) to enable the printer to follow the signal pulses of 2.3 millisecs. minimum duration which represents a single image square (Fig.7).

13.5. The output from U7 to valve No.11 is for operating the motor start-stop relay. RO.11 applies a positive voltage for unblocking the start-stop valve No.12 when a certain voltage value has been reached by the azimuth scale signal. The negative bias for RO.12 is at W.44/W.45, while the rectified voltage appears across C.15/W.41. The time constant here is such that the start-stop relay will not operate during the short intervals between two DF signals and the delay obtained is 1.5 seconds.

13.6. RO.13 provides automatic gain control for the general azimuth scale amplifying valve RO.7, so that the voltage handled by valves 9, 11 and 13 is maintained at a reasonably constant value. Here the bias voltage is taken from W.46/47 and the time constant is very large (about 25 seconds) in order that during the period between successive receptions of the beam signal there will be no material variations in amplifier gain. C.18 is therefore a large condenser of 20 MFD.

14. THE PRINTER UNITS HS 120 and P SCH 120a

These are illustrated in Fis. 13 and 14 and 20, 21, and 22. They differ considerably in detail but very little in principle. The operation of the printer is illustrated in Fig.16. The method used is for the paper to be drawn slowly at short intervals past the rapidly rotating printing drums and is pressed against the printing drums by the printing magnet according to the signals received.

14.2. The actual operation of the printer unit HS120 is an elaborate one and includes a synchronising device for ensuring the correct spacing of the lines and two printing drums, an upper and a lower one for printing the indicator mark, and the azimuth scale, respectively. The lower drum carries three raised helical lines, and writes three lines per degree of the azimuth scale (Fig.7). The upper printing drum writes 6 lines per degree and carries 6 helical projections accordingly. Synchronising takes place on the azimuth scale and is done by a synchronising magnet coupled in series with the writing magnet (Fig.16). Synchronisation is effected as follows. The printing drum is not fastened to its spindle but is connected thereto by a sliding coupling. The driving motor is centrifugally governed to operate about 1½% faster than necessary Thus at every degree stroke a pause must be observed equivalent to about 4% of the time taken for 1° (One twelfth of a second), which is equal to about 1½ "squares" on the diagram Fig. 7. This pause is obtained by a ratchet which engages with what is termed the "synchronising cam" on the printing drum at the end of each revolution, and is released by the operation of the synchronising magnet. The period of time allotted to the next degree commences with the new stroke of the azimuth scale and as the synchronising magnet is in series with the writing magnet, the pulse producing this stroke operates the synchronising magnet, frees the drum from the ratchet and allows rotation to continue, thus ensuring synchronisation of the rotation of the drum with the signals it records. Without this synchronising device the effect is for the scale to "slide down the paper" if the drive is too fast (as is normally the case). This is due to the fact that the top of each line is printed after the top of the printing drum has passed the correct position and the line therefore commences an increasing distance from its true position. This form of synchronisation is not necessary with the indicator printing drum because here a saw-tooth voltage which actually operates the printing magnet is produced by the cam contact system driven in the printer unit from the same motor as the printing drum and is therefore already synchronised.

15.3. The PSch.120a operates on the same principle as the HS120, except that instead of the paper running past a window between 2 drums, it feeds out of the PSch 120a as on a tape machine and is detached to be read. On the HS120 the paper is illuminated from behind and a dimmer switch is provided to adjust the intensity of the light required.

15.4. The indicator printing drum on PSch 120a has only four lines compared with the six on that of the HS120, and the saw-tooth mechanism accordingly carries only 4 cams instead of 6. In addition, the on-off mechanism of the 120a printer is mechanically operated and this operation can be effected by operating the press stud (for maximum gain) in order that the motor may be made to run when required to reel out paper to read the last of a series of markings.

16. RANGE

The range of the apparatus depends on the height of the aircraft and the following table indicates the ranges obtained at various heights:-

Height of a/c above the ground in ft.	Range in miles
300	90
1500	110
3000	130
6500	185
16000	250
25000	310

G.W. Calvert
S/Ldr.
for Wing Commander.

A.I.2(.)
D. of I.
20.2.46.

DISTRIBUTION/

DISTRIBUTION:-

AIR MINISTRY

D.G. of S.	1
D. of Tels.	1
D.D.I.2.	1
D.D.Sc.	1
D.S.M.	1
A.D.I.Sc.	2
A.I.1(d)	1
U.S. Air/A.M. Branch	11
D.A.F.L.	1

M.A.P.

D.C.D.	1
R.A.E. For Int.Sect.	1
R.A.E. Radio Dept.	3
S.I.G.E.S.O.	3
P.S.6. Sec.	1

COMMANDS AND UNITS

Bomber Command	2
Fighter Command	2
Coastal Command	1
Transport Command	3
Tech.Training Command	2
A.F.D.U.	1
26 Group	1
C.D.S. West Drayton	1
A.D.(C.C.)	1
C.B.E.	1
C.F.E.	1
R.W.E.	1

ADMIRALTY

D.S.D.	1
A.S.E.	1
H.M.S. Sigs.Sch.	2

WAR OFFICE

M.I.8.	1

OVERSEAS

B.A.F.O.	6
F.I.A.T. (Air Branch)	4
A.C. of S.A2	
U.S.A.F.E.Main	1
H.Q.12th T.A. Cmd.	
A.P.O. 696 U.S.	1

DOMINIONS

H.Q. R.A.A.F.	1
" R.C.A.F.	6
" R.N.Z.A.F.	1
" R.C.N.	1
N.R.C. Ottawa	1
H.Q. S.A.A.F.	1

ADDITIONAL

B.I.C.S.	3
C.R.B.	15
Netherlands Air Force	1
Dutch Mission, The Hague	1
Air Attache, Paris	1
Air Attache, Belgium	1

COMPONENTS OF FuG 120 and FuG 120a

ITEM	GERMAN NAME	TYPE NO.	DESCRIPTION	REF. NO.	INSTALLATION (FuG 120 or 120a)
	Removable Components				
1	SCHREIB-VERSTARKER	SV 120	Teleprint, Amplifier	28985	Both
2	UMFORMER	U 120	Motor-generator	28988	"
3	SIEBGERAT	SG 120	Filter Unit	28989	"
4	HELLSCHREIBER	HS 120	Printer Unit	28990	120
5	PFEILSCHREIBER	PSch 120a	Printer Unit	28997	120a
	Fixed Components				
6	UMFORMER FUSSPLATTE	UF 120	Mounting for U 120	28980	Both
7	RAHMEN fur SV 120	RSV 120	" " SV 120	28981	"
8	STEBGERATE FUSSPLATTE	SGF 120	" " SG 120	28982	"
9	UMSCHALTGERAT 120	UM 120	Change-over-switch	28983	"
10	VERTEILERDOSE 120	VD 120	Junction-box for SV 120	28984	"
11	SPRECHKNOPF	SpKf 1a	Thumb switch	28986	"
12	ZWISCHENLEITUNGSKUPPLUNG	Zlk VIII S3	Connection Box	28987	"
13	RAHMEN fur P Sch 120a	RPSch 120a	Mounting for PSch 120a	28998	120a
14	VERTEILERKASTEN	VK 120a	Junction box 120a	29310	120a
15	REGLERKASTEN	RgK 120a	Control box	29311	120a

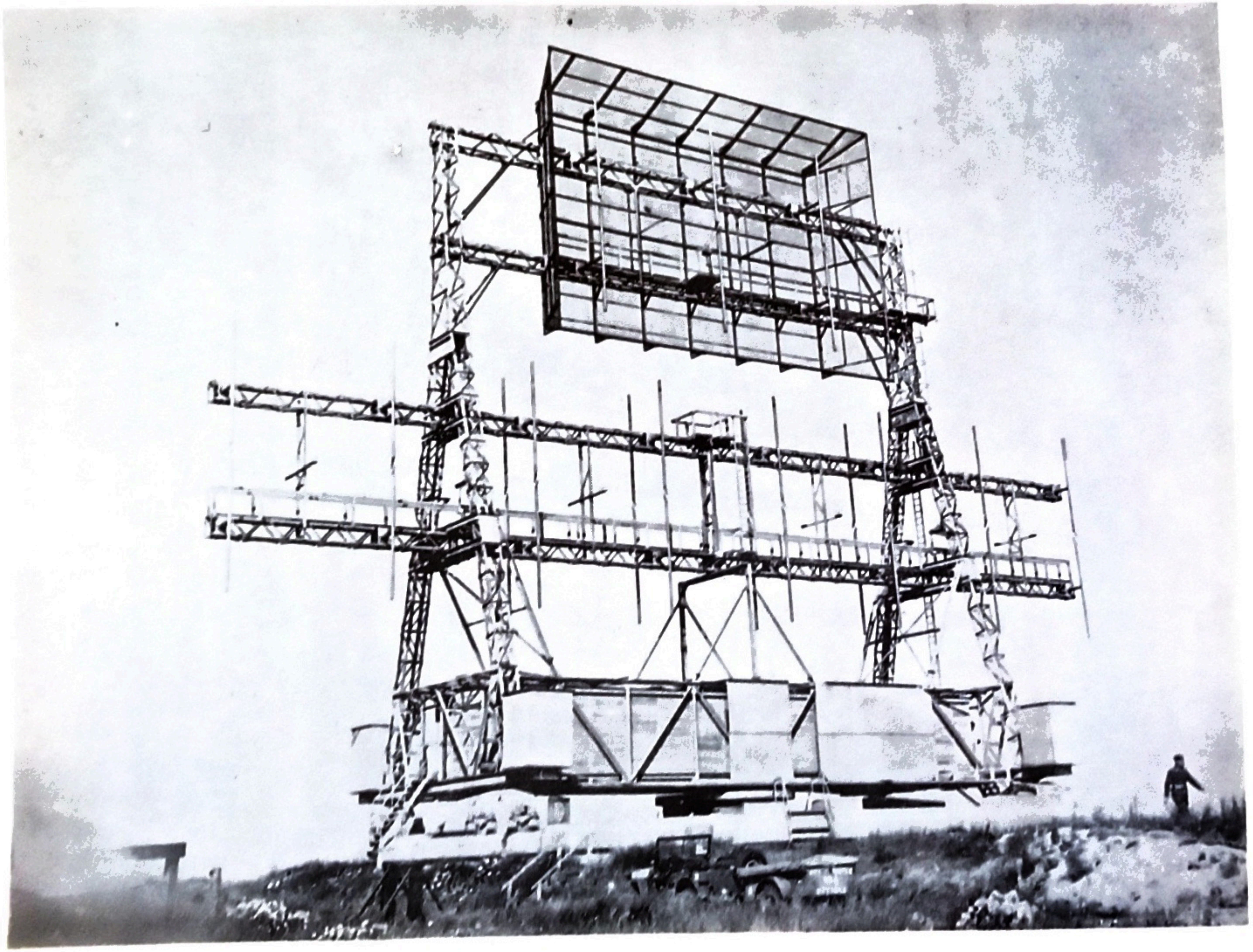

FIG 1. BERNHARD STATION "W" AT HUNDBORG.

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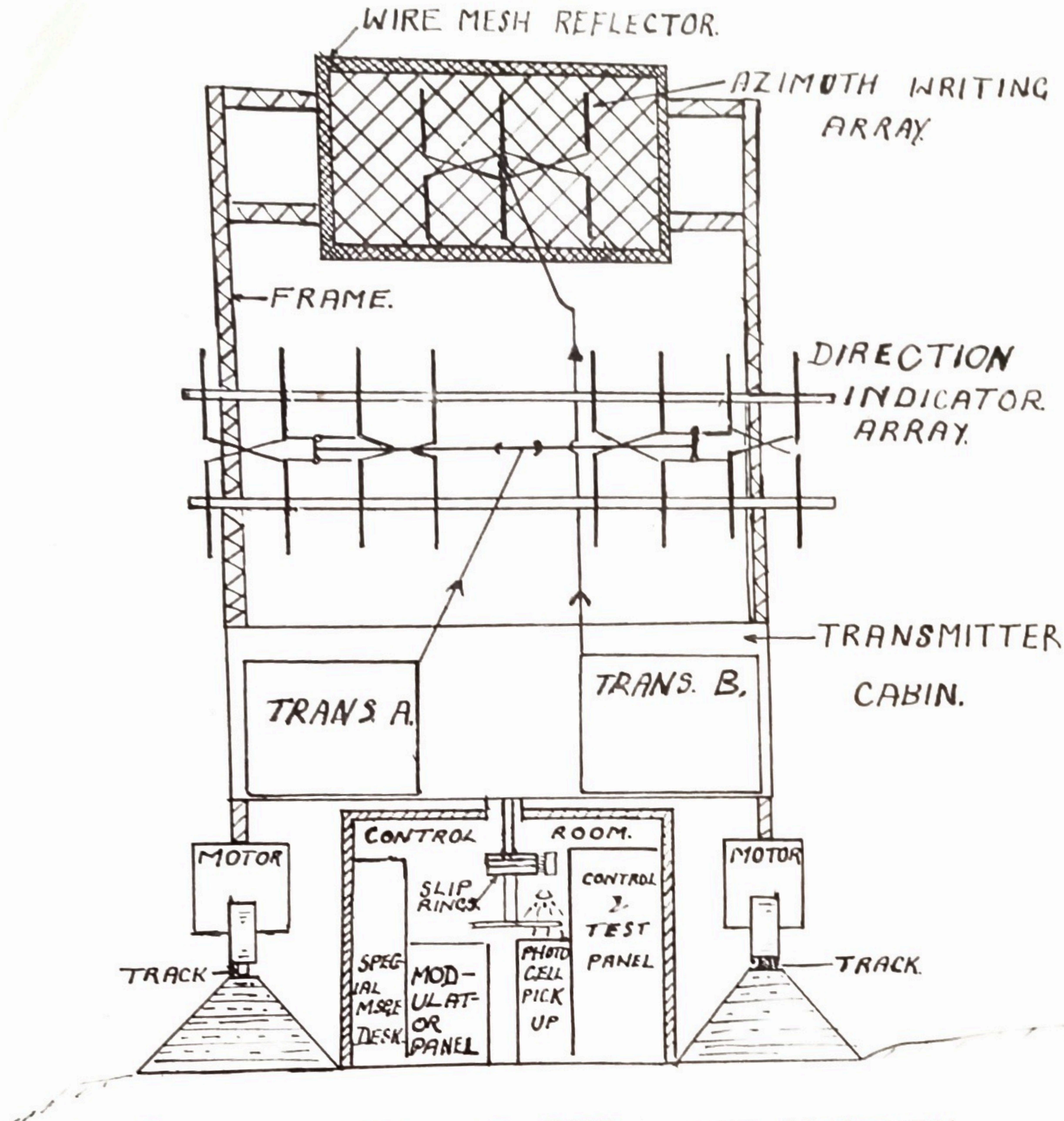

FIG. 2. DIAGRAM OF BERNHARD STATION.

FIG 3. SKETCH OF RADIATION PATTERNS.

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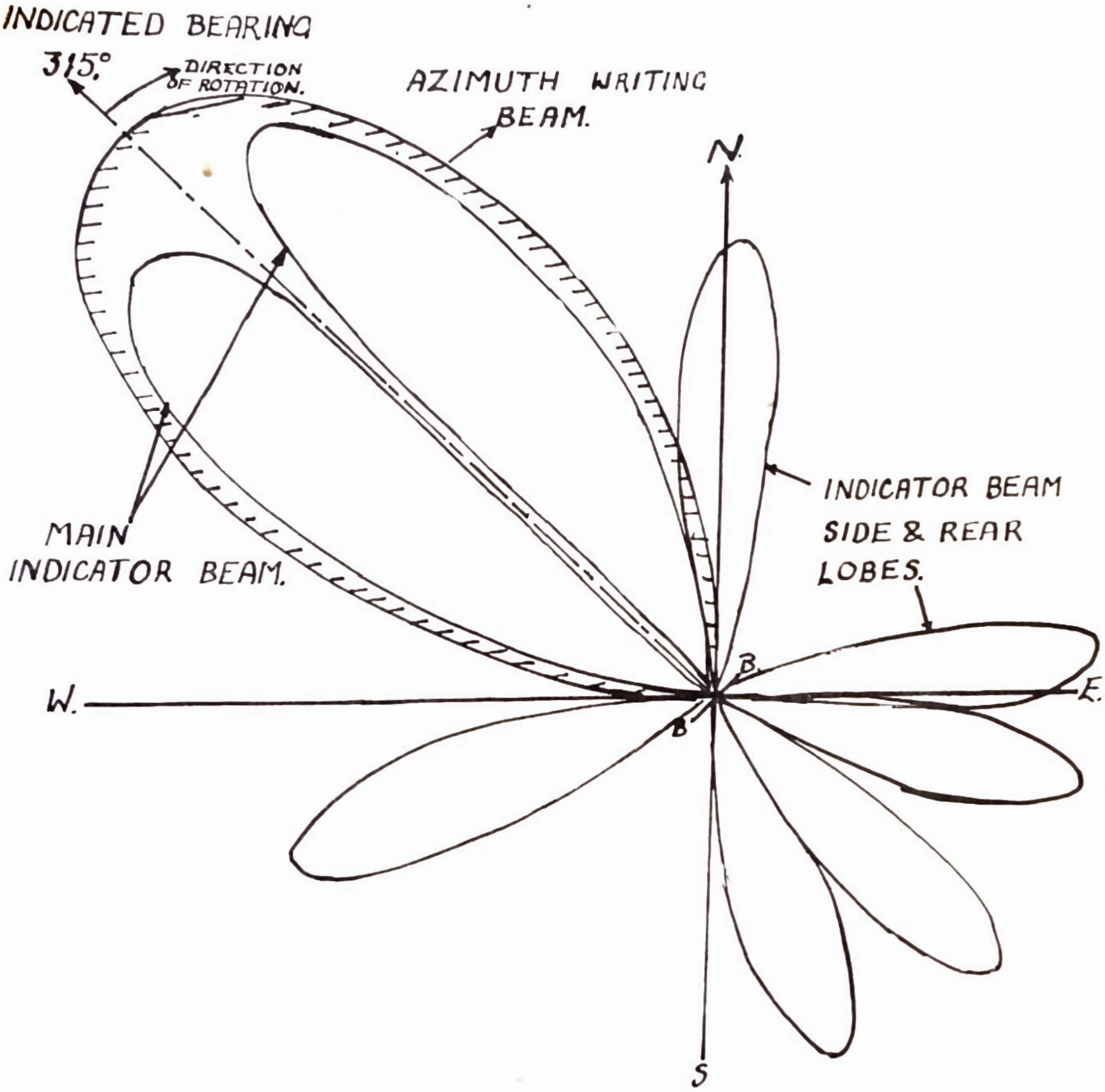

FIG 3. SKETCH OF RADIATION PATTERNS.

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BEAMS RADIATED FROM "BERNHARD" STATION.

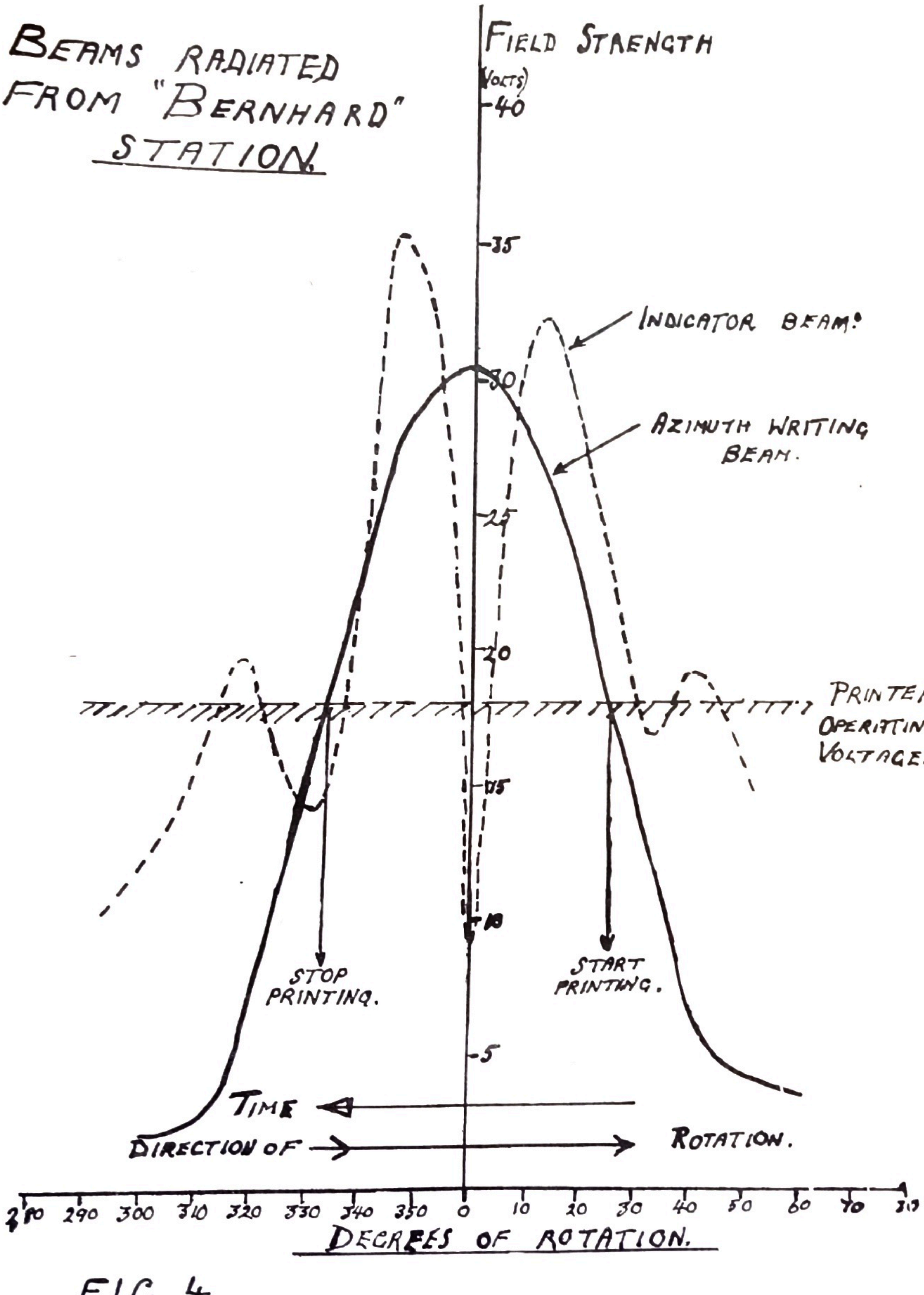

FIG. 4.

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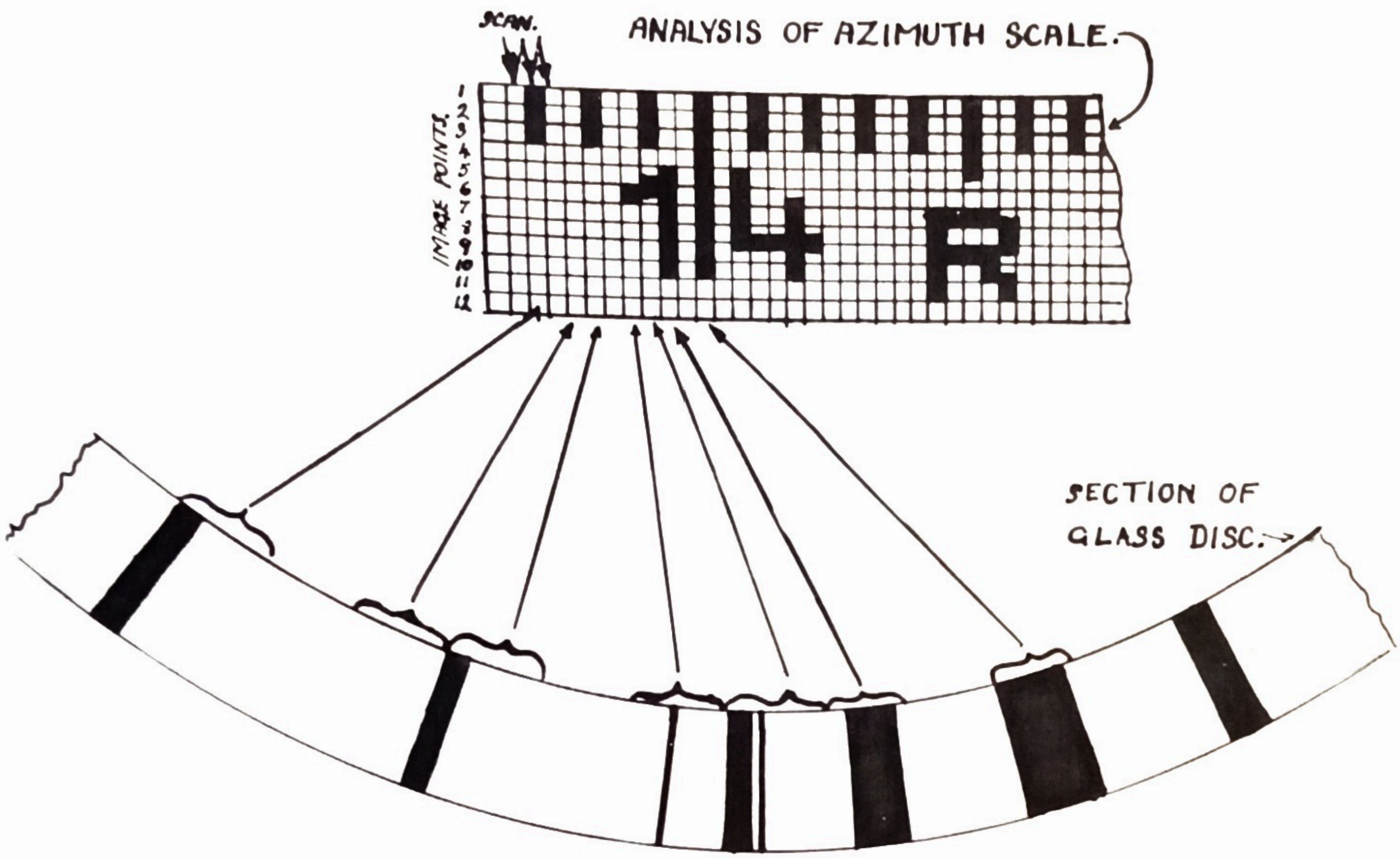

FIG. 7. SECTION OF GLASS DISC SHOWING HOW THE ENGRAVING IS DERIVED.

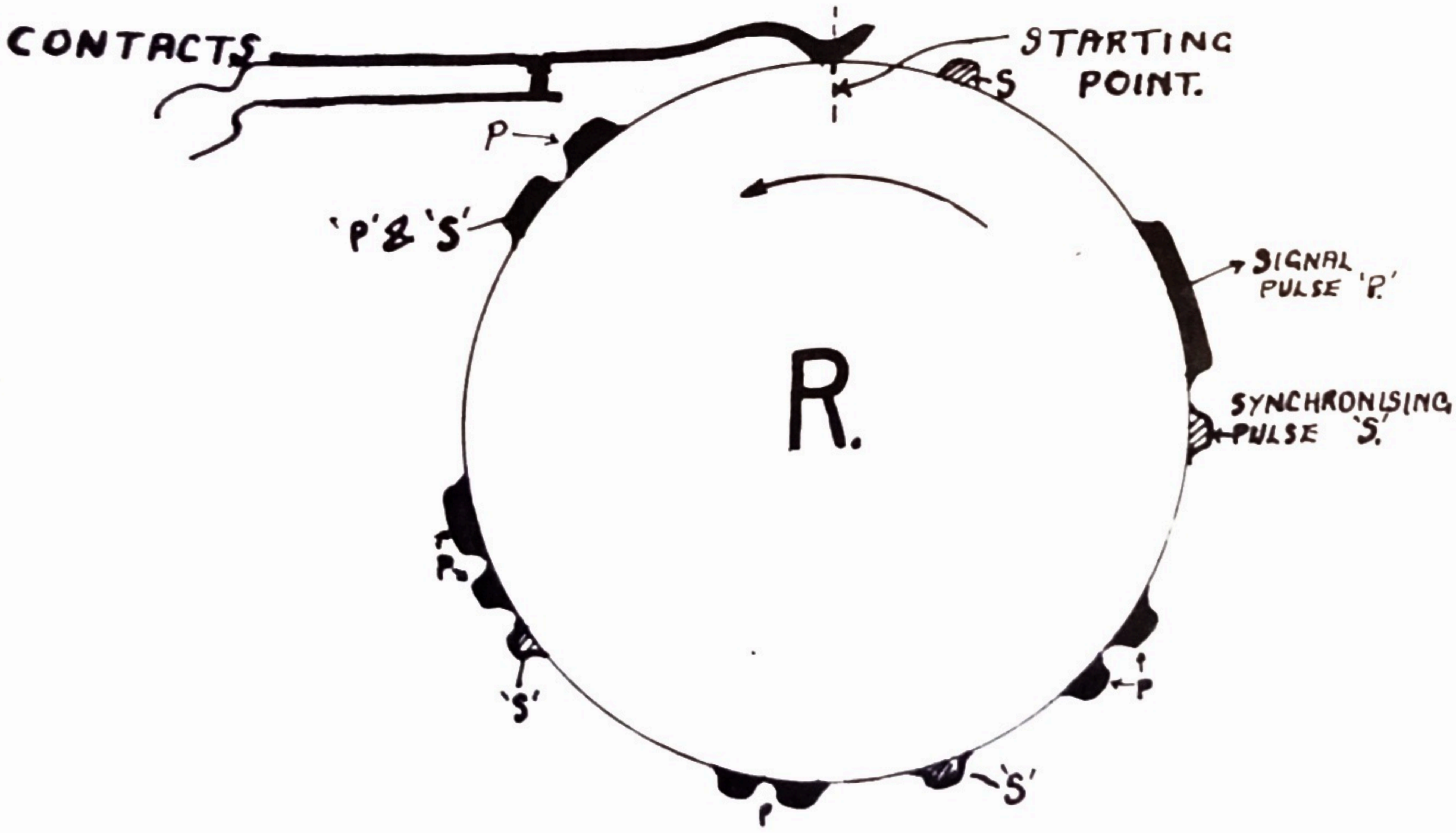

FIG 8. LETTER DISC FOR LETTER "R."

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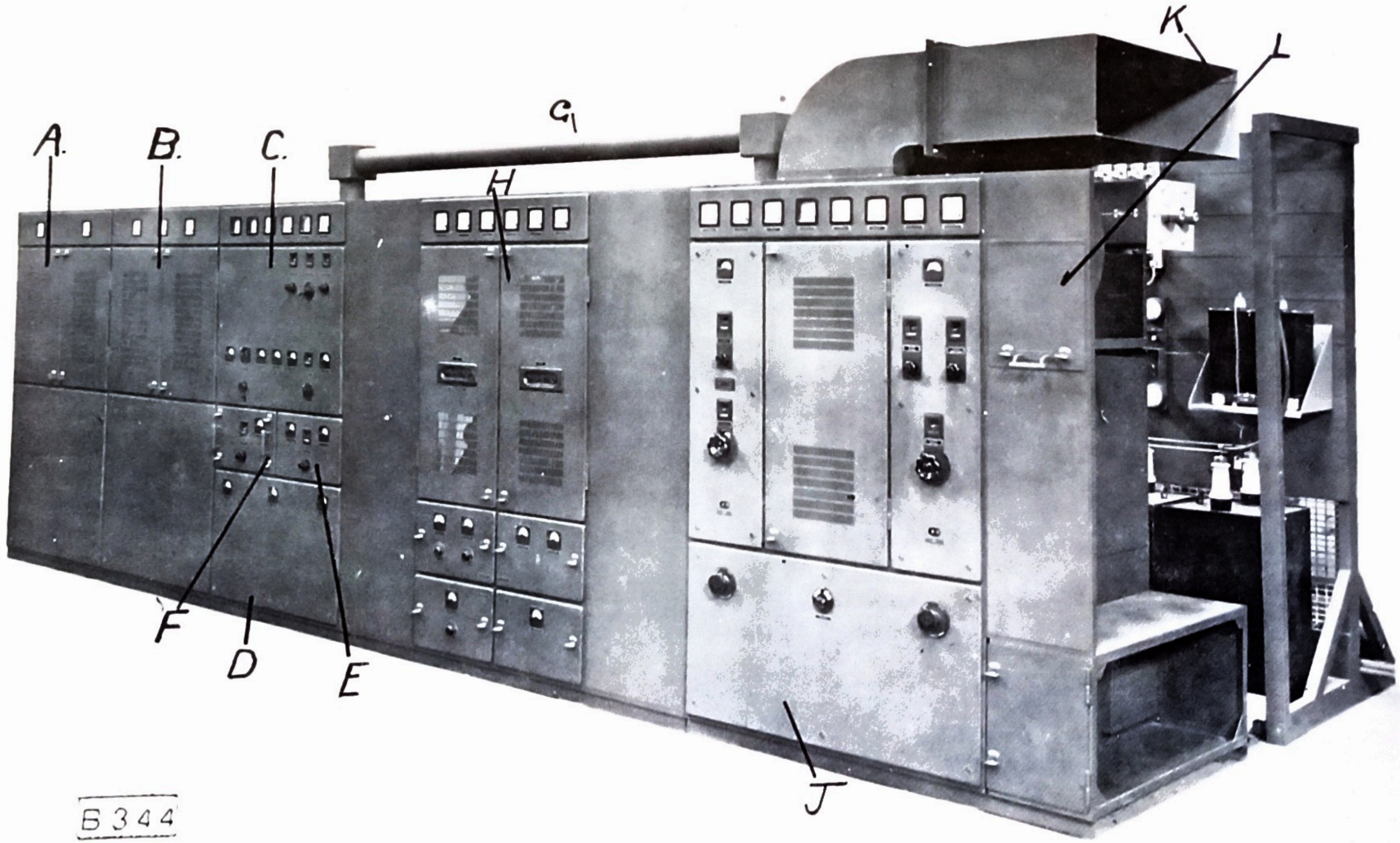

B 344

FIG 9. 5 KW. TRANSMITTER.

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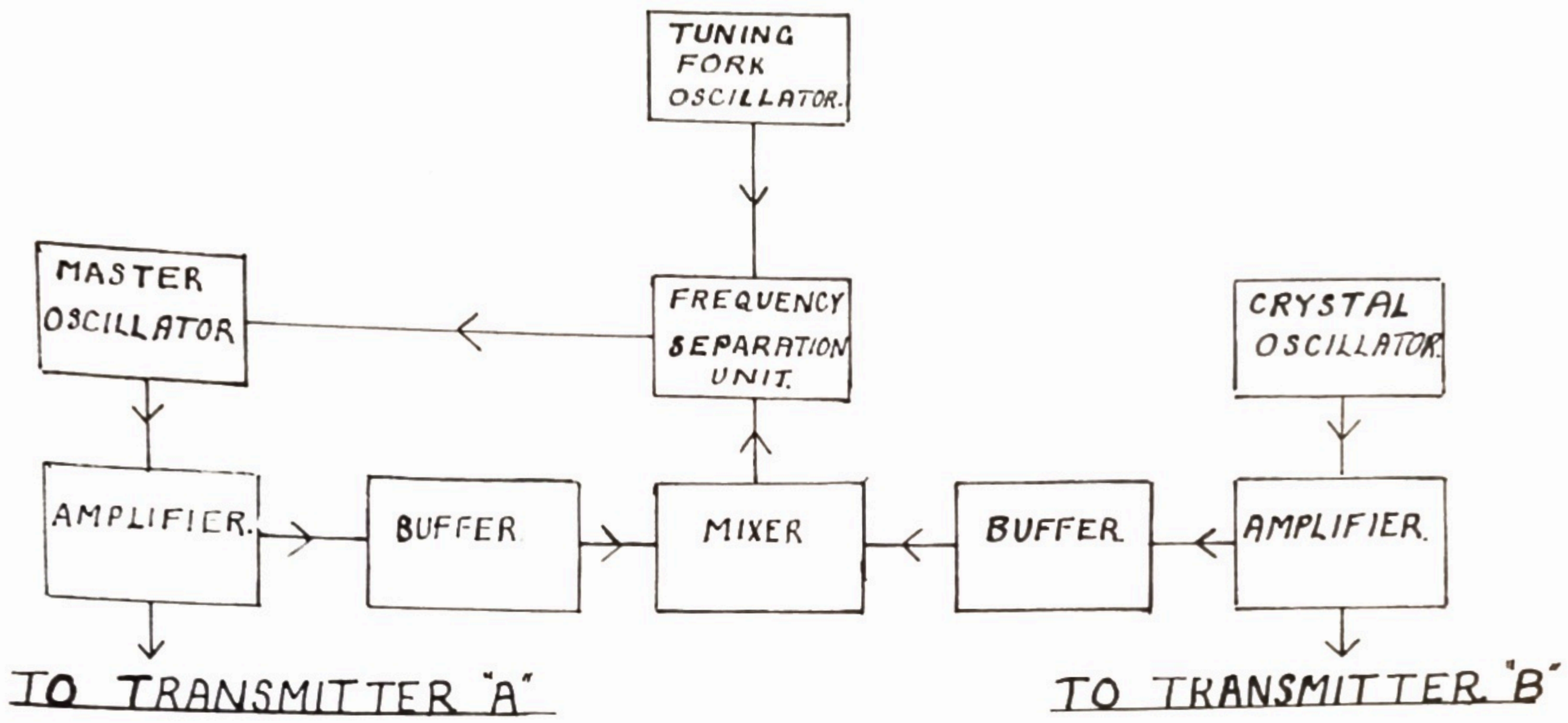

FIG.10.

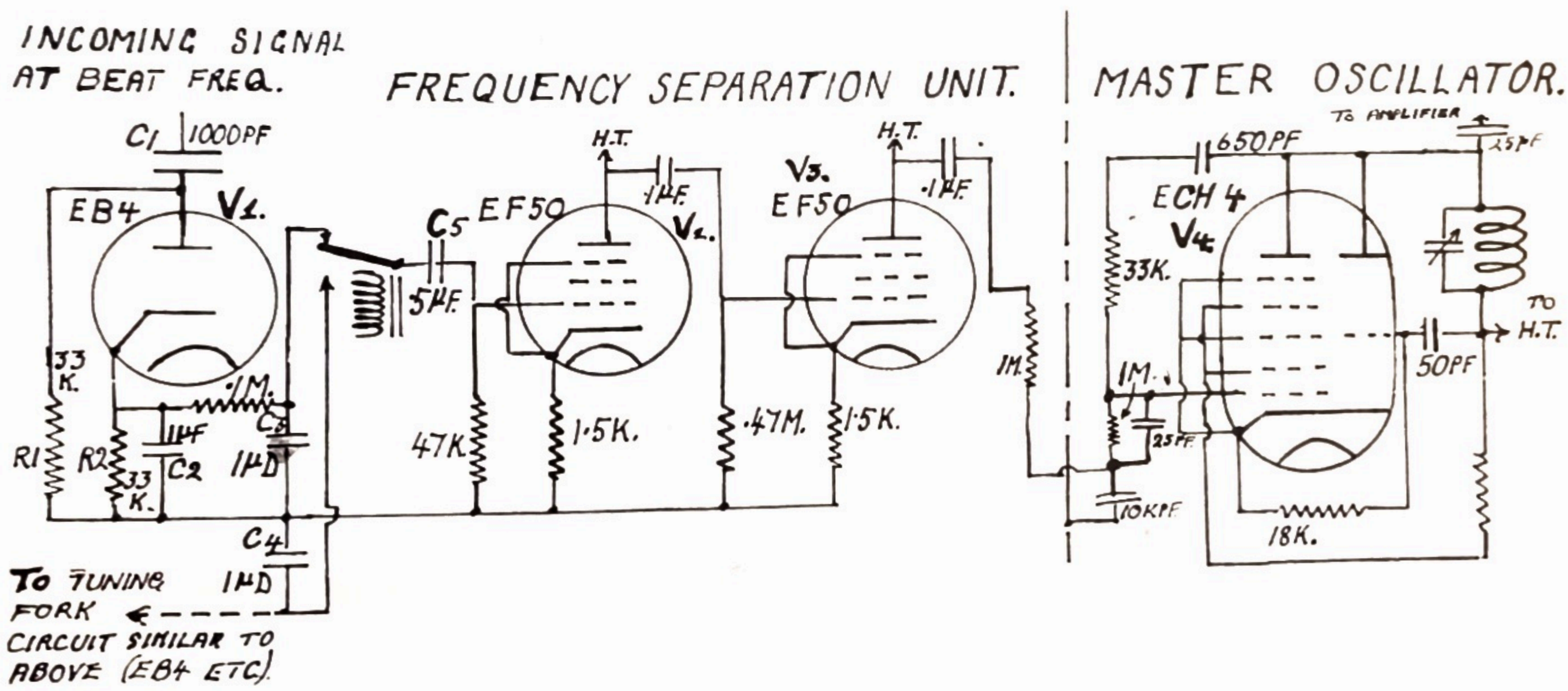

FIG II. FREQUENCY CONTROL CIRCUIT.

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— ITEMS INCLUDED IN FUG 120 AND 120a
--- ALTERNATIVE 120 OR 120A ITEMS

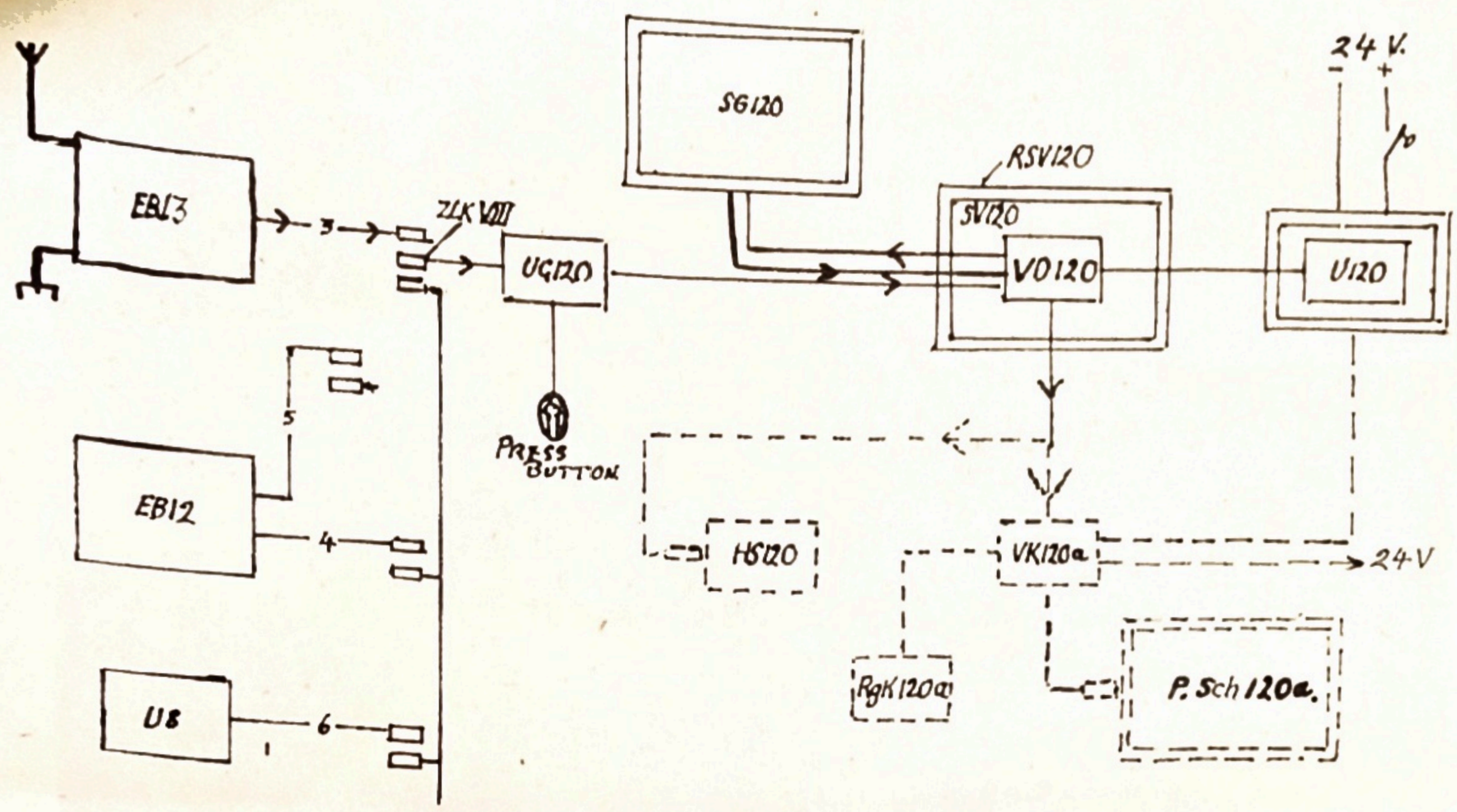

FIG 12. SCHEMATIC DIAGRAM OF FuBl 2 CONNECTED TO FuG. 120 OR FuG. 120a

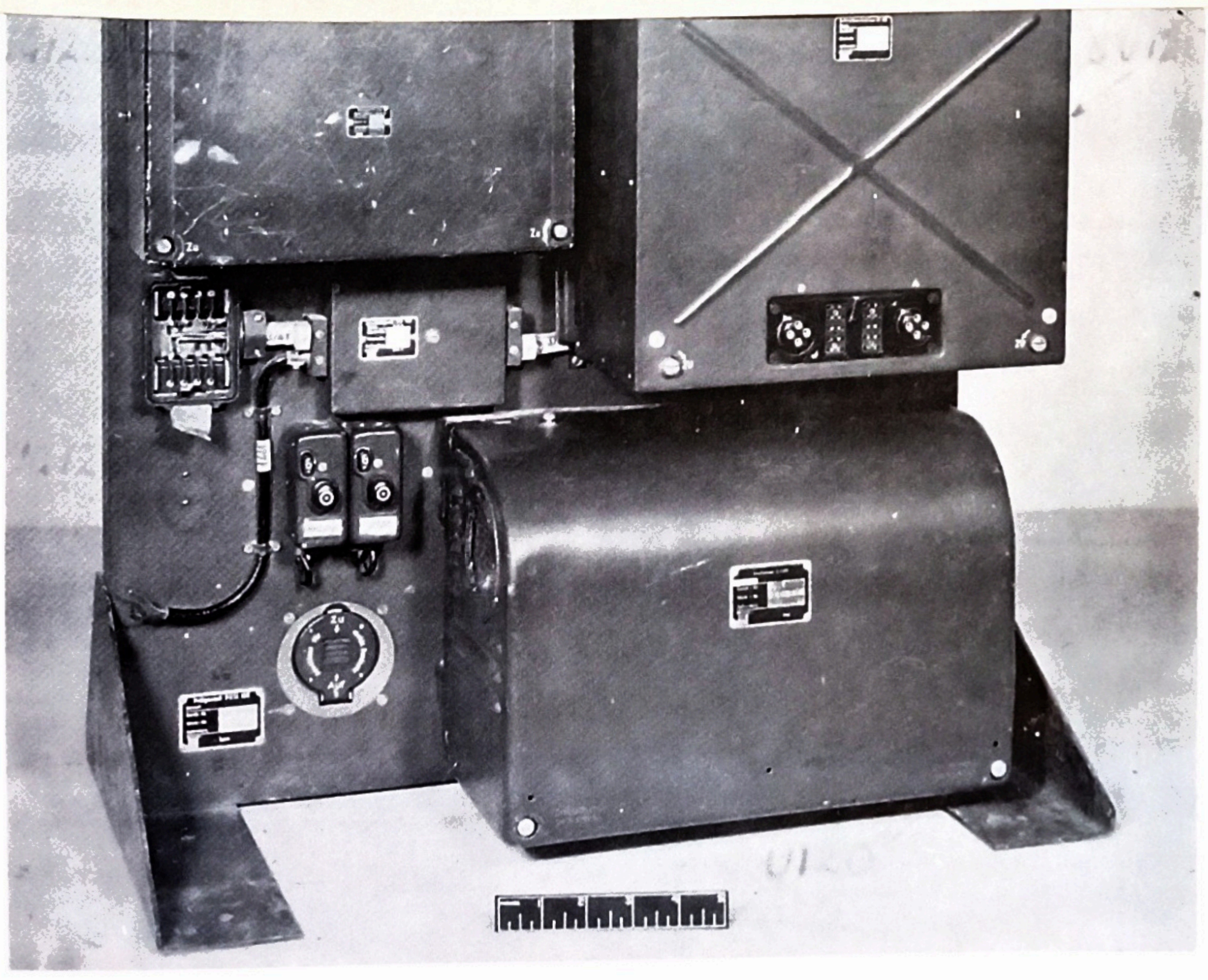

FIG. 13. TESTING PANEL FOR FUG. 120. & 120a.

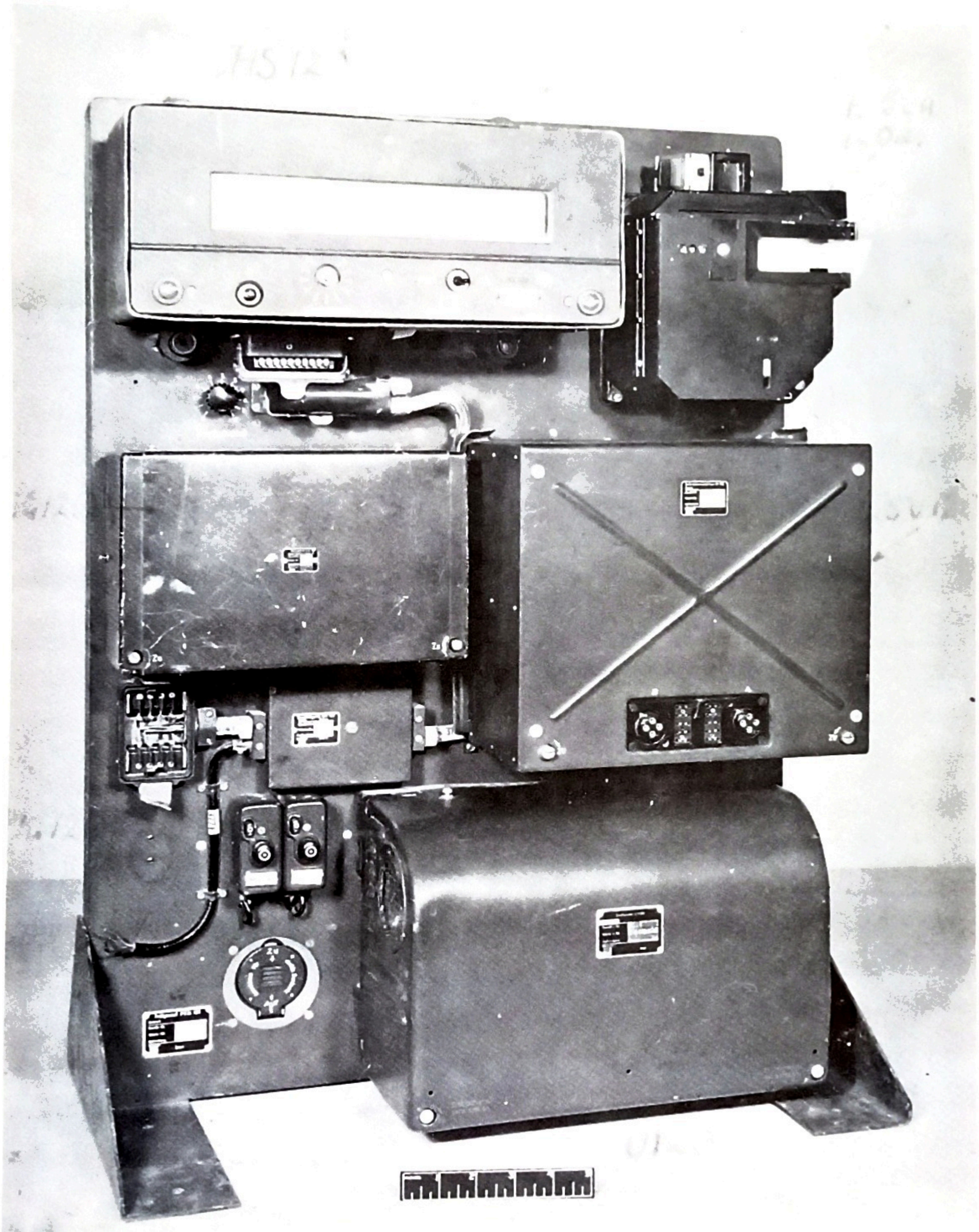

FIG. 13. TESTING PANEL FOR FUG. 120. & 120a.

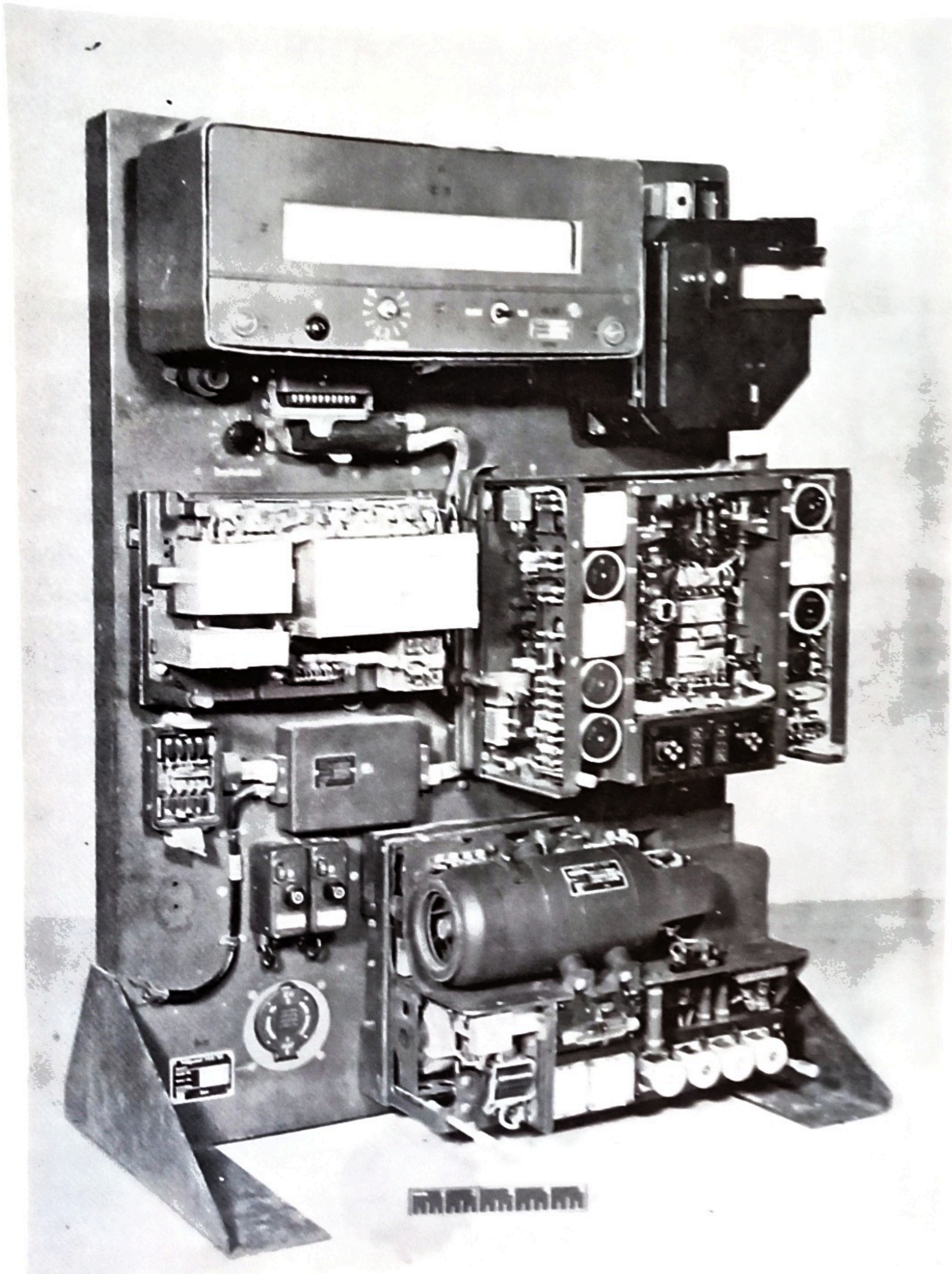

FIG. 14. TESTING PANEL (COVERS REMOVED).

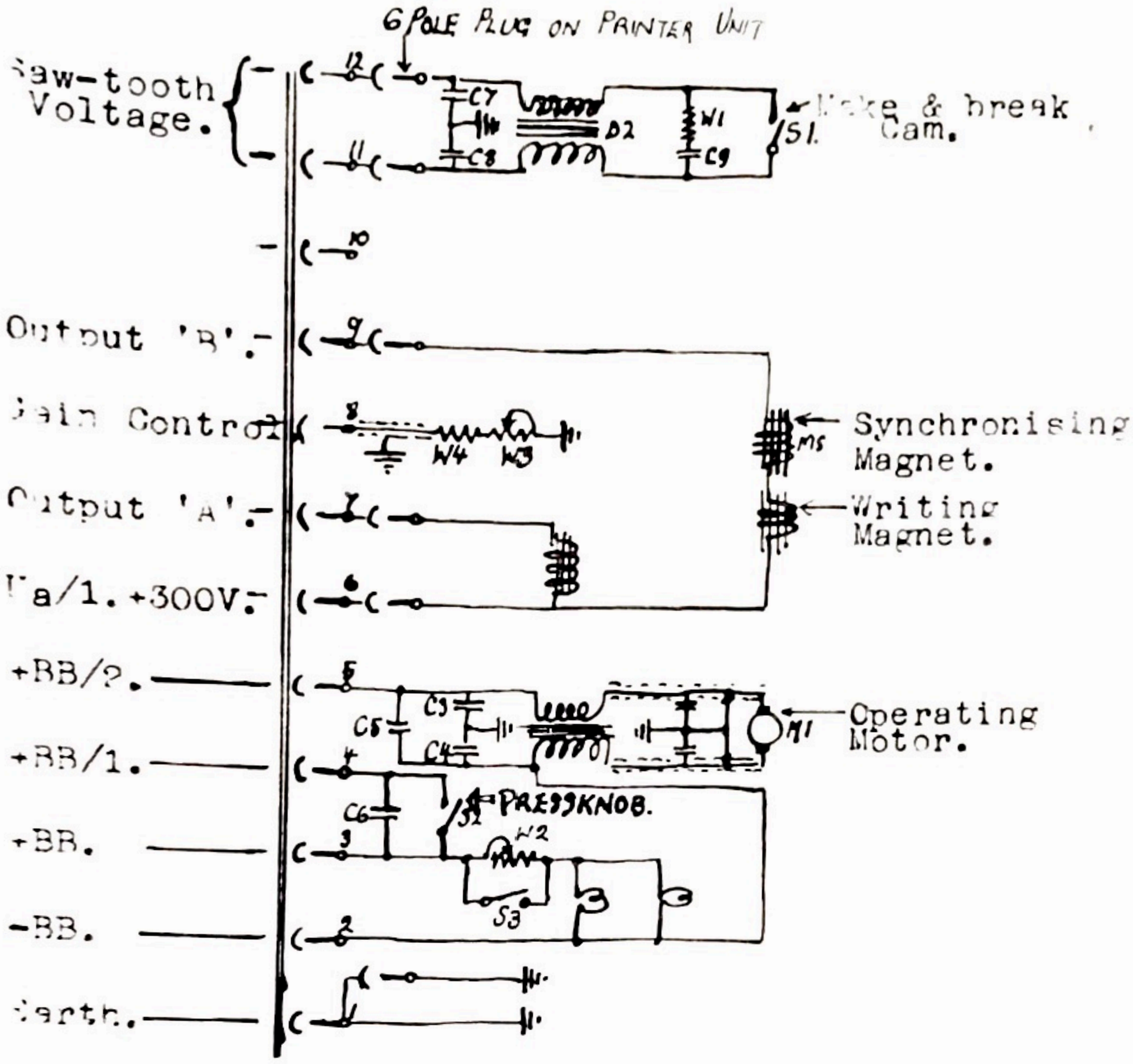

Fig.15. PRINTER UNIT HS120. INTERNAL CONNECTIONS.

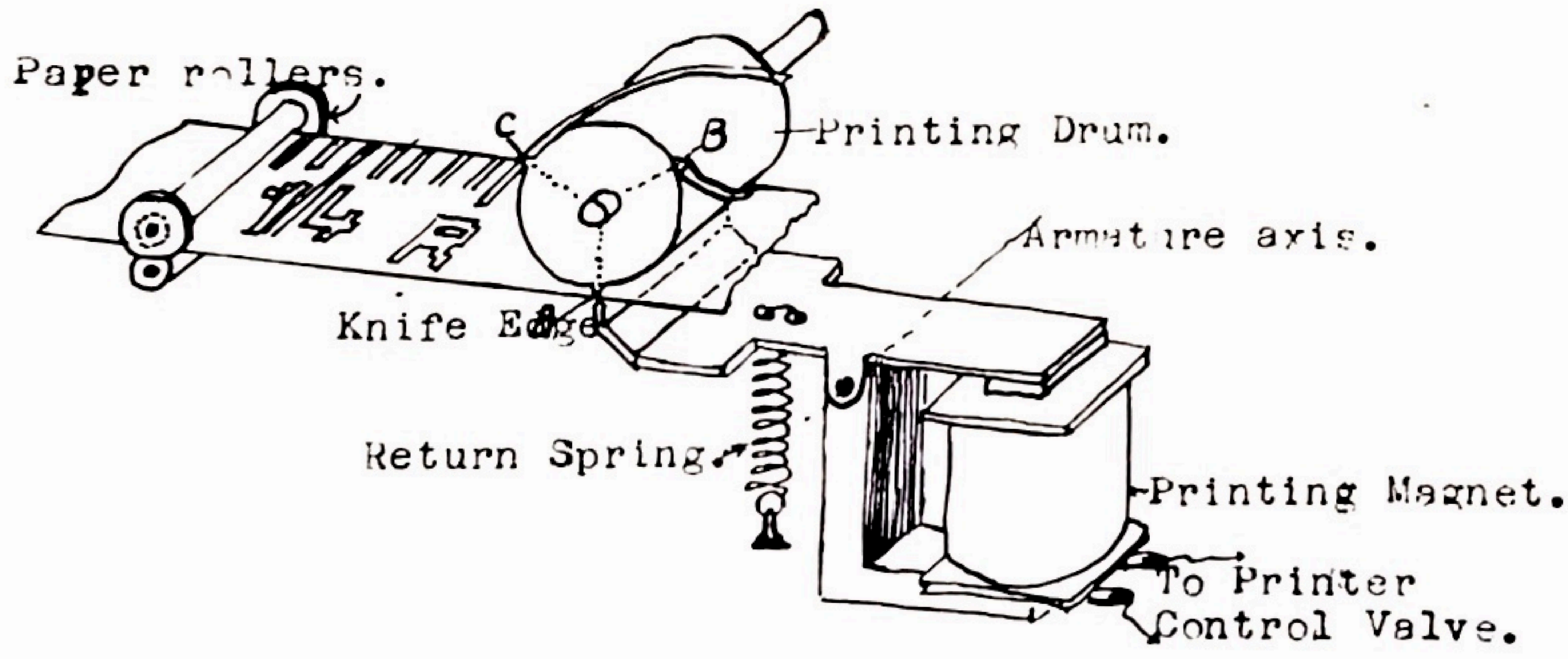

Fig.16. SKETCH OF PRINTING DEVICE FOR AZIMUTH SCALE.

A = H.T. Supply.
RB = Aircraft Battery (24 V.).
Bü. = Connection box.
C. = Condenser.
D. = Inductance Coil.
H. = Heater.
HM. = Heater supply mid-point.
R. = Relay.
Rö. = Valve.
U. = Transformer.
W. = Resistance.

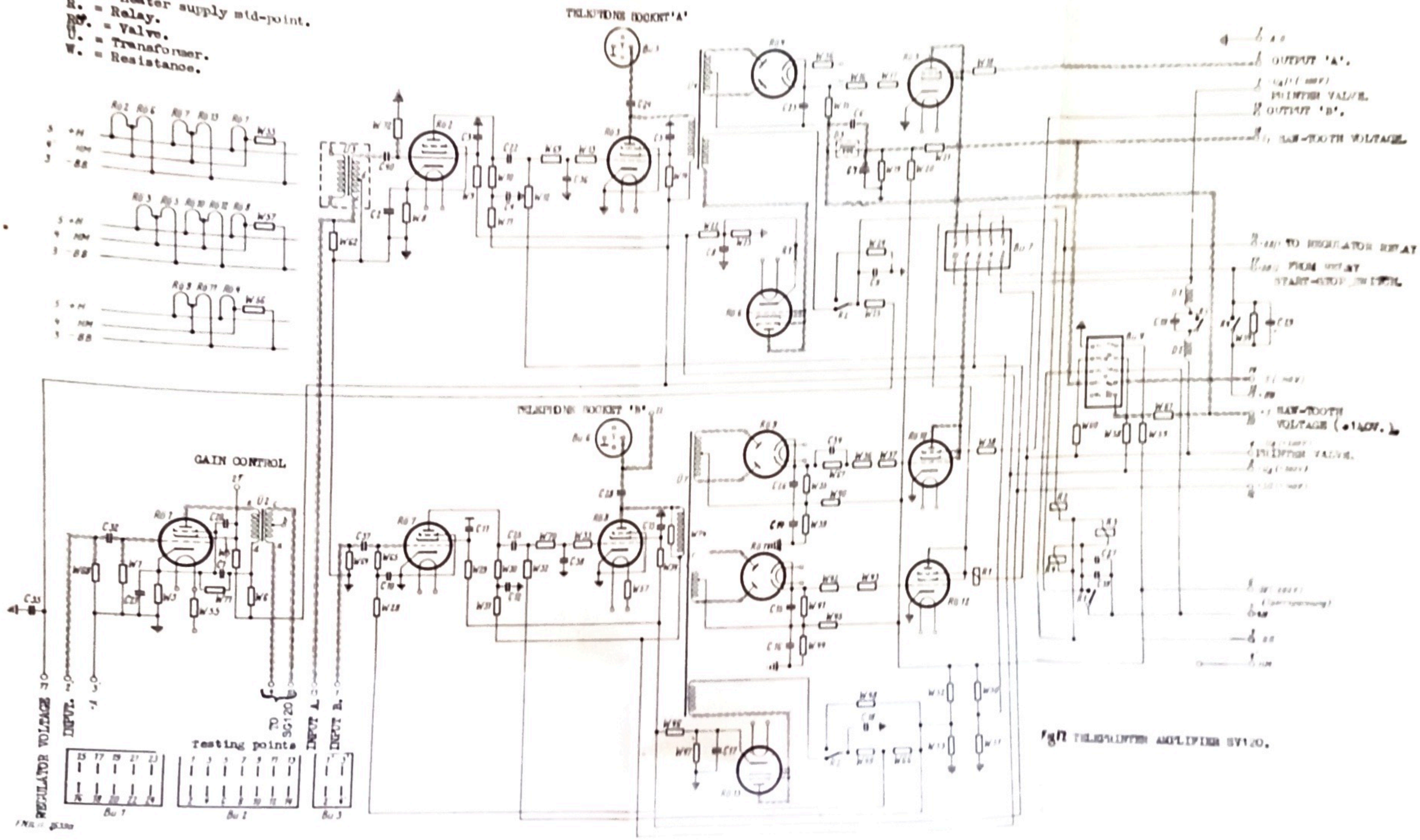

Fig 17 TELEPRINTER AMPLIFIER SV120.

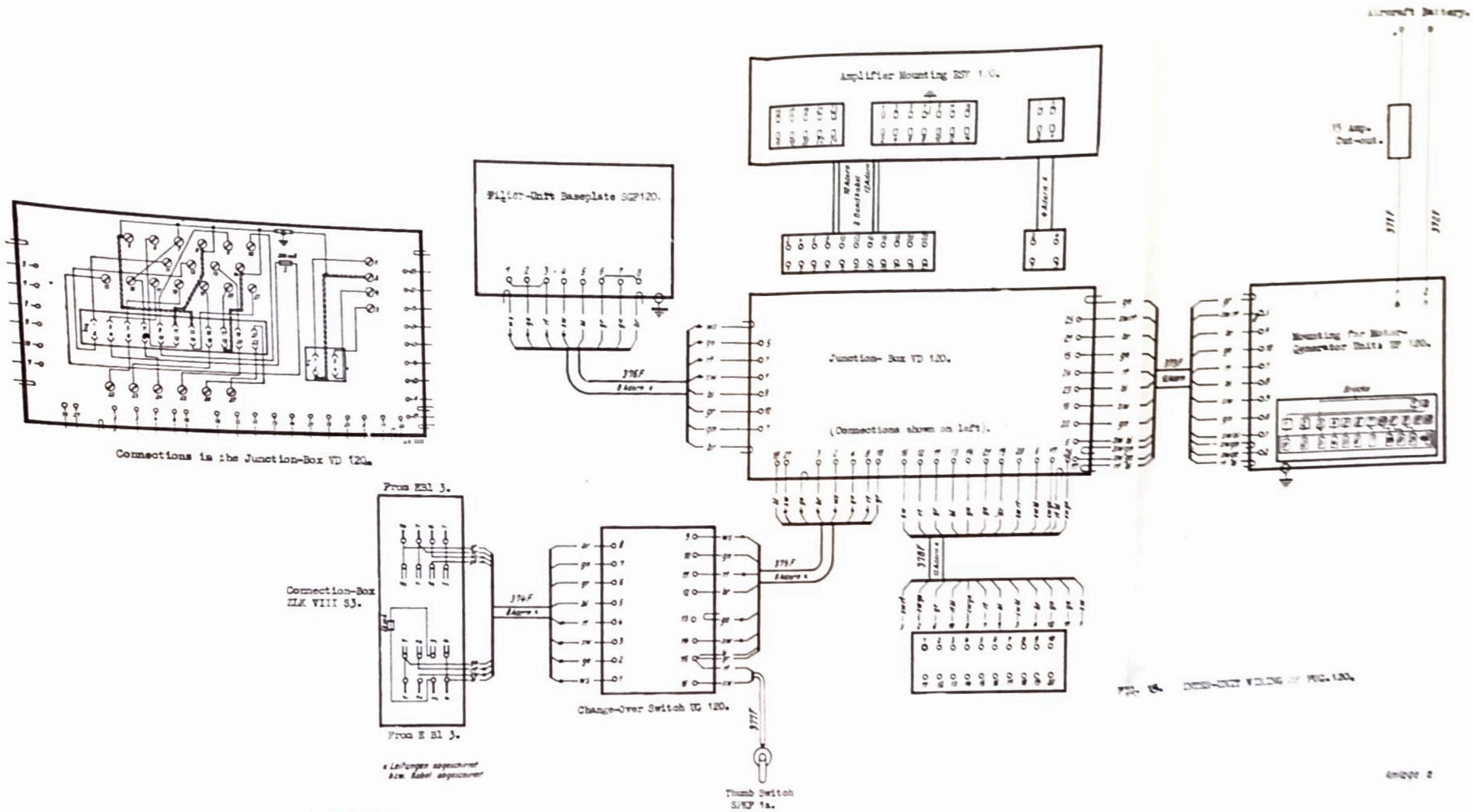

FIG. 18 INTER-UNIT WIRING OF FuG. 120.

FN/Lfl. 7776 a

Anlage 8

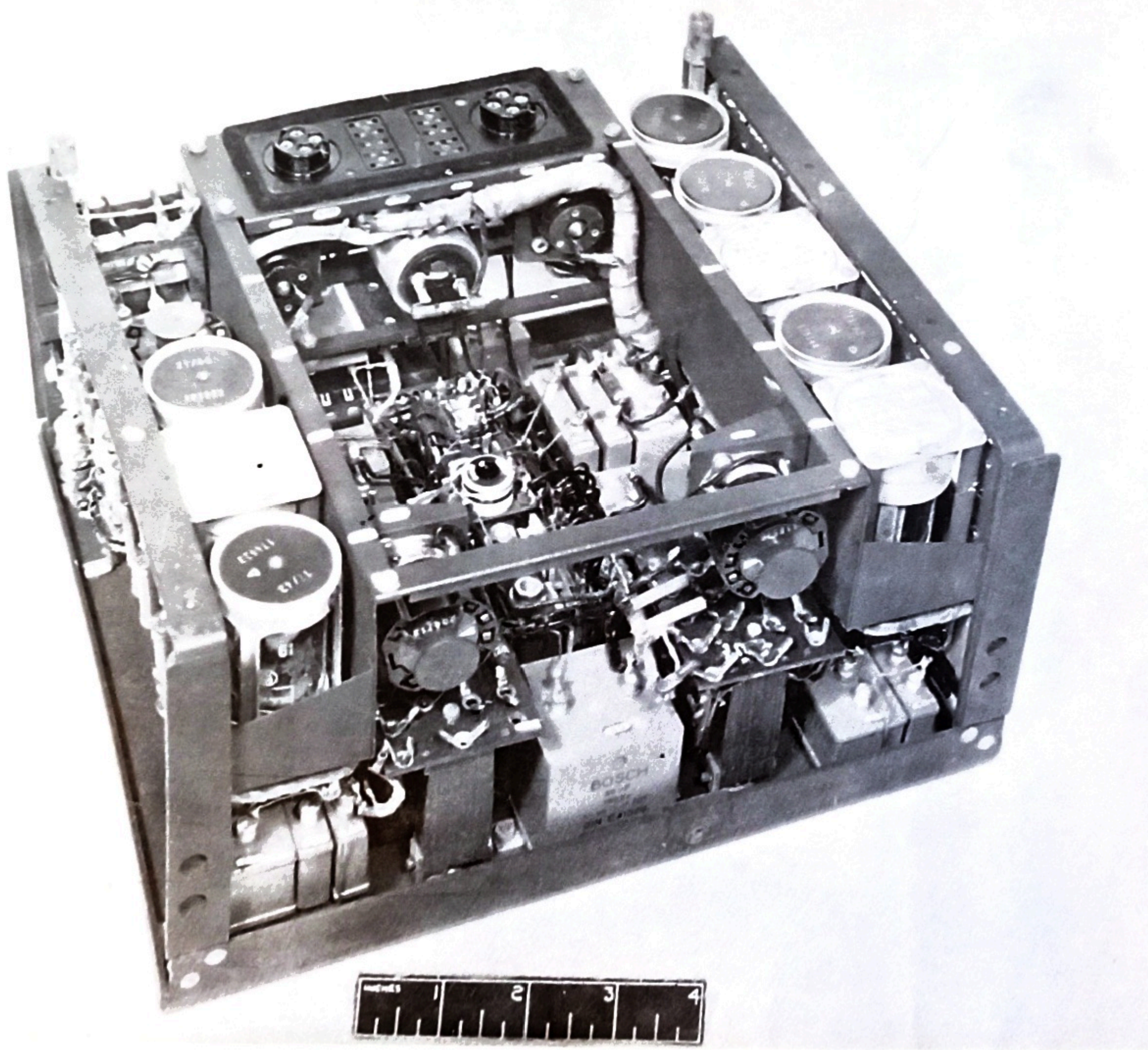

FIG. 19. SV120. TELEPRINTER AMPLIFIER, COVER REMOVED.

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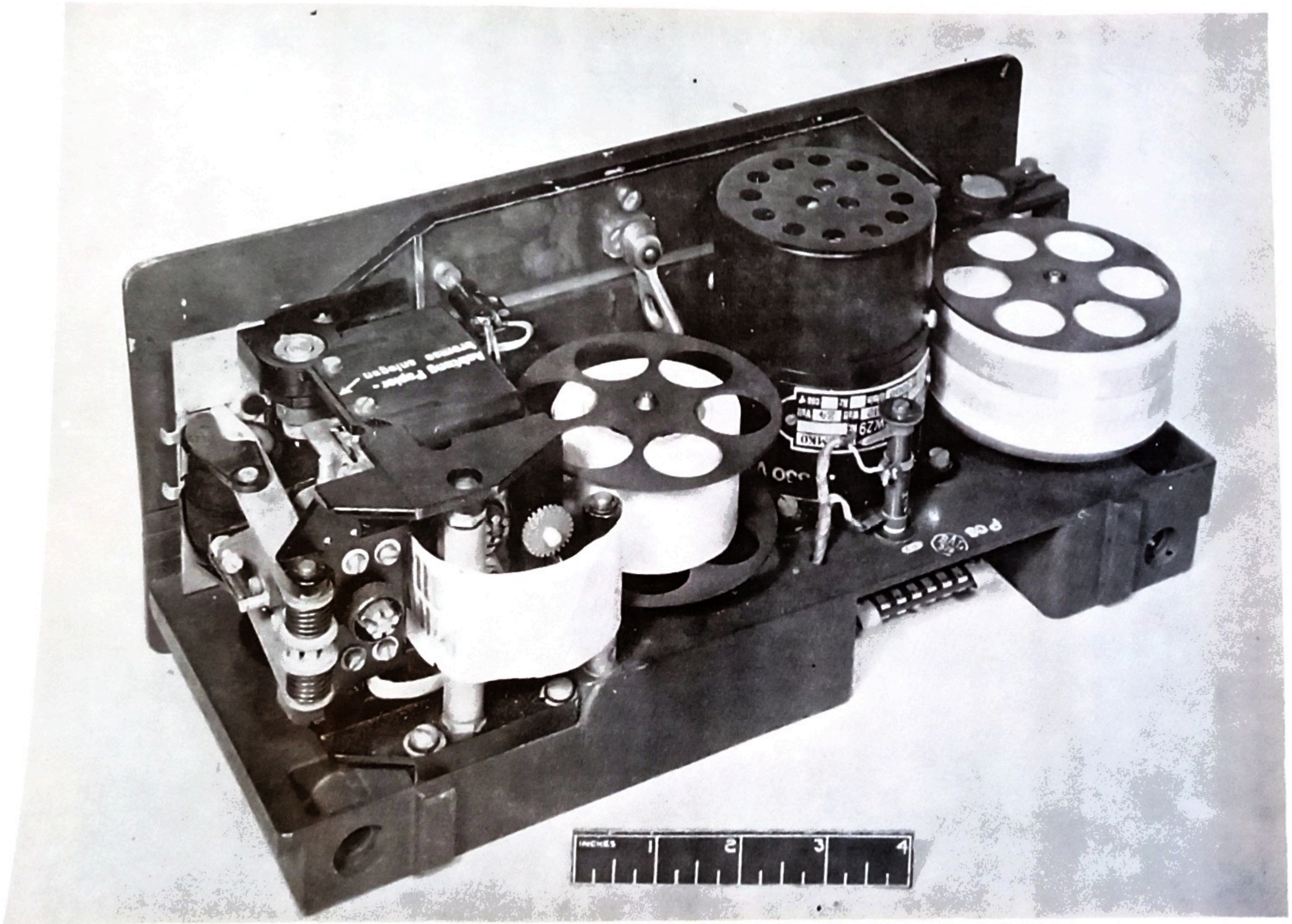

FIG.20. HS120. REAR VIEW, COVER REMOVED.

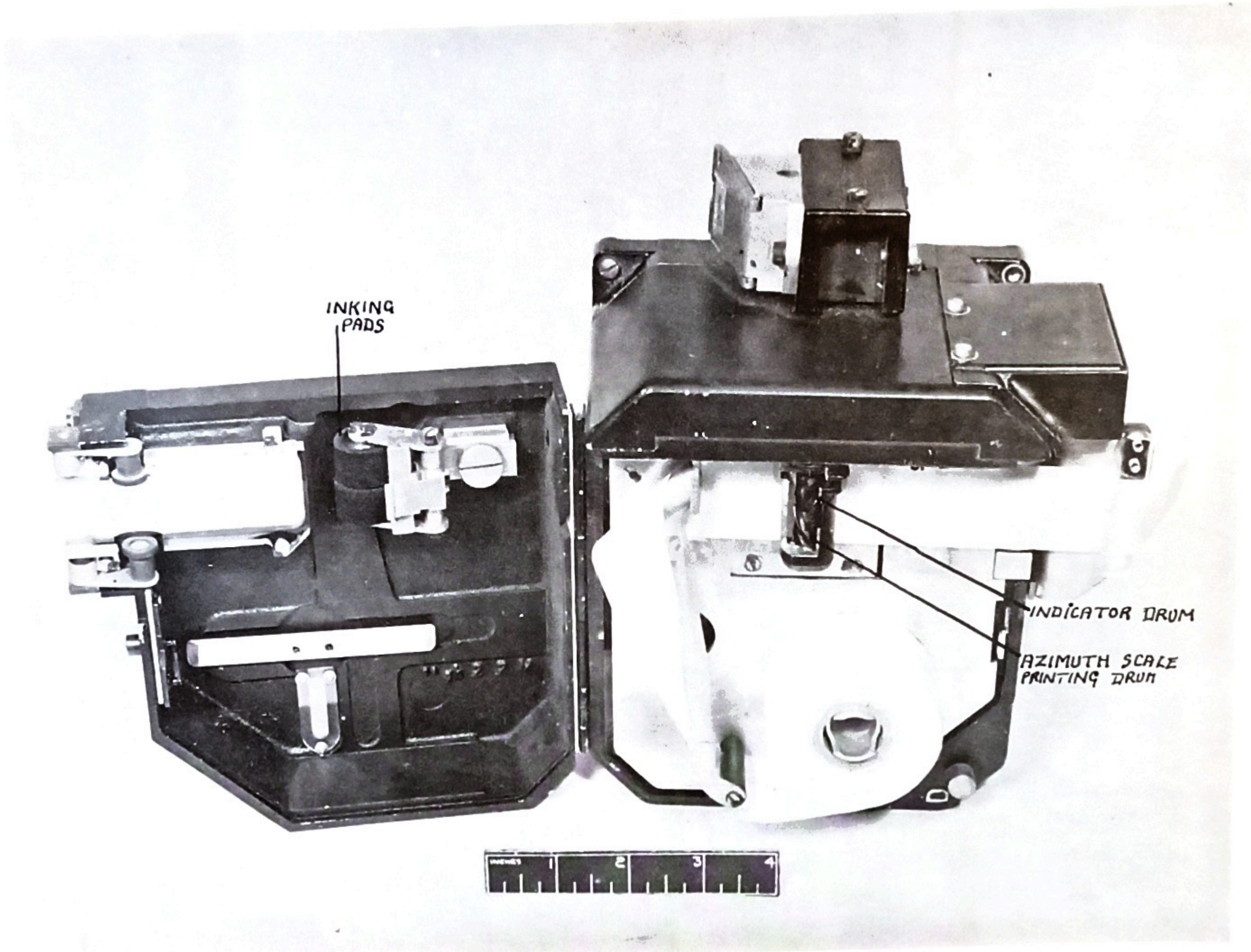

FIG.21 PSch120a. PRINTER UNIT, COVER OPEN.

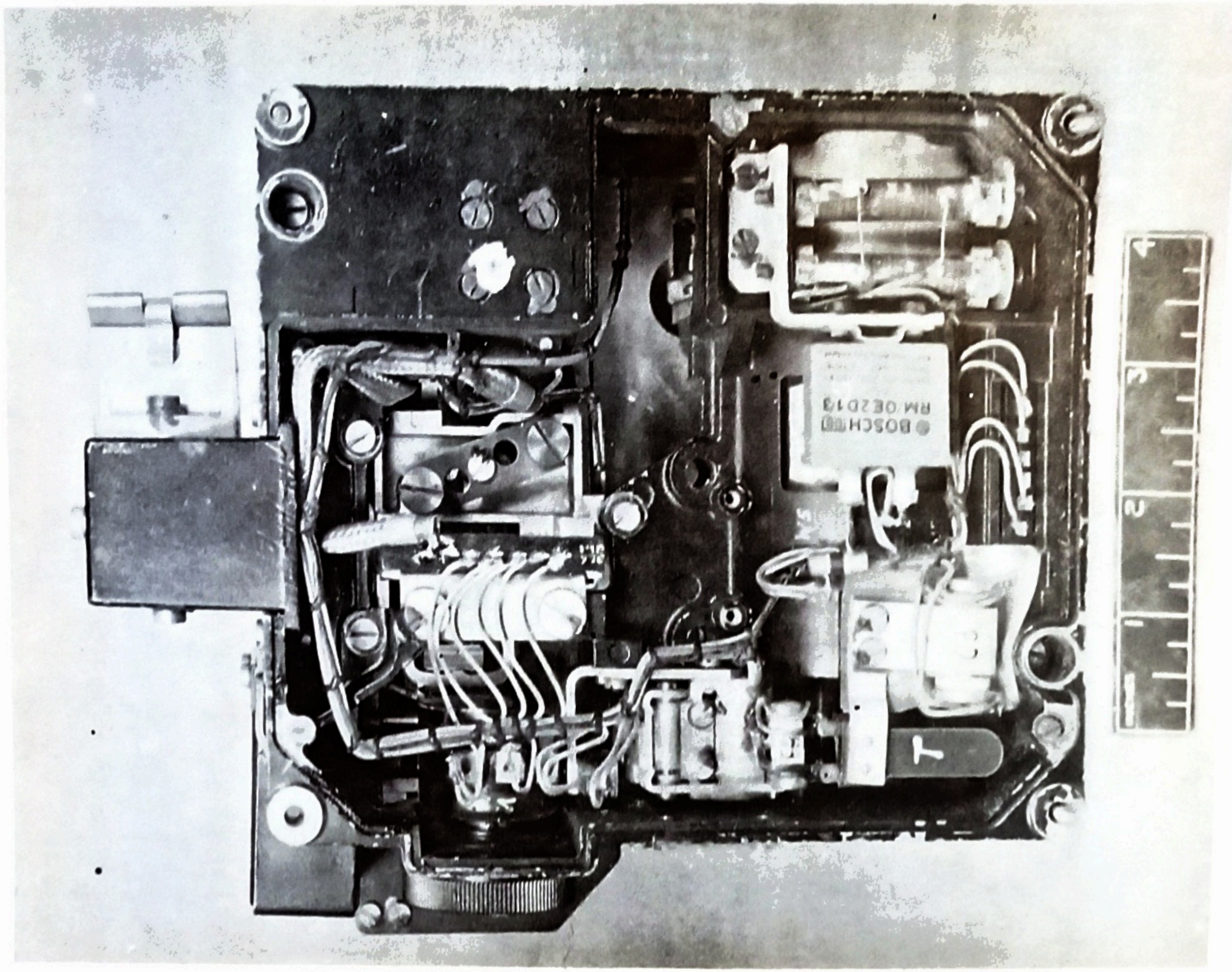

FIG22. PSch120a. PRINTER UN[illegible] VIEW FROM UNDERNEATH, COVER REMOVED.

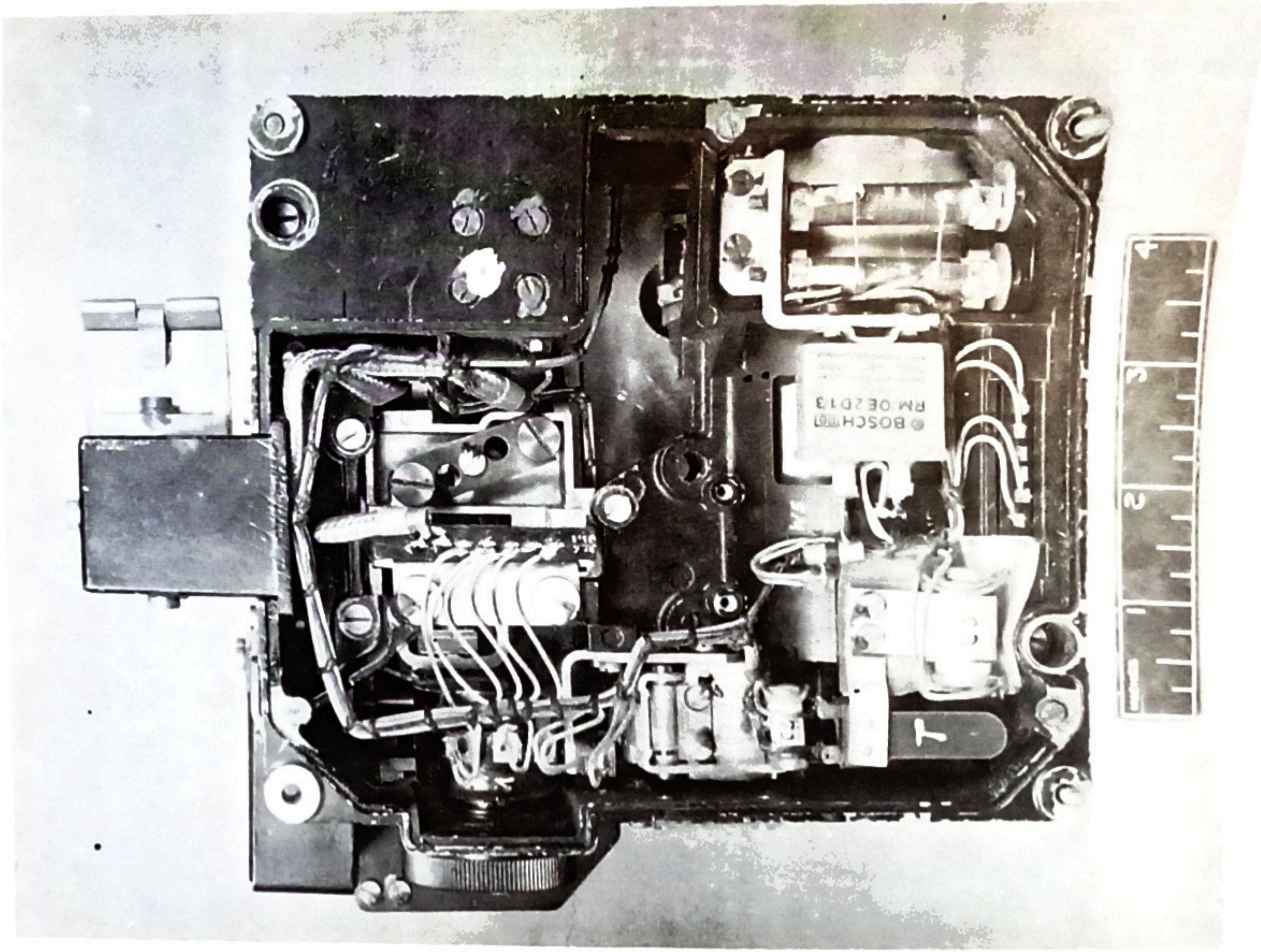

FIG22. PSch120a. PRINTER UN[redacted] VIEW FROM UNDERNEATH, COVER REMOVED.