Specifications and description on short wave cathode ray direction finder

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NATIONAL RESEARCH COUNCIL OF CANADA

SPECIFICATIONS

AND

DESCRIPTION

ON

SHORT WAVE CATHODE RAY DIRECTION FINDER

OTTAWA

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Section One

General Principles

The principle of operation of the cathode ray direction finder is shown briefly in the accompanying sketches. Figure 1 shows the basic idea of two directional aerials (in this case loops) mutually at right angles and each connected to a pair of plates of the cathode ray tube. If for convenience the loops are considered as oriented in the N-S and E-W directions, then a signal of frequency f arriving at an angle θ to the N-S direction will induce a voltage in the N-S loop- $K \sin 2 \pi f \cos \theta$ and in the E-W loop $K \sin 2 \pi f \sin \theta$. These voltages impressed on the plates of the cathode ray tube will cause the spot to be deflected in a line, making an angle θ with the axis representing the N-S direction. If an amplifier is introduced into each of the circuits as in Figure 2, the sensitivity will be increased, but the above relations unchanged, provided the two amplifiers have the same gain and that each imposes the same phase displacement on the signal. These amplifiers may take the form of superheterodynes, as shown in Figure 3, using a common beat oscillator to help fulfil the condition of equality of phase shift. Also shown in Figure 3 is a method of providing sense by use of a third amplifier, fed by a vertical aerial, whose output is rectified and connected to the brilliancy electrode of the cathode ray tube. Properly arranged this serves to darken the spot on one-half of each radio frequency cycle, obliterating one-half of the line.

In a practical application of the above principles a number of refinements will of course be necessary. For instance, controls will be required to maintain the identity of phase shift and gain of the three amplifiers, and means to test for these conditions must be available: buffer amplifiers will usually be required to isolate the three channels at the common beat oscillator: and so on.

A fine account of the history and early development of the cathode ray direction finder will be found in "The Cathode Ray Oscillograph in Radio Research" by R.A.Watson Watt, J.F.Herd and L.H.Bainbridge-Bell. One of the more recent developments is described in Wireless Engineer, August 1938. Section 3 of this specification is an account of the National Research Council's development work on cathode ray direction finders.

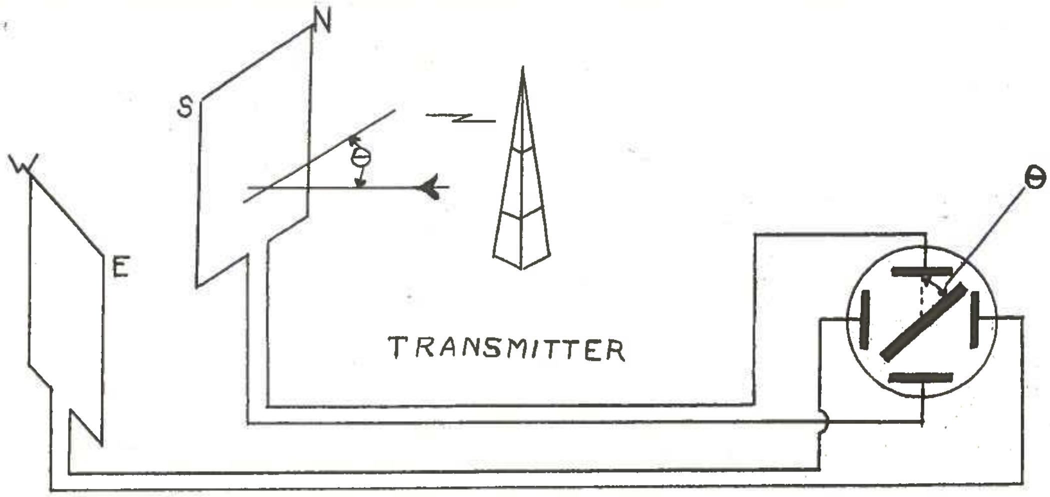

Fig 1

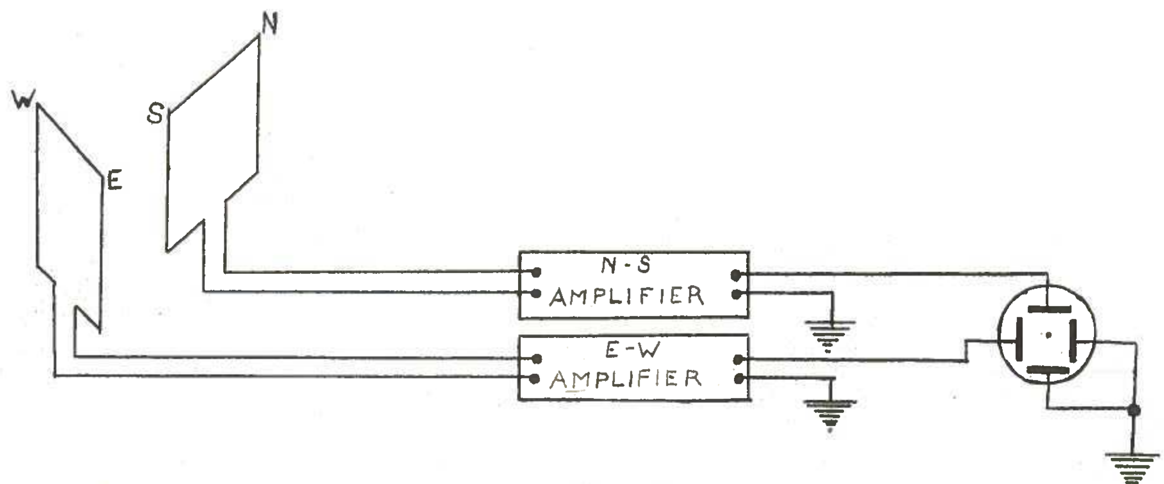

Fig 2

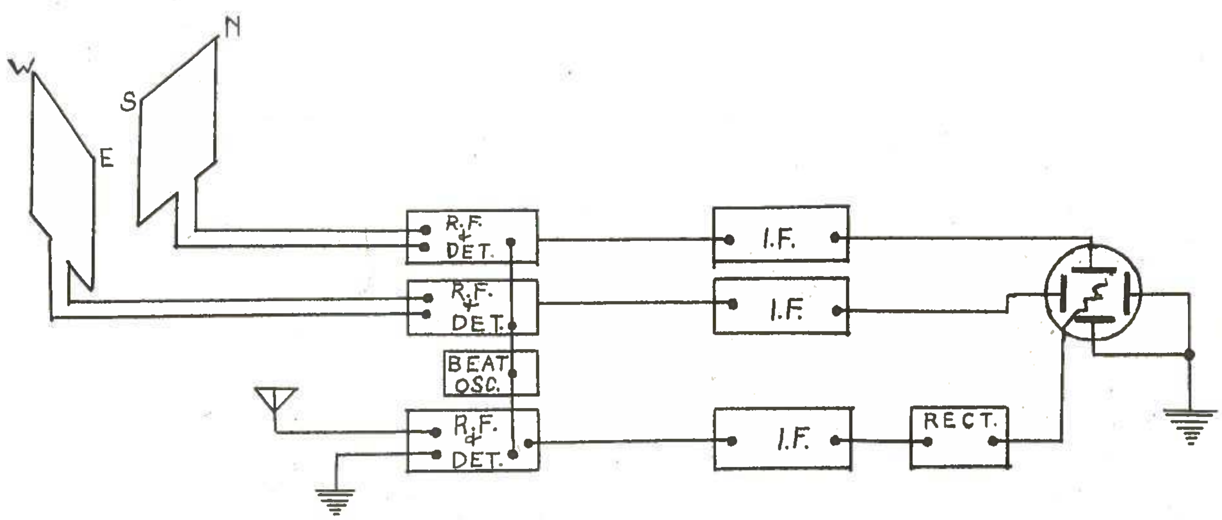

Fig 3

SHORT WAVE CATHODE RAY DIRECTION FINDER

Section Two

SPECIFICATIONS

The specifications outlined below represent the minimum general requirements of a cathode ray type of direction finder which meets the operating conditions of the Royal Canadian Air Force. It is believed that in some cases the manufacturer can improve the performance of the receiver without making any major modifications to the suggested design. These points are referred to in Section Three, and wherever possible the improved performance should be incorporated in the manufactured product.

(1) General

1.1 The electrical wiring must meet the requirements of the Canadian Electrical Code. The workmanship and general construction must comply with such requirements and tests as will be laid down by the Royal Canadian Air Force.

1.2 Adequate electrical protection of the circuits by fuses etc., and adequate protection for the operator against shock must be incorporated.

(2) General Layout

2.1 The direction finder should be constructed in a number of units in such a manner that those having operating controls may be installed to suit the operator's convenience and the remainder placed under the operating table or in some other out of the way space. For the purpose of these specifications a distinction is drawn between operating controls, such as tuning etc., and adjustments, for alignment, etc., which normally the operator does not alter.

2.2 Essentially a cathode ray tube, three identical amplifier channels, three aerials coupled separately to the three channels, and an audio monitor must be provided.

(2) General Layout continued

2.3 A suitable division of the instrument would be:-

(1) Cathode Ray Tube in a box suitable for table mounting, with cursor and scale, centering, brilliancy and focussing controls.

(2) Intermediate Frequency Amplifiers arranged for relay rack mounting but having sufficient flexibility of connections that they do not necessarily have to be on the same rack as the radio frequency amplifier. No operating controls should be mounted on the intermediate frequency units.

(3) Radio Frequency Amplifier, with tuning dial, volume control, band change switch, trimming controls for phase and gain, arranged for rack mounting in such a manner that if mounted on a table rack the controls would be at a convenient operating height.

(4) Power Supply: a separate unit with sufficient length of cable to permit placing on the floor under the operating table or elsewhere. For convenience all power supplies should be in one unit but practical considerations dictate separate supplies for receiver and cathode ray tube.

(5) Control Box or Panel for field oscillator, suitable for table mounting.

(6) Field Oscillator for remote operation out of doors at some distance from the receiver building.

(7) Audio Monitor: could be conveniently built into (1).

(3) Frequency Range

3.1 The receivers shall be continuously variable over the range 1500/Kc/sec to 7500/Kc/sec; single dial control of tuning shall be provided. The frequency range may be covered in two or three bands with adequate overlap between each band. A change from one band to another must be effected by not more than one switching control.

(4) Selectivity

4.1 The band width shall be not less than 2000 cycles at an attenuation of 6 db and not greater than 7000 cycles at 20 db and 15,000 cycles at 40 db respectively.

(5) Image Selectivity

5.1 Image ratio should be greater than:

5,000 at	7	megacycles
7,000	6	"
15,000	5	"
60,000	4	"
70,000	3	"
100,000	2	"

and other spurious responses should be suppressed at least this amount.

(6) Sensitivity

6.1 The input voltage required to produce an output deflection greater than 5 times the noise deflection and a line on the cathode ray tube greater than 1", must be less than 2 microvolts on all bands (and should preferably be less than 1 microvolt) at an input impedance of approximately 400 ohms. The corresponding value of $\frac{V^2}{Z}$ should be less than $\frac{1}{100}$ micro-micro watts. The above are minimum sensitivities which it is desirable to increase.

(7) Operating Controls

7.1 The number of controls should be kept at a minimum. Those considered essential are:-

(1) ON and OFF switch.

(2) Tuning Dial: this should perform all the functions of the tuning dial on a single dial receiver and should be the only prominent control.

(3) Volume Control: this will probably require two dials - a fine and coarse gain control.

(4) Phase Trimming Dial: a small knob providing the small phase adjustment necessary for precise alignment.

(5) Gain Trimming Dial: a small knob providing the small gain adjustment necessary for precise alignment.

(6) Band Switch: a small knob or toggle switch which performs all the operations necessary to change bands.

(7) Input Paralleling Switch: a small knob or toggle switch which performs the operations necessary to test for and obtain precise alignment.

(8) Brilliancy Control of cathode ray tube. (9) Focussing Control of cathode ray tube (10) Spot Centering Controls for cathode ray tube. (11) Audio Volume Control. (12) Audio Beat on and off. (13) Audio Beat Tone.	Small Knobs

(7) Operating Controls continued

7.1 continued:

(14) Switch to connect audio to any one of the three intermediate frequency channels. This might be accomplished automatically as suggested in paragraph 17.1.

(15) Sense Button: a toggle or push switch which makes sense indication available.

(16) Cursor Rotator: a knob or hand-wheel which rotates hair-line to coincide with cathode ray line and makes available an indication of the bearing.

(17) Field Oscillator ON-OFF switch.

(18) Field Oscillator spot frequency and volume dial.

(19) Field Oscillator continuous tuning dial.

(20) Line Voltmeter.

Of these 2, 3, 4, 5, 7, 15 and 16 are required for each station tuned in and should be very conveniently arranged for ease of operation.

1, 6, 8, 9, 10, 11, 12, 13, 17, 18 and 19 are less often used and should be arranged so that they do not interfere with the use of the former group. All controls, especially 2, 3, 4, 5, 7 and 16 should be non-critical in operation.

7.2 The purpose of all control knobs should be clearly indicated by the marking on the instrument.

(8)
Volume Control

8.1 The volume control provided must permit attenuation of at least 80 db without causing overloading or other distortion that would in any way introduce errors. An additional attenuation of 20 db would be useful for local reception but the requirements of zero error would not be so rigorous for this setting. The control should be continuously variable and perhaps is best provided in two controls: 70 db variable in steps of 10 db, and another smoothly variable over 10 db. Operation of these must not contribute to relative phase shift or gain change as it is sometimes desirable to operate them without re-checking alignment.

8.2 The coarse control at least should be so located in the circuit as to attenuate noise and signal in proportion so that the signal to noise ratio is not impaired.

(9)
Phase and Gain Trimmer Controls

9.1 The controls provided for the operating adjustment of relative gain and phase shift must have adequate range to permit making the optimum adjustments under any condition encountered. From paragraph 11 this requirement would be $\pm$ 20% in gain and $\pm$ 15° in phase. To make for ease of operation it is desirable to limit the range of these controls as much as possible and yet comply with the above requirements.

9.2 In order to effect precise alignment with only one adjustment of each control, it is essential that, either the gain trimmer produces no phase shift, or the phase trimmer produces no gain change.

9.3 These controls should be so located in the circuit that a slow drift of gain or phase due to the adjustment of the controls (such as might occur due to tube element temperature changes, slow charging of condensers etc.) will not occur after the control has been adjusted.

(10) Cathode Ray Tube

10.1 The cathode ray tube should be about 6" in diameter with a sufficiently flat face to permit use of a 5" deflection without parallax. The brilliancy of the spot should be sufficient to permit observation in direct sunlight coming through a window. In this regard it has been found that the blue-green or blue screens are superior to white or white-red screens. The spot should be small and round and of uniform size at any position on the screen to give a clean uniform line. To obtain this, a high vacuum tube with push-pull electrostatic deflection has been found most satisfactory.

10.2 The tube should be mounted in such a manner that no error greater than 1° in its calibration can be introduced by changing the orientation in the earth's magnetic field or by other factors likely to occur such as proximity of loud speaker or power supply. It must be possible to reduce this error to less than 1/4° by re-checking the X, Y and 45° positions. It is preferable to mount the cathode ray tube box so that it cannot be moved at all.

10.3 The cursor and scale must be arranged to permit taking the bearing of the line on the cathode ray tube rapidly. (The bearing may be indicated as a reading on a scale but preferably an illuminated dial showing the angle could be used.) The centering and focussing controls provided must permit their intended operations to be fulfilled under any possible conditions of earth's field, low line voltage, etc. The controls should be placed so that they cannot be confused with the audio monitor controls.

10.4 The type of cathode ray tube used should be such that undue selection of tubes is not required to maintain the calibration of the instrument, and such that the cathode ray tube does not contribute more than 2° to the departure from a true geometric bearing. The tube should have reasonably long life under the operating conditions.

(11) Instrumental Accuracy

11.1 There shall be no fixed departures from the geometric scale other than those contributed by the cathode ray tube, greater than 1/10 of 1 degree. The combined effect of all sources of instrumental error, apart from the fixed errors which are allowed for in the calibration charts, shall be less than 1/2 degree when the receiver is operated in the manner described in paragraph 21. This accuracy shall be maintained for any condition of signal strength or modulation within the operating range of the receiver. This shall apply for a range of variation of line voltage of 95 to 125 volts and a range of temperature variation of 50°F to 100°F.

(12) Stability

12.1 The long period stability of the instrument shall be such that no departures of one receiver relative to either of the others shall exceed ± 20% in gain and/or ± 15° in phase shift. In addition the variation of gain and phase with Off-Resonant frequency (as described in paragraph 13) shall not exceed 1/2° (2%) for gain and/or ± 2° for phase as the frequency is changed from resonance to a point where the output is 1/5 its value at resonance. This stability must hold in normal operation for a period of not less than three months.

12.2 For a variation of line voltage over the range 95 volts to 130 volts there shall be no change in gain greater than ± 20% or greater than ± 5° in phase shift of one receiver relative to either of the others. In addition the relative variation of gain and phase with Off-Resonant frequency must not exceed ± 1/2° for gain and/or ± 2° for phase, due to the above line voltage variation. These same limits must hold for a variation of temperature in the range + 50° F to + 100°F.

(12)
Stability
continued

12.3 The relative sizes of major and minor axes of ellipses resulting from 2^o, 5^o and 15^o of phase shift are approximately 57:1, 23:1, and $7\frac{1}{2}$:1 when the major axis is at 45^o.

12.4 Under normal operating conditions of line voltage or temperature variation the change of gain and phase should be sufficiently small and slow that an error of more than $1/2^o$ cannot occur by allowing a lapse of 2 minutes between making the operating check of alignment as in paragraph 23 and taking the bearing. The type of tubes and circuits used must be such that undue replacement of tubes is not necessary and that undue selection of tubes for replacement is not required to ensure normal operation after a tube replacement.

(13)
Alignment

13.1 It is essential that the three receivers have identical gain and phase displacements not only at the carrier frequency but also over the band of frequencies on either side of the selectivity curve to a point where they are attenuated 20 times. This practically dictates that the total phase and gain displacements of the intermediate frequency amplifier be made equal by making those of each and every corresponding component in the three channels equal.

13.2 Adjustments must be provided for any parameters which might be expected to vary due to shipment, aging, etc., to restore them to their optimum values. Test points and commoning arrangements must be provided to permit their accurate alignment.(see also paragraph 2.1). It should be possible to inject signals at these points. All these adjustments and fittings which are to be treated as non-operating controls should be arranged so that they may be covered and locked, as with a door in a false cover. Examples of such adjustments might be: capacity of the intermediate frequency tuned circuits, Q of the intermediate frequency tuned circuits, gain of tubes, tracking of condensers, inductance of the radio frequency coils, etc.

(13)
Alignment continued

13.3 These controls should be made adequate to permit aligning the three receivers at any one frequency to perfect phase equality, perfect gain equality, and at the same time to permit aligning so that when the frequency is varied on either side of resonance to a point where the output is 1/5 its resonant value, the alteration of relative gain does not exceed 1% (i.e.1/4°) or of relative phase shift does not exceed 1/4°. When the frequency is varied to a point where the output is 1/20 its resonant value these figures must not exceed 1°. The adjustments of tracking provided in the radio frequency amplifier must be adequate to keep the relative phase change to less than 15° as the receiver is tuned across its frequency range with phase trimmer and gain trimmer controls untouched. The 1/4° at 5 times down and 1° at 20 times down must remain within these limits throughout this operation.

13.4 All alignment adjustments which should be non-critical and free from hand capacity should be readily accessible, preferably through a door as mentioned in 13.2.

(14)
Cross-talk

14.1 When any one or two of the receivers have inputs applied and the third has no input, the output of the third receiver must be less than 1/4 of 1% of the output of either of the other two. This must be true at any frequency setting and at any gain control setting and must hold with any normal connection of the input circuits, grounds or cables. When making any adjustments it is also essential that no cross-talk be introduced into the part of the receiver under test by the commoning arrangements or test injections required for the test.

(15)
Shielding

15.1 The output of the receiver, for any given field strength X microvolts per meter, obtained when the aerial input is disconnected from the receiver and with any normal connection of shielding, leads and grounds, and at any gain control setting, must be less than that which would normally be obtained from a signal of X/10,000 microvolts applied at the input of the receiver at the same gain control setting.

(16)
Sense and Sense Rectifier

16.1 It is intended that the sense indication be provided by extinguishing the spot on the cathode ray tube in such a manner that only half the deflection shows, indicating the true direction and sense of the incoming signal. The signal from a sense aerial is amplified in a receiver identical with the other two up to the output of the intermediate frequency amplifier. The intermediate frequency output of the sense receiver is rectified and the rectified voltage applied to the brilliancy control electrode of the cathode ray tube to extinguish the spot for one-half its travel. The alignment of the sense receiver is not ordinarily as critical as that of the N-S and E-W but it is desired that the sense receiver be similar in design and equal to them in performance so that it may be electrically interchanged with one of them in an emergency.

16.2 The sense rectifier should be located in the cathode ray tube box, and should be designed to have very little phase displacement and to give good half-wave output waveform. If these conditions are satisfied the line on the tube should be extinguished quite sharply near the centre of the tube when the three receivers are paralleled at any point, after they have once been identically aligned. The original alignment of the sense receiver is made by electrically substituting it for the N-S or E-W receiver. Care must be taken with the insulation of the sense rectifier circuit as the rectifier tube is in the high voltage circuit of the cathode ray tube.

16.3 A switch (control 15) should be provided to keep the sense receiver inactive until the switch is operated. This should preferably operate by short-circuiting the output of the sense receiver to prevent any action by circuit noise. The sense receiver must not create any noticeable effect on the spot brilliancy or focus when this switch is in the "no-sense" position, and must not create any deflection of the spot under any circumstances.

(16)
Sense and Sense Rectifier continued

16.4 The phase of the signal from the sense aerial is different to that of the resultant signal from an Adcock pair, and in general the difference is dependent on frequency. Provision must be made so that these signals may be co-phased. This might be provided by having a variable phasing device controlled by the tuning mechanism which can be altered to suit individual aerials.

(17)
Audio Monitor

17.1 An audio system should be provided with built-in speaker and provision for two pairs of phones which will permit monitoring when the signal on the cathode ray tube is as small as 1/4". It should be so arranged that the main volume controls, in attenuating the signal to a usable size on the cathode ray tube prevent overloading of the audio, i.e., the intermediate frequency signal fed to the audio monitor should be proportional to the cathode ray deflection. It should have provision for voice, or CW beat reception, with a beat-note frequency control and an output volume control. It must be capable of operation from either the N-S or E-W receivers and this might be accomplished advantageously by having a switch-over circuit operated by some form of AVC to connect the audio unit to the louder of the two channels. Provision for manually switching the monitor to any one of the three channels (including sense) must be made.

17.2 The monitor must be so arranged that it does not contribute to cross-talk, or cause any audio or beat oscillator frequency deflection of the cathode ray spot. The signal to noise ratio of the audio output should be comparable to that shown visually on the cathode ray tube. Since the monitor is to be used mainly for voice and CW its frequency characteristic should be arranged to drop rapidly above 3500 Kc. A noise silencer of the peak-limiter type might advantageously be incorporated. This audio monitor can be built into the cathode ray box unit for convenience.

(18) Hum

18.1 No noticeable deflection or change in size of the spot must occur due to hum, magnetic field from power transformers etc., or from other sources of noise except that due to tube and thermal noise tolerable under paragraphs 6 and 8.

(19) Input Circuit

19.1 As mentioned in paragraph 10, the input impedance should be approximately 400 ohms. An optional terminal providing 100 ohms would be an advantage. The terminals provided should be for co-axial fittings and should be arranged so that the sheath of the cable is not necessarily grounded to the receiver shield.

19.2 In order to comply with paragraph 11 a dummy antenna impedance will probably be required when control (7) is in the paralleled position. Since no data for the antenna is at present available and since the receiver should operate on any antenna, this might best be handled by providing jacks for a plug-in device for this dummy antenna.

(20) Input Paralleling Switch

20.1 This switch is provided for the purpose of connecting all three receivers together at their input terminals to make the operating check of alignment. In order to use the signal from the distant station for checking the alignment it will be necessary to use the sense aerial so that the test signal will be independent of direction. The switch will have to disconnect the two directional aerials from the receivers and to connect the sense aerial to the inputs of all three receivers in parallel. The local field oscillator can be used to replace the distant signal for alignment purposes or can be used on one of the crystal controlled frequencies to permit exact tuning of the receiver.

(20) Input Paralleling Switch continued

20.2 Great care must be taken with the location and shielding of this switch to avoid introducing cross-talk. Care must be taken with the associated circuit wiring to avoid introducing errors.

(21) Field Oscillator

21.1 A field or test oscillator continuously variable over the same frequency range as the receiver must be provided. All controls for this oscillator must be available at the receiving operator's position through some form of telephone dial switching mechanism. The unit may be A.C. operated from the receiving hut provided the remote control cable is properly buried in earth. The unit must be enclosed in a weather-proof case. (It may be necessary to heat this unit in wintertime to ensure frequency stability). In addition to the continuously variable frequency range the oscillator must have provision for crystal control on ten channels and must have the intermediate frequency. A 400 c.p.s.modulation tone arranged to be switched on at will could be provided but it is not a necessity. Remote control of volume must also be provided.

(22) Automatic Volume Control

22.1 AVC is not necessary for this receiver although cathode ray direction finders have been constructed in which the control was obtained from the sense amplifier channel and the gain of all three receivers altered by the signal input to the sense aerial. It is found difficult in practice to make this system operate satisfactorily over a reasonable range. Since bearings taken on signals which have faded to small amplitudes are usually greatly in error it is desirable that the fading should show on the cathode ray tube. AVC minimizes the fading and would lead to taking erroneous bearings.

(23)
Method of Operation

23.1 It is intended that the operation of the direction finder be as follows:-

1. Tune in the desired signal, adjusting gain to give an output of reasonable size on the cathode ray tube.

2. Parallel the input circuit, adjusting the trimmer controls of phase and gain to give a straight line at 45° on the cathode ray tube.

3. Release parallelling switch. Read bearing.

4. Press sense button and note sense.

(24)
Spare Cathode Ray Tubes and Calibration Charts

24.1 At least two spare cathode ray tubes with their calibration curves must be provided. When the calibration charts of station are prepared, separate charts for each cathode ray tube should be drawn. When a cathode ray tube is replaced the operator simply makes use of the appropriate calibration chart.

(25)
Spare Radio Tubes

25.1 A spare set of radio tubes for the receiver should be tested in the direction finding unit and supplied.

(26)
Accessibility

26.1 The construction should be such that the tubes may be readily replaced and such that the units may be easily removed for repair without disturbing the alignment of other units.

(27)
Instruction Books

27.1 A booklet giving the "Operating Procedure" and also a brief description of the type of results likely to be encountered in normal practice should be supplied with each unit. In addition a booklet giving full details of alignment procedure and initial adjustments on installation should be given in ordered sequence. Complete circuit diagrams should be included together with details of the sizes and ratings of the various components used. A list of replacement parts should be given. A description of the initial construction of the aerial and station layout could conveniently be given in a third booklet.

SHORT WAVE CATHODE RAY DIRECTION FINDER

Section Three

DESCRIPTION OF SHORT WAVE CATHODE RAY DIRECTION FINDER CONSTRUCTED BY THE NATIONAL RESEARCH COUNCIL

Appended to this Section is a copy of a brief paper "A Cathode Ray Direction Finder" and a copy of the operating instructions for long wave cathode ray direction finder No.4, which describe the development and construction of a long wave cathode ray direction finder suitable for use in coast stations.

In the course of development and testing of this long wave model, a number of general design considerations became apparent which formed a basis for the design of a new model for short waves.

The most important of these concerns the condenser tracking necessary for single dial control of a cathode ray direction finder. If the R.F.and mixer tuning condensers of a superheterodyne depart from true tracking by 1 or 2% in capacity, the only result is a slight decrease in gain and image selectivity, but, if the tuning capacity of one stage in one receiver of a cathode ray direction finder departs 1 or 2% from tracking with the tuning capacity of the corresponding stage in another receiver, then the discrepancies in phase shift of one receiver relative to the other may be very great. Consideration of this factor will show that for coils of average Q, and a tuning range of 2 to 1 (capacity range 4:1) this error in tracking must be kept to the order of about 1/10 of 1% if the relative phase shift per stage is to be kept to the order of 5°. It is at once apparent that a gear or belt drive to couple the corresponding condensers in the three channels is very undesirable, since even minute amounts of backlash will result in very large phase shifts. In the long wave instrument, this system was used and gave trouble despite the very narrow band widths (and hence large tolerances) involved. Since in our case the construction of a 9 or 10 gang condenser was not feasible and since the tracking between the elements of a single receiver is not too critical, the solution seemed to be the use of a three gang condenser to tune the three mixers, another for the three second R.F's, and another for the three first R.F's, with a gear or belt drive to turn the three gangs and the beat oscillator in unison. The mechanical discrepancies in tracking thus taken care of, it becomes a relatively simple matter to provide cam driven trimmers or other devices to achieve the necessary electrical precision should it be greater than that of available condenser gangs.

The use of the above ganging system however, complicates the electrical isolation of the three channels. If the usual condensers in which the three rotors are supported by a common metal shaft and the stators only partially shielded were used, it is possible that the multiple connections between critical points in the three channels would introduce cross-talk. To avoid any such troubles it was decided to be on the safe side by using condensers in which the three sections were completely isolated electrically although still mechanically connected by an insulated frame and rotor shaft. The condensers chosen were also well designed mechanically so as to be free of play in the bearings.

A third problem which affects the general layout of the receiver is that of accessibility for repair. Previous experience has shown that it is highly desirable to be able to remove a chassis from the complete assembly without in any way upsetting the ganging of the condensers. From many considerations it was decided to accomplish this by mounting the condenser gangs as separate units connected through co-axial lines to the rest of the circuit.

The beat oscillator circuit buffers were considered essential for high frequencies (although they may be eliminated at frequencies up to 1500 Kc.) and it was decided that the three of them might advantageously be built into a unit by themselves instead of each being incorporated into its associated receiver channel. With this arrangement it is possible to make their operation sufficiently stable to eliminate several adjustments otherwise required.

Figure 1 is a back view of the cathode ray direction finder constructed according to these principles. The three vertical boxes contain the N-S, E-W and sense R.F. amplifiers. Each box contains two R.F.stages and a mixer stage. Immediately above and connected to them by co-axial leads are the three, 3-gang tuning condensers. The uppermost one tunes the three first R.F.stages, the next tunes the three second R.F. stages and the bottom one tunes the three mixer stages. Immediately below is the beat oscillator (black box) on the back of which is mounted a box containing the three buffer tubes, the outputs of which go to the three mixers through short shielded leads.

The I.F. outputs from the mixers are connected to the I.F.amplifiers on the bottom of the rack by flexible co-axial cables. The condenser gangs, R.F.amplifiers and beat oscillator are mechanically mounted on a rigid brass plate fastened to the back of the rack but are electrically insulated from it and from each other.

Figure 3 is a front view of this brass plate showing the gearing mechanism for turning the 4 condenser gangs in unison, the mechanism for operating the wave change switches, and the R.F.commoning devices. All these are rigidly fastened to the brass plate. The units mounted on the back of the plate, except the oscillator, may be removed without disturbing the mechanisms on the front and when replaced will be sufficiently well aligned by their mounting screws to permit normal operation. As far as possible, all alignment controls were made available for adjustment from the front of the plate. The motor at the top operates the band change switches. The other motor, actuated by the dummy tuning dial, rotates the tuning condensers to a position corresponding to the reading on the dial.

Figure 2 is a back view of the R.F.amplifiers with covers removed. Note that the N-S and E-W units are mirror images of each other. This idea was incorporated to make the commoning connections as short as possible in order to keep their impedance low. In this photograph the inner shields and coil shield lids have been removed from the right hand receiver so that the inner construction is visible. The small plug at the top of the box is the antenna input connection, the top chassis is the first R.F., the middle chassis is the second R.F. and the bottom one is the mixer. It is worthy of note that the three remaining connections between the three receivers (leads to power supply, leads to buffers and leads to I.F.amplifiers) are all grouped together on the bottom chassis and, so far as introduction of cross-talk is concerned, may be regarded as a single connection.

The three units at the bottom of the rack in Figures 1 and 3 are the I.F.amplifiers. These are almost identical in construction with those in the long wave cathode ray direction finder. The intermediate frequency was increased to 440Kc. to give sufficient image selectivity when using only three R.F.tuned circuits. The input and output connections to the I.F.units are made through flexible co-axial cable which allows some latitude of choice when selecting the position for installing the I.F.amplifiers. The three coarse gain controls carefully shielded from one another have all been placed together in a separate unit to facilitate mounting the operating knob. This box is mounted behind the main panel alongside the beat oscillator and in between the main panel and the box holding the three buffer tubes. The electrical connection of the coarse gain control to the circuit is made through a "T" connector in the co-axial lead joining the R.F. and I.F. units. The output tubes protrude from the box to minimize heating effects.

Figure 4 shows the false covers and desk in place on the front of the rack as the instrument was first assembled for field tests. The only controls mounted at this time were the tuning dial and coarse and fine gain controls. Since then the On-Off switch, band change switch, gain and phase trimmers and antenna parallelling control have been mounted near the tuning dial. By opening the doors as in Figure 5 practically all alignment controls become accessible.

The cathode ray tube and box shown in these photographs is one of the units designed for the long wave receiver. Brilliancy and focussing controls have been added and the I. F.output circuits housed in the box changed by the addition of a coil in parallel with each of the load resistors. These coils were designed to have the same value of reactance at 440Kc. as the parallel capacity due to cables, connectors etc. They lower the plate supply voltage required to 550 volts, while the Q of the resulting resonant circuit is so low (due to the 20,000 ohm resistors) that all the advantages of the original resistor load are retained.

This cathode ray tube unit was used because it was already at hand. A six to eight inch tube in a box suitable for table mounting and containing the audio monitor would be a preferable arrangement.

Figures 6 and 7 show the power supply unit which supplies all the filament,plate and bias voltages required for the whole instrument. Three separate rectifiers are used, - one supplying 2000 volts for the cathode ray tube, one supplying 550 volts for the output stages, and one supplying 250-100 volts for plates and screens.

Alterations suggested by Field Trials

It is believed that some of the difficulty in maintaining alignment of the three I.F.amplifiers over a wide range of room temperature is due to the gradient in temperature which usually exists between the levels of the three units causing each to be at a different temperature. An obvious remedy for this condition would be to mount the three boxes vertically side by side as was done with the three R.F.units.

1 mmf. trimmer condensers operated by belt driven cams were provided to permit tracking the E-W and sense condensers within 1/10 mmf. of the N-S condensers. These cams, one of which is visible in Figure 2, consist of brass cylinders having 72 screws arranged radially which may be varied to change the effective cam shape. In practice, it was found that these cams were very tedious to adjust because the condenser must be rotated 1/3 revolution to bring each screw from its working position to a position where it can be adjusted. By making these cams in the form of discs with screws arranged axially passing completely through the disc so that a screw can be adjusted from one end while the other end is still in contact with the condenser, the alignment operation is enormously facilitated. Also it would be advantageous to have the cams adjustable from inside the front door instead of from the back.

The tuning range of the instrument as constructed is 1.5 to 3.2 and 4.0 to 7.2 mc. Consideration of short wave direction finding problems has since shown the desirability of operating at still higher frequencies and since no serious difficulties were encountered up to 7 mc. it is believed that the addition of a third band, 7 to 14 mc. or higher, would be quite justified. Although this additional frequency range was not specified in Section Two, it is felt that it should be included.

The sensitivity of the present arrangement is about that given in Section Two. Somewhat greater sensitivity would sometimes be an advantage.

If a small variable condenser across a tuned circuit is to be used as an operating phase trimmer, it is of course only possible to keep the overall phase shift equal in the three channels and it is not possible to obtain precise alignment of each corresponding tuned circuit. With the precision of tracking between receivers secured in the present case (1/10 mmf.) the variation of input impedance between receivers due to this departure was still a noticeable source of error when a simple input parallelling switch was employed. To illustrate this, consider the case of antennae impedance of Z ohms, E-W receiver input impedance Z ohms, and N-S input impedance .92 Z ohms. Then if the receivers are adjusted to give a 45° line with the inputs paralleled (effective impedance of switch is 0 since it maintains the same voltage on both receivers) i.e., with the input currents in the ratio 1 to .92, then when the parallelling switch is opened (input currents of the ratio 2 to 1.92) a signal producing equal voltages in each aerial will show as a line at approximately 44°, - a 1° error. At some frequencies the errors from this cause were found to be as large as 2½°. Because the impedances involved are complex, these errors usually show as a combination of error in bearing and an ellipse. It is not permissable to leave these errors in the instrument and allow for them in the calibration chart because it is likely that variations in tracking of about this order will occur as bearings wear etc. The remedy applied in this case was a change of the parallelling switch circuit so that with the switch in the paralleled position, dummy impedances approximately equal to the antenna impedance are included in the receiver input circuits. With this arrangement these errors are reduced in proportion to the precision with which the dummy antenna impedances approximate the real antenna impedance. Because the elimination of the errors is at best only partial any additional effort spent on removing the discrepancies in tracking, the primary cause of the errors, is justified.

Field Oscillator

The original intention was to provide a test oscillator to permit alignment of the cathode ray direction finder in the absence of a signal from the desired transmitting station so that a minimum time would be required to take a bearing on signals from a station whose frequency was accurately known beforehand. To provide the greatest utility in this respect the oscillator was to have push button selection of a number of crystal controlled frequencies as well as continuous tuning.

Later experience has shown that if this test oscillator coupled to a short vertical aerial, is located several hundred yards from the Adcock aerial it can fulfil an additional and very useful function by providing a readily available check on the antenna stability. It is also useful as a check on the sense indication.

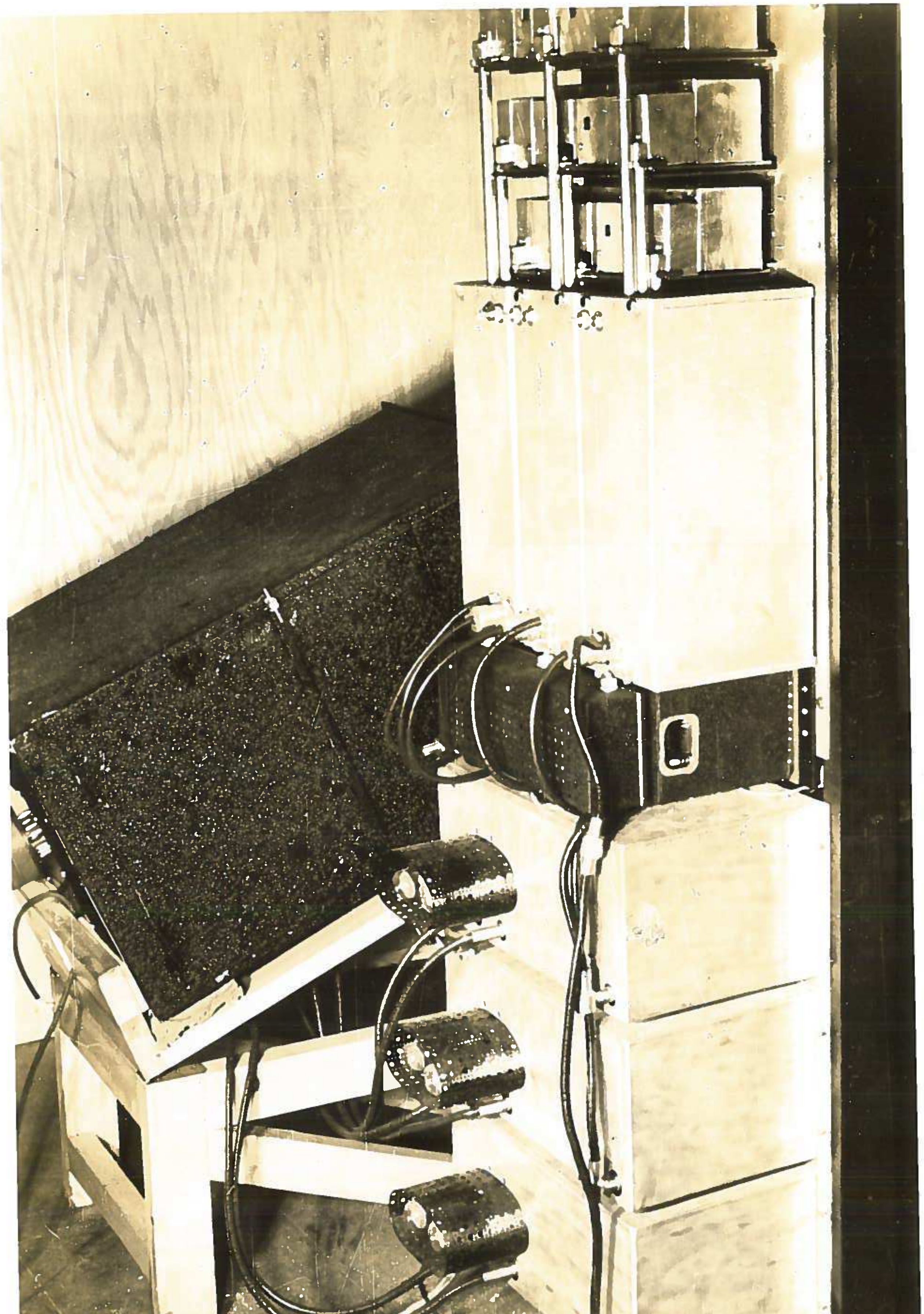

Fig. I

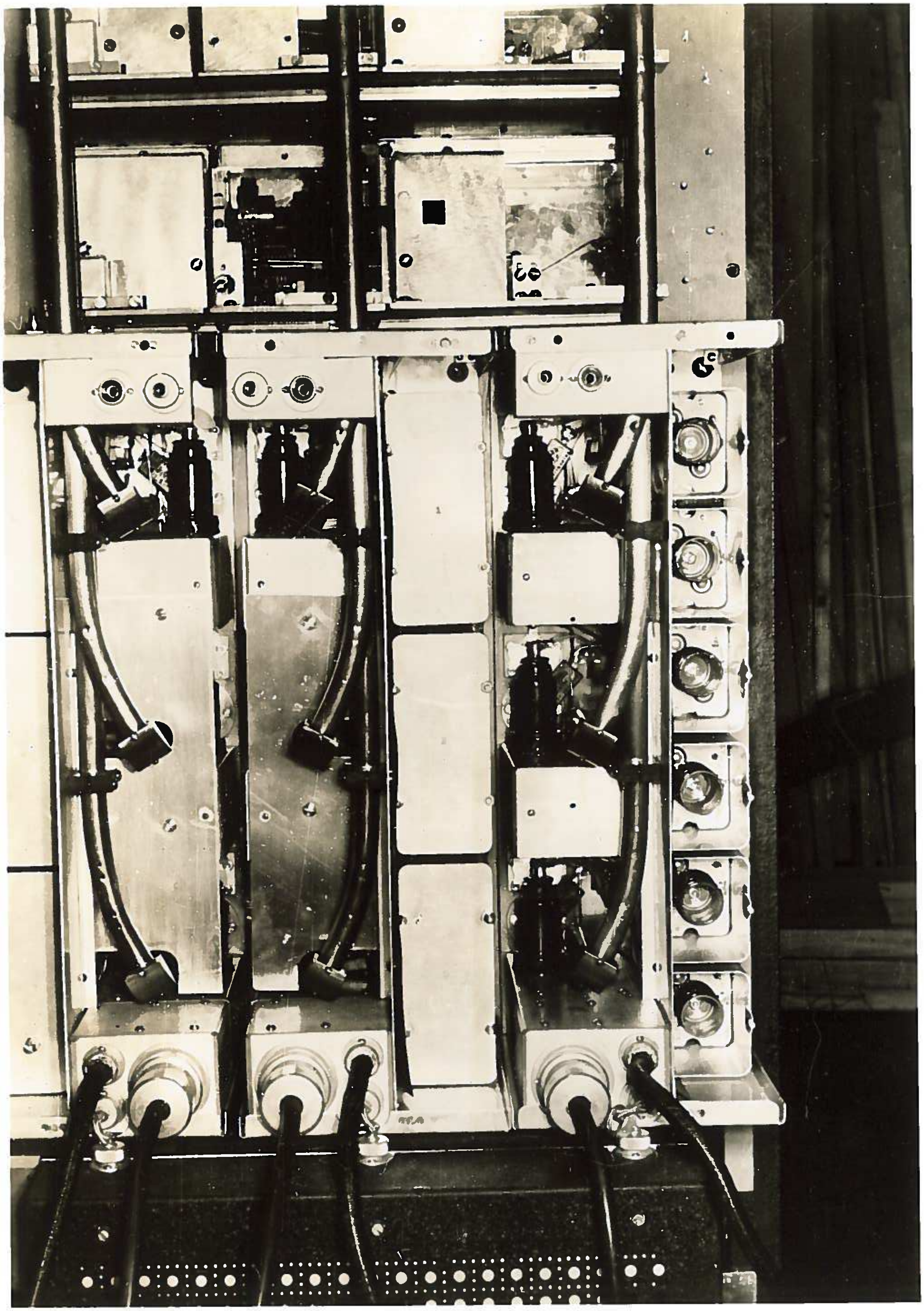

Fig. 2

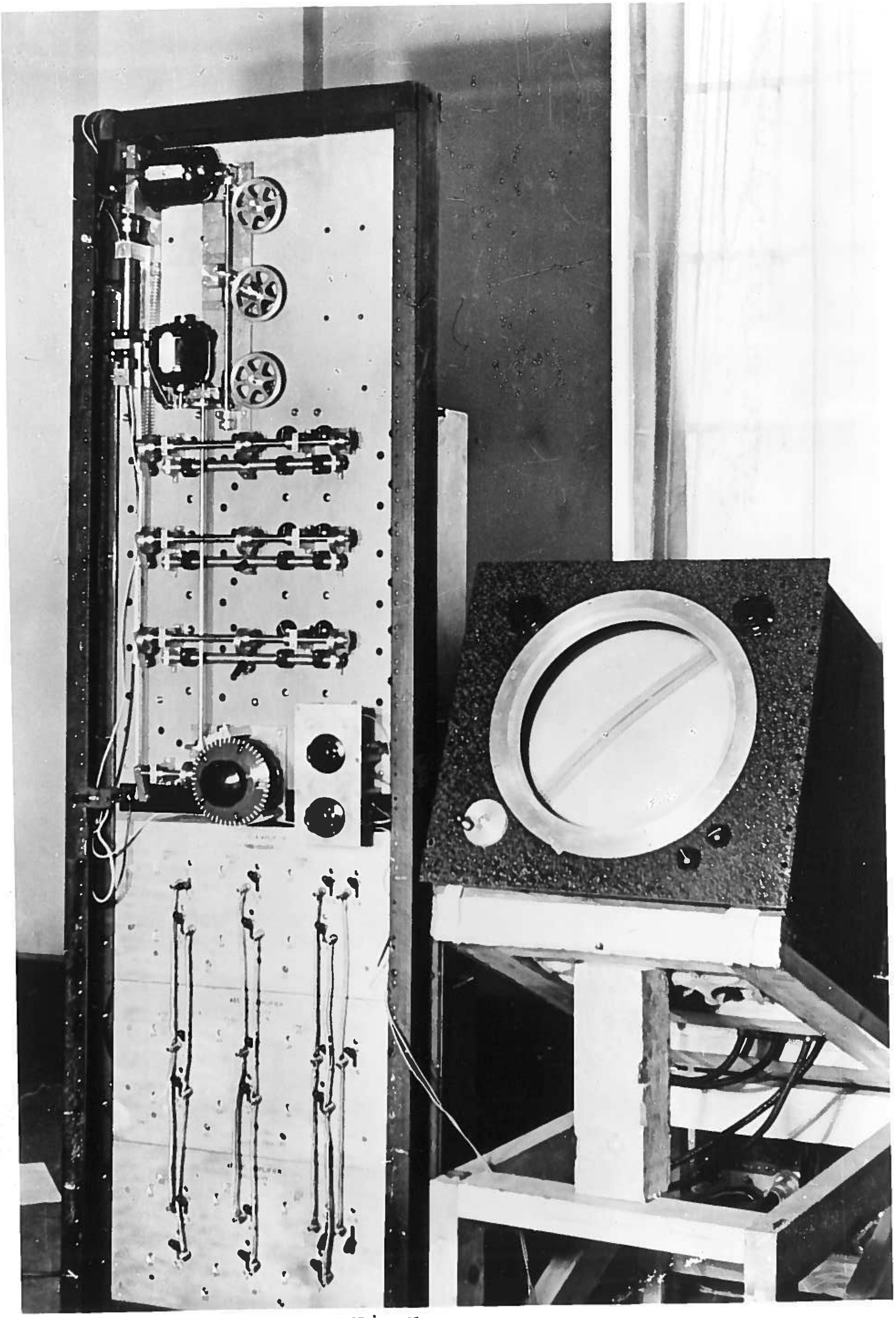

Fig. 3

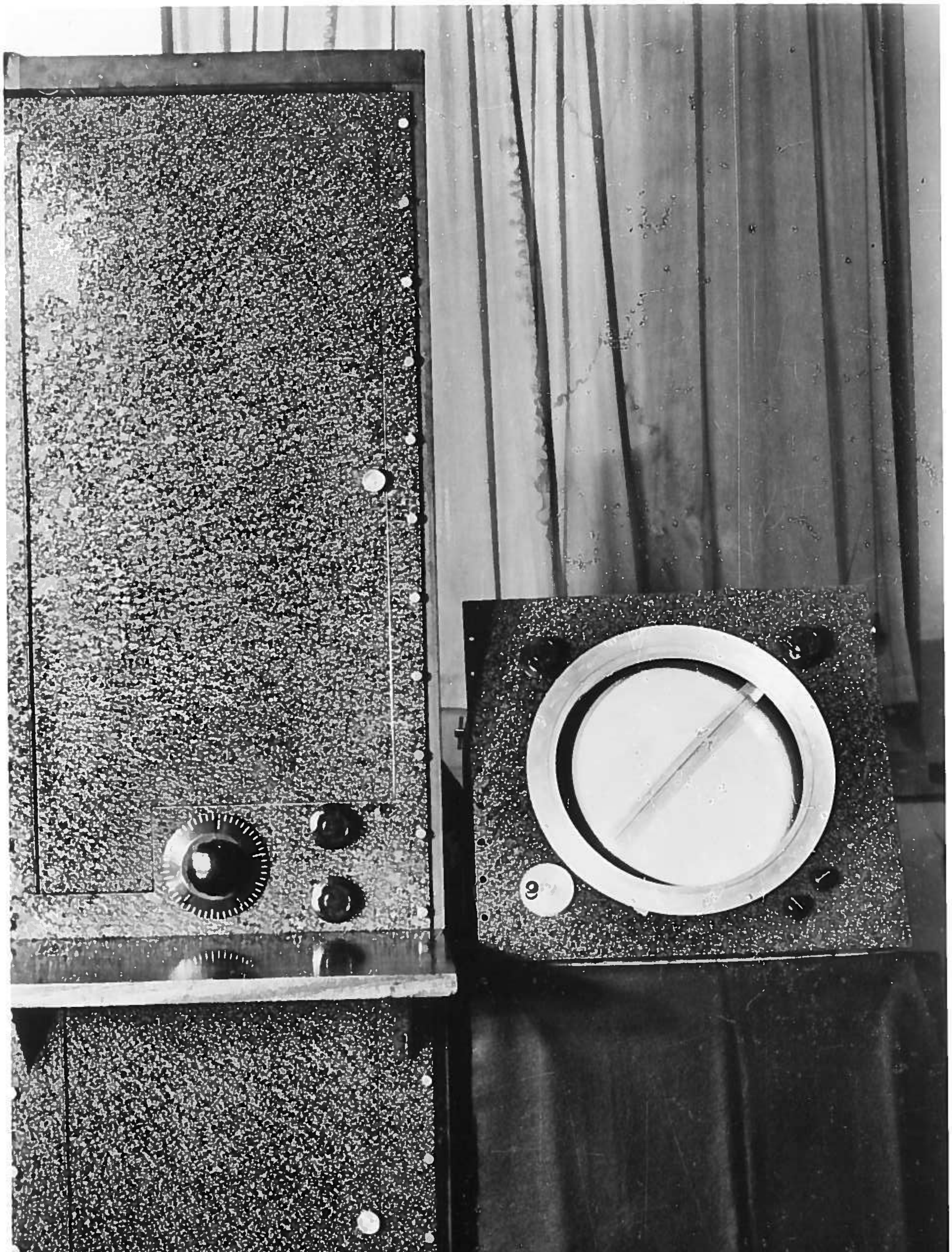

Fig. 4

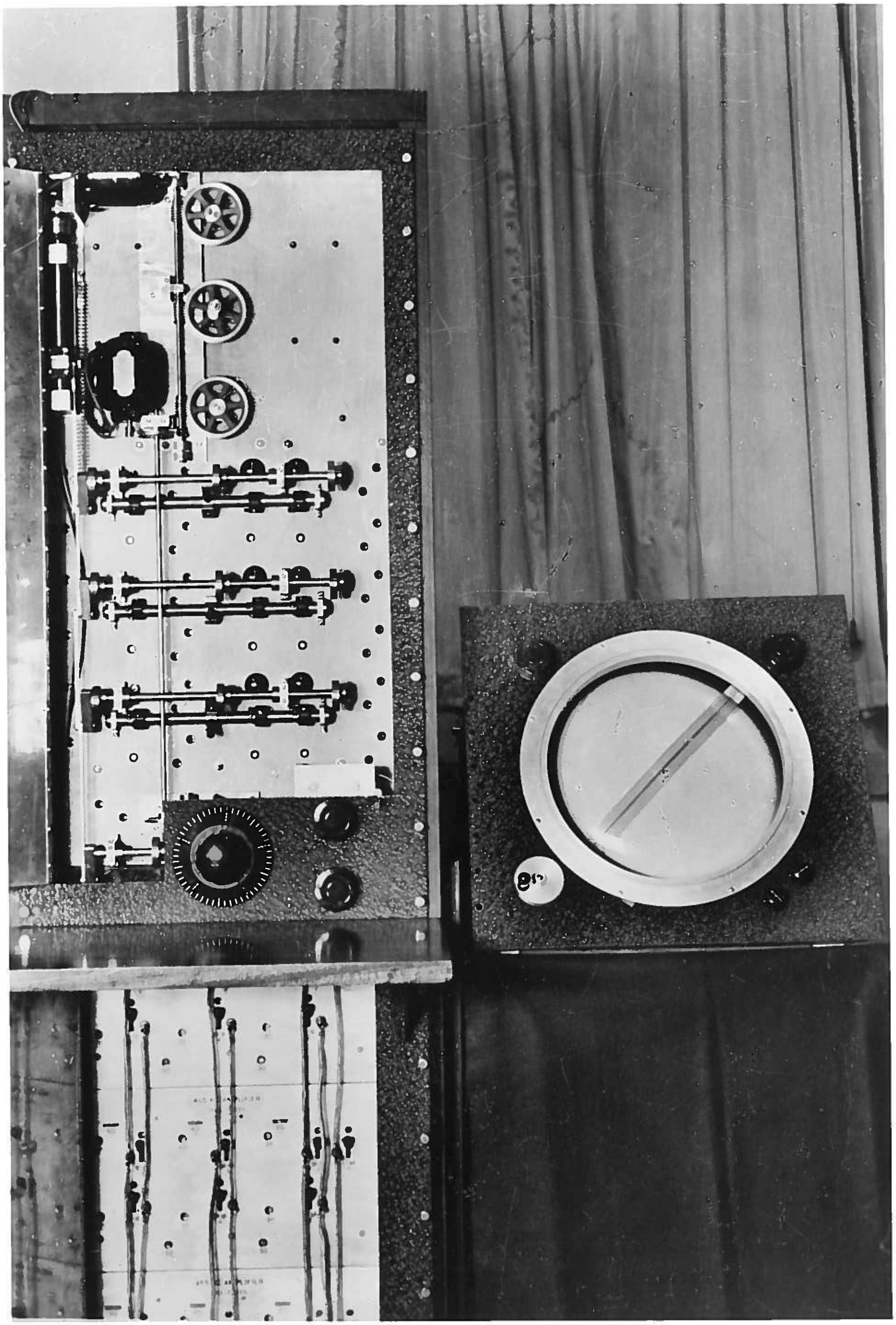

Fig. 5.

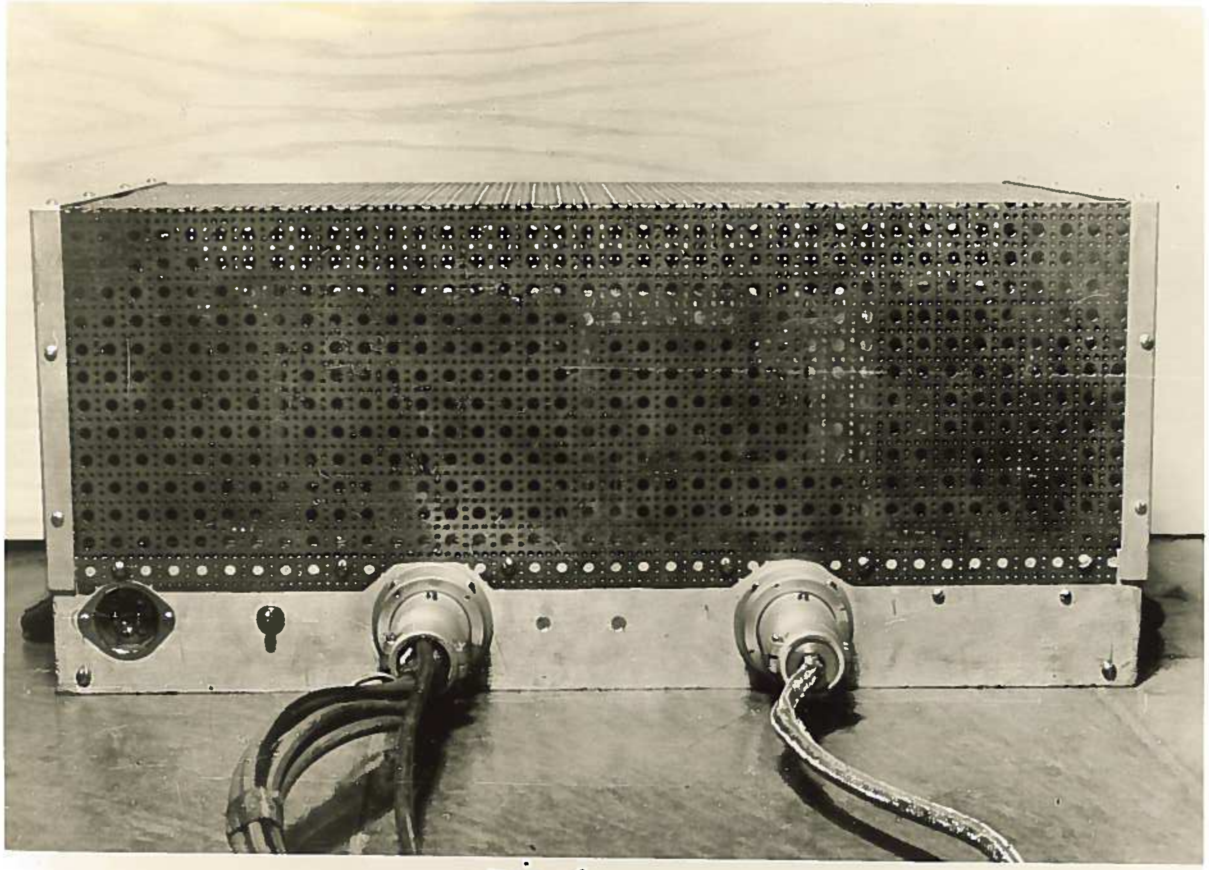

Fig. 6

Fig. 7

I N D E X