TECHNICAL INSTRUCTION

T.4

BBC Variable-frequency Drive Equipment

First Issue, October 1955

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PHOTOGRAPHS

DRAWINGS AT END

NOTE *Technical Instruction T.4 replaces Technical Instruction TT.4, copies of which should be destroyed.*

BBC VARIABLE FREQUENCY DRIVE EQUIPMENT

SECTION 1

INTRODUCTION

General

The BBC Variable-frequency Drive Equipment comprises apparatus which, by suitable selection and combination of various units, can be used to provide drive at any frequency between 140 kc/s and 22·4 Mc/s.

The nucleus of the equipment is a standard Variable-frequency Oscillator, Type VFO-4, which has a frequency coverage of 0·7 to 1·4 Mc/s, and is used in conjunction with frequency converters for producing frequencies outside this fundamental range. The frequency stability of the oscillator, after an initial ageing period of about two months, is $\pm 1/10^6$ approximately over a period of several hours; for a period of a week the stability is $\pm 10/10^6$ approximately. The frequency discrimination of the oscillator is such as to allow, without exercising great skill, adjustment of the frequency-control dial to given settings with sufficient accuracy to ensure that the resulting carrier frequencies are within the frequency tolerances laid down by international agreement. At present, these tolerances are:—

Low-frequency broadcasting band (150 kc/s to 285 kc/s):

± 20 c/s for transmitters in service before January 1st 1950, and ± 10 c/s for transmitters in service after that date.

Medium-frequency broadcasting band (525 kc/s to 1,625 kc/s):

As for low-frequency band, excepting International Common Frequency channels (± 20 c/s after January 1st 1950).

High-frequency bands (within range 3,950 kc/s to 26,100 kc/s):

± 30 parts in 10^6.

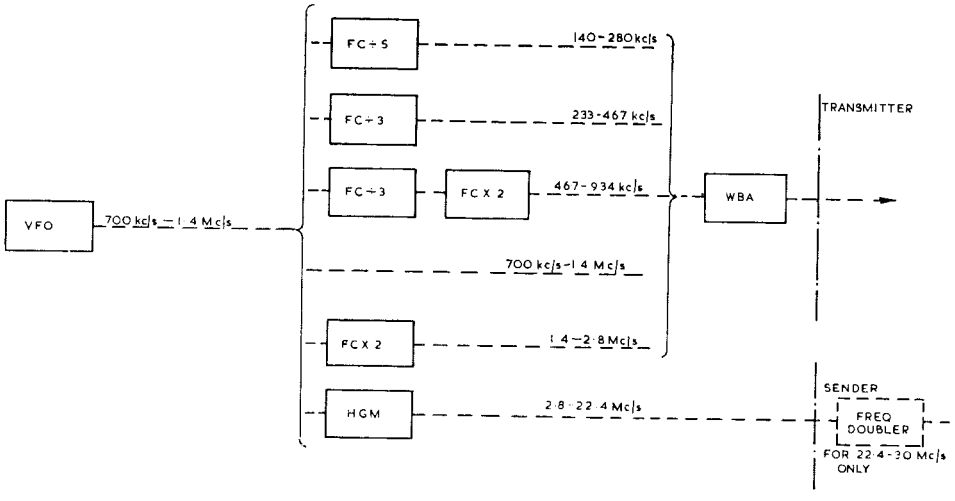

Fig. 1.1. Alternative Combinations of Variable-frequency Drive Equipment, showing Frequency Ranges covered

Fig. 1.1 is a schematic diagram showing the different arrangements of equipment with which the complete range of carrier frequencies is obtained. The derivation of frequencies below the fundamental range of the oscillator is effected with two forms of frequency convertor, one being a

divider and the other a multiplier. The divider can be made to divide by either 5 or 3, this being determined by the adjustment of certain circuit values. For the purpose of indicating which factor is involved, units adjusted for division by 5 are known as Type-FC÷5-1 Frequency Convertors, whilst those set for division by 3 are known as Type-FC÷3-1 Frequency Convertors. This method of code numbering is applied also to the multiplier which, with a multiplication factor of 2, is known as the Type-FC×2-1 Frequency Convertor. This convertor is used in association with the Type-FC÷3-1 convertor for applying a division by 1·5 to the fundamental range of oscillator frequencies. The Type-FC×2-1 convertor is also used for producing frequencies in the range 1·4 to 2·8 Mc/s.

The Wideband Amplifier, Type WBA-1, is used on frequencies below 2·8 Mc/s to provide the necessary r.f. power for driving the transmitter. A Harmonic-generator Multiplier, Type HGM-4, is used for deriving frequencies in the short-wave bands. This unit provides alternative multiplication factors of 4, 8 and 16 and its final stage is a power amplifier providing the requisite r.f. output power for driving a sender. For carrier frequencies above the upper limit available through the HGM-4 a stage of doubling is provided in the sender and the drive equipment is set up for half the carrier frequency.

Cabinet Layouts

The drive equipment is housed in steel cabinets. Different layouts are used in accordance with the particular requirements of an installation. Figs. 1.2(a) and 1.2(b) show a selection of typical cabinet layouts.

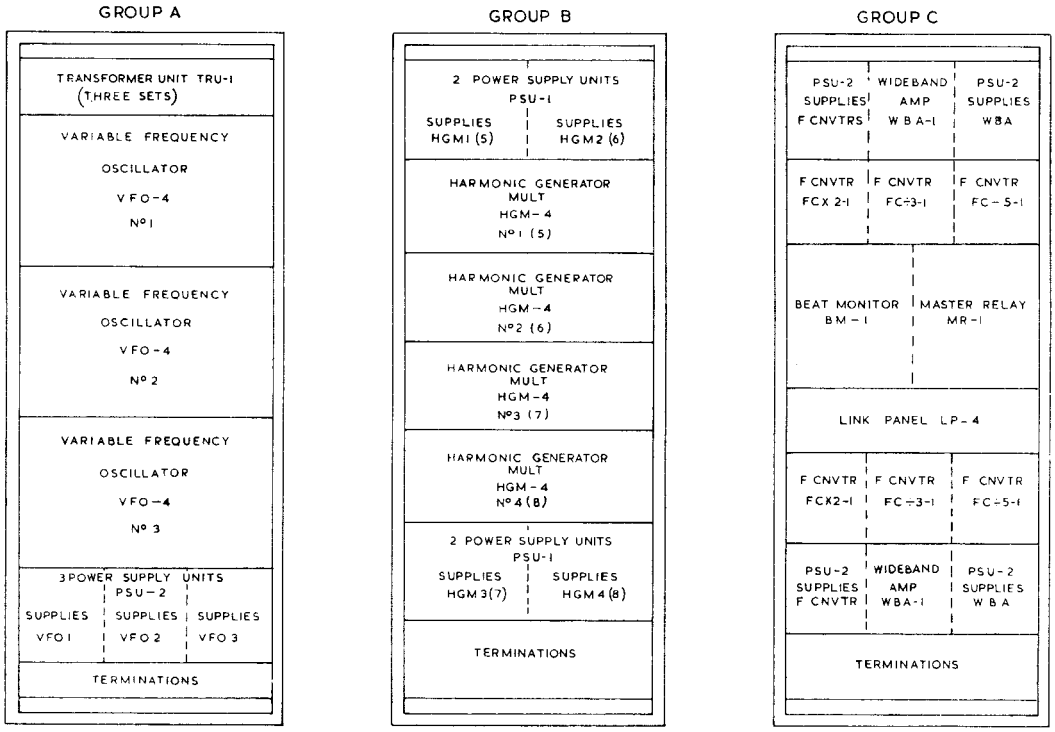

Fig. 1.2a. Variable-frequency Drive Equipment. Cabinet Layouts, Groups A to C

Three of these cabinet layouts, groups F, G and H, form completely self-contained variable-frequency drives in themselves. Groups F and H each provide a single variable-frequency drive channel covering carrier frequencies between 2·8 and 22·4 Mc/s while group C provides a single variable-frequency drive channel between 140 kc/s and 2·8 M/cs.

The remaining cabinet layouts, in combination, are capable of meeting the most extensive requirements. For example, a typical installation for the main drive room at a station having six short-wave

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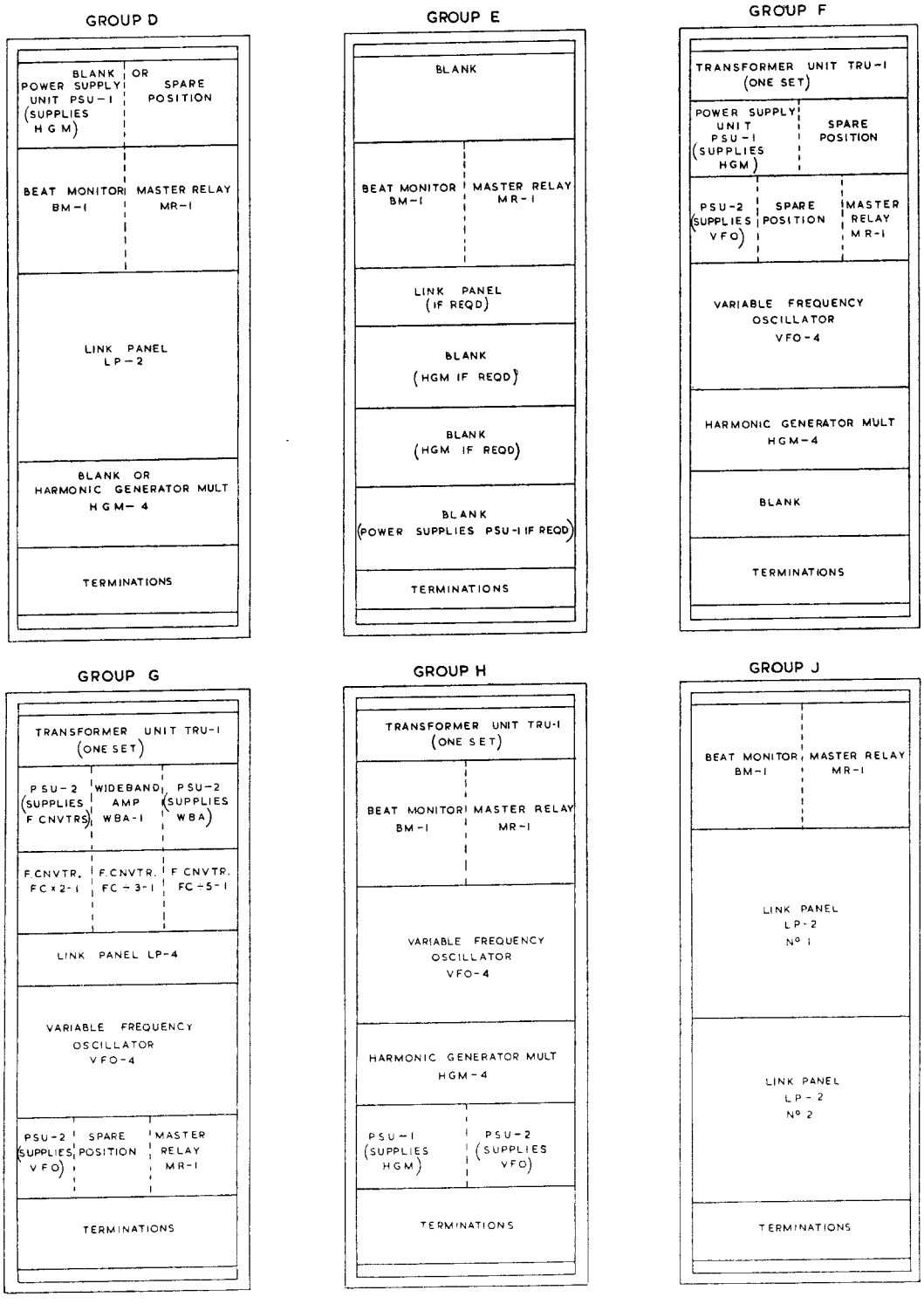

Fig. 1.2b. Variable-frequency Drive Equipment. Cabinet Layouts, Groups D to J

senders required to operate between 2·8 and 22·4 Mc/s would comprise six cabinets as follows:

3 group A
2 group B
1 group D

This installation would accommodate three spare channels if required.

All units of the cabinet layouts, with the exceptions of oven assemblies and transformer frameworks, are easily removable from the cabinets for maintenance. The oven assemblies and transformer frameworks, owing to their weight, need partial dismantling before removal, and unlike the other units are not provided with plugging connectors.

The mains supply for each cabinet is taken to a distribution box fitted in the base of the cabinet; also in the base of the cabinet are screening boxes through which external r.f. connections are made.

Valves

The types and quantities of values used in the various units of the equipment are given in the following table

	AC/SP3*	D42	AL60	5B/250A	UU5
Variable-frequency Oscillator	6	1			
Harmonic-generator Multiplier	2		1	2	
Power-supply Unit, PSU-1					2
Power-supply Unit, PSU-2					1
Beat Monitor	3		1		1
Frequency Convertor, FC×2-1	1				
Frequency Convertor, FC÷3-1	4				
Frequency Convertor, FC÷5-1	4				
Wideband Amplifier		1	2		

*Grade B

SECTION 2

POWER-SUPPLY EQUIPMENT

General

The four types of unit concerned with supplies for the variable-frequency drive equipment comprise:—

Power-supply Unit, Type PSU-1
Power-supply Unit, Type PSU-2
Transformer Unit, Type TRU-1
Master Relay, Type MR-1

The first two items provide operating supplies for the various amplifiers. The Type-PSU-1 unit is used only with the harmonic-generator multiplier (Type HGM-4), for which it provides a grid-bias supply in addition to h.t. and l.t. supplies. The Type-PSU-2 unit is employed generally with the remainder of the amplifiers, and a single power unit is capable of supplying h.t. and l.t. for a variable-frequency oscillator (Type VFO-4), a wideband amplifier (Type WBA-1) or, with their smaller individual demands, a group of frequency convertors (Types FC×2-1, FC÷3-1 and FC÷5-1).

When used with the variable-frequency oscillator, the Type-PSU-2 unit is fed with a voltage-stabilised a.c. input, which is obtained by interposing a constant-voltage transformer in its mains supply. The transformer is situated in a Type-TRU-1 unit, where it is paired with another transformer through which are derived low-voltage supplies used for heating purposes in the associated oven assembly. Thus, a pair of transformers have complementary functions in supplying a single variable-frequency oscillator. The Type-TRU-1 unit is designed to accommodate three similar pairs of transformers but is only equipped in accordance with the number of variable-frequency oscillators mounted in the cabinet.

The main function of the Master Relay, Type MR-1, is to provide temperature-alarm facilities for one or several variable-frequency oscillators. The latter is the more common practice, and all the v.f.o. equipments will not necessarily be installed in the same cabinet as the master relay. The unit incorporates the necessary conversion apparatus for supplying its internal alarm devices and also the temperature-alarm relays in the individual variable-frequency oscillator assemblies. The master relay provides a separate l.t. supply for use with indication lamps employed for signalling r.f. output switching conditions. These lamps are fitted (a) on Type-LP-2 link panels and (b) in variable-frequency oscillators and harmonic-generator multipliers. Apart from two lamps which, in each variable-frequency oscillator, are connected in oven-heating circuits all other indication lamps in equipments under item (b) are supplied from valve-heater circuits.

The four types of power-conversion equipment are designed for operation with a.c. inputs between 200 and 250 volts, all power transformers, excepting the constant-voltage type, being tapped for 10-volt increments between these limits. No meters are fitted on the Type-PSU-1 and Type-PSU-2 units, but provision is made for metering h.t. supplies in the equipments served by them.

The power-supply units and master relay employ a chassis with a standard front-back dimension (19½ in.) and height (4 in.), the width being either 7 in. or 9 in. dependent on the number of terminal connections required.

Power-supply Unit, Type PSU-1, Fig. 1

This unit, used exclusively with the Type-HGM-4 harmonic-generator multiplier, has the following outputs:—

H.T. supply:	300/350 volts, 250 milliamperes.
L.T.A.C. supplies:	4 volts, 5 amperes, centre-tapped, 6·3 volts, 3 amperes, centre-tapped.
Bias supply:	80 volts, 120 milliamperes.

Two mains transformers are used for deriving these supplies, through circuits of conventional arrangement as shown in Fig. 1.

The unit has a 9-in. wide chassis, on the front face of which are fitted a mains-supply switch and fuses, h.t. and bias fuses, and an indication lamp (orange) connected across the 4-volt a.c. output. At the rear of the chassis is a 10-way male connection block through which the external connections are established. On this block is a row of knife contacts which engage female contacts on a block fixed to the tray carrying the supply unit. The female contacts, with the exception of two for connecting the mains supply, are wired to a 12-way plug-and-socket connector at the back of the harmonic-generator multiplier. The interconnection can be ascertained by relating the information given in Fig. 1 with that shown in Fig. 9.

Power-supply Unit, Type PSU-2, Fig. 2

Fig. 2 is a circuit diagram of the supply unit, the output ratings being:—

H.T. supply: 300 volts, 120 milliamperes.
L.T.A.C. supplies: Two at 4 volts, 5 amperes, centre-tapped.

Note:—The tapping leads for the primary of the mains transformer, TR1, must be set for a 230-volt supply when the unit is feeding a variable-frequency oscillator, because an input at that voltage is provided through a constant-voltage transformer situated in the Type-TRU-1 transformer unit.

Transformer Unit, Type TRU-1

The transformer unit has a steel framework designed to hold three similar pairs of transformers, each pair comprising an oven-heating transformer with two outputs and a constant-voltage transformer. The unit is placed at the top of cabinets housing variable-frequency oscillators, and fitted with the requisite number of pairs of transformers. At the rear of the framework is a steel panel on which are mounted a pair of Slydlock-type holders, for fuses connected in a common mains supply, and three groups of six screw-in type holders (Belling-

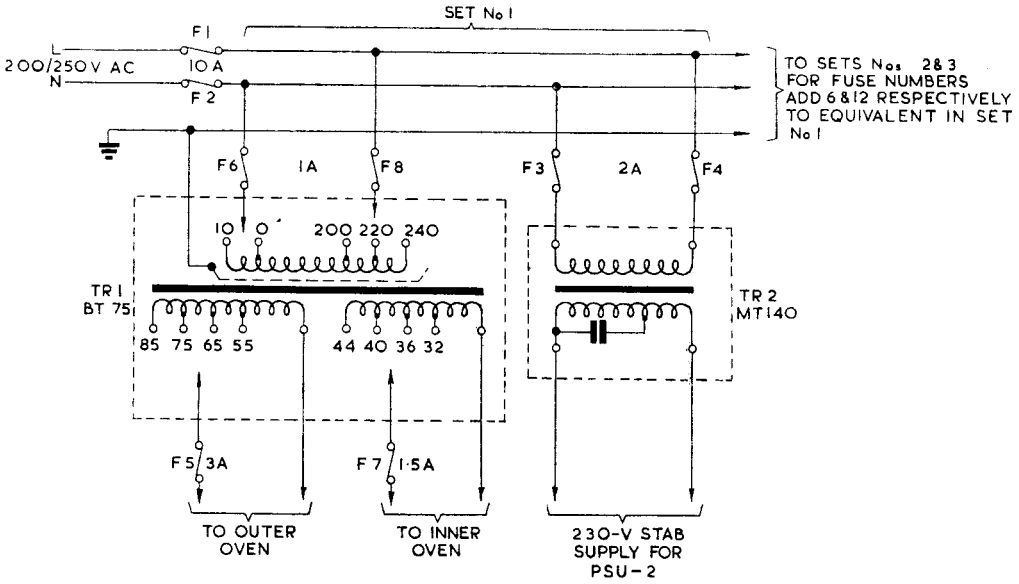

Fig. 2.1. Circuit Diagram for Transformer Unit Type TRU-1

The components are mounted on a chassis of 7-in. width, an 8-way male connection block being fitted at the rear. The mains on/off switch, mains-supply and h.t. fuses, and an indication lamp (orange) are mounted on the front of the chassis. The rear contacts of the power unit engage a female connection block wired, apart from the mains connections, to a tag block fixed to the tray carrying the variable frequency oscillator assembly. Details of the interconnection are included in Fig. 4, a schematic of the assembly.

Only one of its two l.t. outputs is required when the power unit is used with a wideband amplifier; see Fig. 12. This amplifier has plugging contacts similar to those for the power-supply unit. The same method of connection is employed with the frequency convertors, whose circuit diagrams are given in Figs. 10 and 11.

Lee) carrying fuses for the individual transformer sets. Fig. 2.1 is a diagram showing the method of connection for all three sets.

The tappings on the secondary windings of the oven-heating transformer, TR1, provide for a wide range of adjustment of the voltages applied to the oven-heating mats; suitable working voltages are chosen at the time of installation. The output ratings of the transformer are 120 watts (maximum current 1·5 amperes) for the outer-oven winding, and 25 watts (maximum current 0·6 amperes) for the inner-oven winding. The figures for maximum possible dissipation with full voltage applied to both ovens are approximately 98 watts and 23 watts, respectively.

The constant-voltage transformer is rated for 150 watts and maintains the input voltage of a Type-PSU-2 unit at 230 volts$\pm$1 per cent for mains

voltages between 190 and 260 volts. The transformer is a saturated-core type with a primary wound for 220 volts, the approximate mean of the input-voltage range. The design ensures that the core begins to saturate with a low input voltage, about 20 volts, and with inputs of the order of 220 volts it is operating well into the saturated portion of the B-H characteristic. The constant-voltage characteristic is obtained at the expense of distorting the secondary-voltage waveform and, as a means of improving the waveform, the main part of the secondary winding is tuned for parallel resonance at 50 c/s with a 20 μF capacitor which is contained in the transformer casing; the open-circuit inductance of the tuned section is approximately 0·5H. A small part of the secondary winding is not included in the tuned circuit and is wound directly over the primary winding, in the opposite sense. Its purpose is to compensate for relatively small changes of secondary voltage with variation of primary voltage, which are the result of the B-H curve of the core not having an ideal saturation characteristic.

The transformer unit is not provided with a terminal position, the outputs of the transformer sets being taken directly to the equipments for which they are intended. From each set, the two oven-heating supplies are fed to terminals on a main tag block behind a variable-frequency oscillator (see Fig. 4) whilst the constant-voltage supply is taken to the connector at the rear of the power-supply unit associated with that oscillator (see Fig. 2).

Master Relay, Type MR-1, Fig. 3

A 7-in. wide chassis, with an 8-way connection block at the back, carries the components of the master relay, a circuit diagram of which is shown in Fig. 3.

The functions of the master relay are to provide (a) a 24-volt d.c. supply for operating an internal relay Y1 and pairs of relays in the temperature-alarm circuits of variable-frequency oscillators, (b) a 6·3-volt supply for supervisory lamps on the larger (Type LP-2) of the two forms of link panel and also for certain lamps with the variable-frequency oscillators and harmonic-generator multipliers and (c) warning of temperature abnormalities occurring in any one of a number of v.f.o. oven assemblies. The above supplies, and also a 4-volt supply for an internal lamp, LP1, are derived through transformer TR1, a half-wave rectifier circuit being used to obtain the d.c. supply. A metal rectifier, MR1, is used in this circuit, for which the output rating is 0·5 amperes at 24 volts. All fuses are on the front of the chassis, together with a mains on/off switch, an alarm indication lamp and an alarm key switch. The aural alarm is given by an external bell, connected in series with a dry battery between terminal 6 of the unit and earth. In addition to acting as a temperature alarm, the bell operates for failure of the 24-volt supply.

Provided there is normal temperature in the inner oven of a v.f.o., one of the two temperature-alarm relays is energised and the other is de-energised; further details of this part of the alarm system are given in Section 3. As a result, a contact on each relay is closed. The two contacts are in series with each other and, being connected between terminals 7 and 8 of the master relay, are responsible for completing an energising supply for relay Y1. Where a number of v.f.o. equipments are associated with a master relay, the corresponding relay contacts of all equipments are in series with the coil of relay Y1. Thus, for normal temperature conditions, relay Y1 is energised and its two contacts are open. Abnormal temperature at any v.f.o. leads to the operation of one of the alarm relays, and consequently relay Y1 becomes de-energised. This causes one of the Y1 contacts to make the supply for the red indication lamp, LP1, on the front of the unit, and the other contact completes the alarm-bell circuit. In this way attention is attracted to the abnormal condition, and the faulty equipment can then be identified by reference to the temperature-fault indication lamps on the individual v.f.o. assemblies.

The three-position key-switch, K1, is provided to enable routine testing of the alarm equipment to be carried out, and for preventing continuous operation of the bell whilst a fault condition exists. With its lever thrown from the central (*Normal*) position on the *Test* position, which is non-locking, the switch breaks the 24-volt supply and the alarms then operate as with a temperature fault. In the *Silent* position of the lever, two switch contacts make a 24-volt supply directly to relay Y1, thus silencing the bell, and another two switch contacts complete the supply for the red indication lamp. The lamp will, of course, serve as reminder that the key switch should be set to *Normal* as soon as possible.

SECTION 3

VARIABLE-FREQUENCY OSCILLATOR TYPE VFO-4

Introduction

The mean operating frequency of the Variable-frequency Oscillator, Type VFO-4, is 1·05 Mc/s, the overall frequency coverage being 0·7 to 1·4 Mc/s. The main consideration in the choice of the mean operating frequency was that of frequency stability; this is a function of

(a) the electro-mechanical stability of the inductors and capacitors, employed in the frequency-determining networks,

(b) the Q values of the inductors.

A mean operating frequency of 1·05 Mc/s permits the use of iron-dust cored inductors which are relatively small in physical size and have optimum Q values near 1 Mc/s.

The total frequency coverage is divided into four ranges as follows:

Range 1: 0·695 to 0·85 Mc/s
,, 2: 0·83 ,, 1·0 ,,
,, 3: 0·98 ,, 1·215 ,,
,, 4: 1·175 ,, 1·415 ,,

An entirely separate tuned circuit is used for each range. This division into narrow ranges enables optimum oscillating conditions to be secured on each range and also permits the use of mechanically-stable variable capacitors of small physical size. The four variable capacitors are ganged mechanically so that a single frequency control and dial system may be used.

General Arrangement of Equipment

The complete variable-frequency oscillator equipment comprises four units, these being:—

An oven assembly containing a constant-temperature chamber in which are the frequency-determining elements.
An oven relay unit.
An oscillator and separator unit.
A meter and switch panel.

Fig. 4 is a schematic diagram showing the interconnection of these units, for which detailed circuit diagrams are provided in Figs. 5 to 8.

The equipment is assembled on a steel tray bolted between the uprights of the cabinet. Fixed to the tray is a pair of angle-steel strips, spaced parallel to one another, serving as guides for bearers fitted to the underside of the oven assembly. Stops are fitted at the rear ends of the guides so that the oven can be slid to a fixed position in relation to a frame work carrying the remainder of the equipment.

A sketch of the framework, which is attached to the tray, is included with the schematic diagram, Fig. 4. This shows a side view, as seen from the oven, of a vertical panel, at right angles to which are side plates tapering towards the front of the tray. Two sections of the panel are cut away to permit mounting the oven-relay unit in the upper part, and the oscillator and separator unit in the lower part. These two units are assembled on separate sub-panels, each being secured in position by milled nuts attached to threaded studs set in the frame. Valves, and also the relays in the oven-relay unit, are placed on that side of the panel facing the rear of the cabinet, and are easily made accessible by removing slide-fitting screening boxes from supporting pillars on the back of the frame. All other components, in each unit, are placed on the opposite face of the sub-panel and are not normally accessible because they are enclosed by a screening box riveted to the frame. As, however, each unit is provided with plugging contacts for establishing all external connections there is no difficulty in removing it. This simply involves unscrewing the nuts retaining the sub-panel and then drawing the unit off the studs, an operation which is performed from the back of the cabinet.

The meter and switch panel is in front of the other two units and arranged to pivot in the outward and downward direction, as indicated by an arrow on the layout sketch. For this purpose, short studs project sideways from the vertical edges of the panel, near the bottom, and engage slots cut in the side members of the frame. The panel is supported at the rear by a bracket extending from the front screening box of the oven relay unit, and fastened by a milled nut engaged with a threaded stud protruding from the bracket through a hole in the panel. After removing the nut, the panel can be swung into the downward position, at which the components mounted on the rear are exposed to view. The panel can be completely removed from its position, by lifting it and pulling forwards at the same time, so as to disengage it from the slots in the supports. A handle is provided to facilitate these operations, but is not shown in the sketch to avoid obscuring the locking nut.

All external connections for the oscillator equipment are made through a main terminal block placed at the back of the tray. Apart from the r.f. output connection of the oscillator and separator unit, the block is concerned with supplies for operating the equipment, as indicated by references near the terminals in the schematic diagram.

Plugging connectors, of the knife draw-out type, are used for inter-connecting apparatus situated in different units and for connecting most of the supplies taken from the main terminal block. Each connector is identified by either a letter or number, and both their circuit and physical positions are shown in Fig. 4. All contacts attached to the meter and switch panel consist of the knife parts of the connectors, one group (A–H) being provided to make connection with the oscillator and separator unit, whilst another (M–T) serves a similar purpose for the oven relay unit. A third group (1–10) establishes connection with femal contacts wired to the main terminal block, and a fourth (J–L) is employed in linking the frequency-determining networks, in the constant-temperature chamber, to the maintaining amplifier. The latter contacts are set on a bracket extending from the left-hand side of the meter panel so that, with the panel in position, they engage female contacts carried on a bracket at the right-hand side of the oven assembly.

A group of knife blades (11–18) is supported on the front screening box of the oscillator and separator unit, and through these are connected certain supplies taken directly from the main terminal block. The oven-relay unit is similarly equipped with a second group of connectors (19–26) for making connection with the main terminal block and the oven assembly.

Constant-temperature Oven Assembly, Figs. 4 and 5

Circuit diagrams for the oven assembly are provided in Fig. 4, a schematic showing the connection of its equipment with that in other units, and Fig. 5 giving details of the oven circuits only. Supplementary information, regarding the construction of the oven assembly and positioning of apparatus, is given in three photographs, Plates I, II and III. The following description deals first with the frequency-determining equipment and the constant-temperature chamber in which it is situated and then with the inner and outer ovens surrounding this chamber.

Constant-temperature Chamber and Frequency-determining Networks

The constant-temperature chamber is a rectangular box built of thick brass plates, keyed to one another by locating pins and secured by screws. The entire LC assembly is mounted on a thick baseplate, also of brass, which is fixed to the floor of the chamber. The retaining screws are placed in line near the rear edge of the baseplate, so that they are easily accessible when the back of the chamber is removed. Two aspects of the interior of the chamber are shown in Plate I, a close plan view, and Plate II which gives an elevation view with the chamber in the normal position, the back having been removed.

The typical arrangement for all four circuits of the LC assembly is represented in Fig. 4. This diagram shows an inductor connected in series with a variable capacitor paralleled by fixed capacitance. The ends of this circuit constitute two terminals of a three-terminal network, the third being taken from the junction of two relatively large values of fixed capacitance connected in series across the circuit. Each circuit is independent of the others, only the earth connection being common, and its connection to the maintaining amplifier is effected through a four-position range selector switch operated from the front panel of the oven assembly. Reference should be made to Fig. 5 for the values of the elements in the four tuned circuits, and the arrangement of the selector switch.

Multi-strand wire (Litzendraht type) is used for the inductors, this being pile-wound on bobbins fitted with iron-dust cores. By using cores of magnetic material the coils take up much less space than would be required for air-cored coils of similar inductance, an important matter in considering dimensions for the constant-temperature chamber. Further, the coils have a higher Q than would be obtained with air-cored coils placed within a chamber of reasonable dimensions. Unfortunately, this class of magnetic material is prone to a long-term 'ageing' effect, which shows itself by changes of permeability, when subjected to temperatures above 15° C approximately. The cores used are of material in which this effect is least pronounced and, as an additional precaution, an open-core construction is adopted. This means that a large part of the path traversed by the magnetic flux consists of air, which minimises the effect of any variations which may occur. The coils are mounted in holders placed on the underside of the platform carrying the LC assembly.