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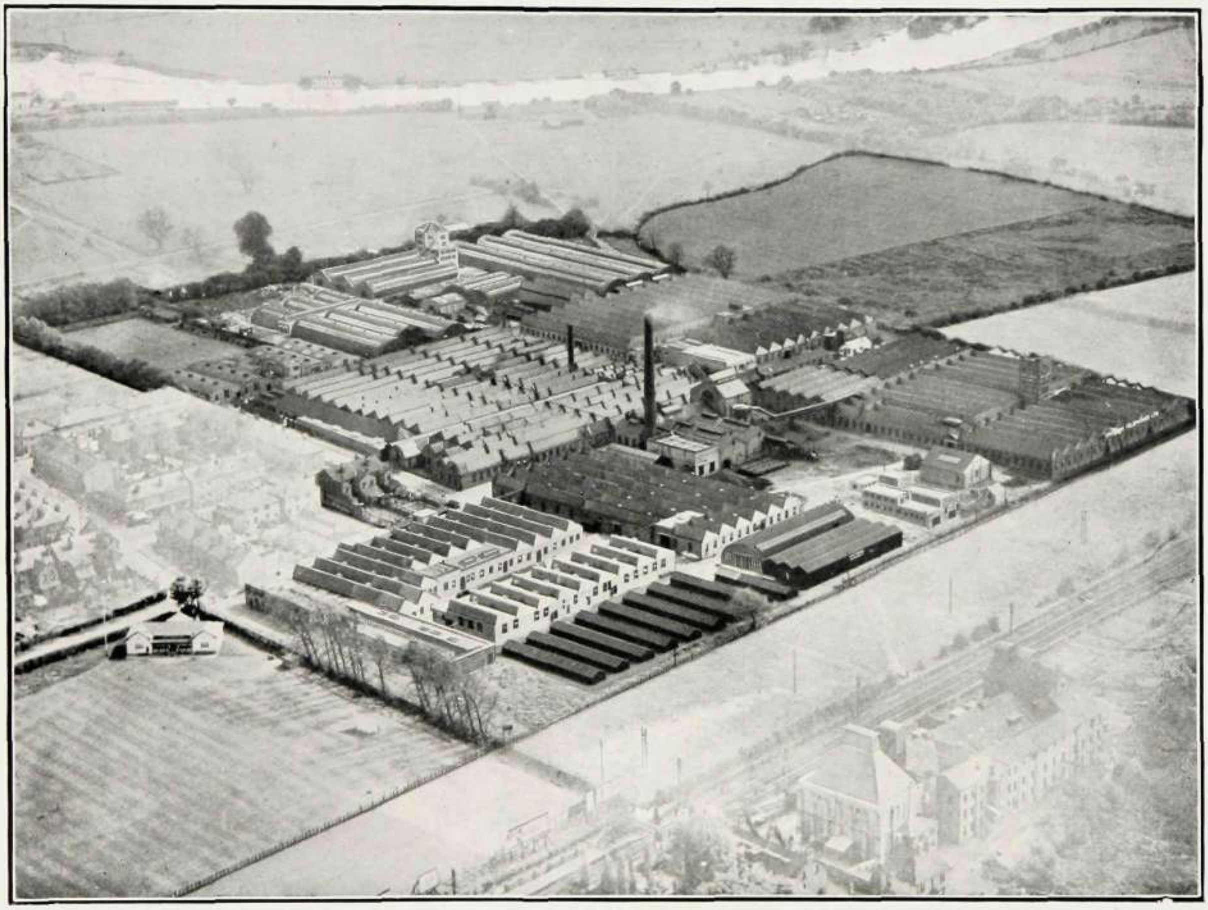


Aerial View of The Ericsson Works, Beeston, Nottingham

Palingenesis

MORE than eight years have elapsed since the issue of the last Ericsson Bulletin, in July 1939; years momentous in the history of the world and not without significance to the Company. In this highly-scientific age, "total war" (as it concerns industry) means an almost complete disruption of peace-time production with the result that the return to normal working is not a simple procedure; however, we are again in a position to keep readers informed of activities and developments and we think that in this revival copy of the Bulletin some account of our efforts and achievements in war production may be of interest.

Space does not permit of this being done in any great detail but the following resumé will serve to indicate the type of products with which we were concerned.

Our War Effort

Since the war ended, phenomenal output figures of munitions in one form or another are familiar to all, nevertheless, it can reasonably be said that the Company's prestige has been enhanced by the extent to which it shared in the burden carried by industry as a whole during the war years.

Our production was exceedingly varied and probably the most outstanding achievements were in the Radar field. Considerable time and effort were devoted to the development and production of this equipment for the Royal Navy and Royal Air Force.

In all, 170,000 Radar sets (including test equipment) were made by the Company, for use in locating enemy aircraft and submarines, to assist our fighter aircraft in their task of intercepting and destroying enemy craft and to guide bombers returning from raids over enemy territory.

In a similar category was the complex and coded identification equipment, known as I.F.F., with which our aircraft was fitted to enable the ground stations to differentiate between friend and foe. More than 60,000 such equipments were made; furthermore, our engineers were responsible for designing an ingenious magnetic plotting rod for the R.A.F. control stations. This device not only resulted in increased working speed and efficiency but also greatly reduced the fatigue of the operators at the plotting tables.

All this equipment was, of course, primarily used for defensive purposes (and history has shown how greatly it subscribed to ultimate victory) but we shared also in the manufacture of offensive weapons.

The Company was one of the first called upon to help in the production of bomb releases for the famous "block-busters" and our output of 100,000 included many of this type.

Further products were bomb distributors, 10,000 bomb sights, and more than 10 million shell fuses.

It will be realized that a very high degree of accuracy was essential in each manufacturing operation for munitions of these types, accuracy which had to be maintained for a very long time, as is evidenced by the fact that the production of one small but vital part was 60 millions. This would have been beyond the capacity of any factory not equipped with very modern machines and a high grade of supervisory skill.

Another product in great demand was the power unit for use in aircraft. Ninety thousand of these units were made.

Less obvious munitions of war which Ericssons delivered included some thousands of tons of special paints and varnishes and approximately 500 tons of aluminium powder for incendiary and seamarker bombs; incidentally, we filled nearly half a million of such bombs.

Notwithstanding heavy commitments for the less familiar products already described, it was to be expected that the supply of a certain amount of tele-communication equipment and associated parts would be required. This was of various kinds including 150,000 field telephones, more than 3 million relays, considerable numbers of quartz crystals, switchboards and much other telephone apparatus.

Needless to say the Company's plant was worked to capacity by day and night and a number of satellite factories were operated in order to tap as large a labour force as possible.

All this meant long hours for the employees, but every effort was made to lighten their labours. In this connection might be instanced a few of the facilities which were provided, namely: "Music while you work," entertainments for day and night shifts, improved lighting and ventilation, works' doctor appointed, optical and chiropodist sections, billiards hall with six full-sized tables acquired for fire guards, tea in break periods, free milk-cocoa for young people, hair-dressing services for men and women, shoe repairing organization, extension of canteen services to cover 24 hours day and night, etc. Our air-raid shelters were probably as good as any in the country and cost nearly £50,000.

We were extremely fortunate in that our factories suffered no damage from enemy air raids although they caused a certain amount of unavoidable inconvenience due to the fact that many employees were engaged on civil defence work of various kinds in addition to their normal occupations.

As a Company we have always been very proud of the high reputation attained by Ericsson products throughout the tele-communication world for upwards of 50 years and it is therefore very gratifying that the many letters and expressions of appreciation received from the Supply Ministries show that we came through the crucial years with no diminution of this reputation.

This, of course, could never have been achieved in the very trying circumstances had it not been for the spirit of co-operation which existed throughout the Company and the very real sense of individual responsibility held by all concerned in the national effort which enabled us to receive regular supplies of materials to perform our portion of the work and ensured the speedy transportation of the finished article to its destination.

Telephone Exchanges in Lancaster House, Liverpool

LIVERPOOL, with a population of 1,000,000 and the centre of a large industrial area, demands telecommunication facilities of a high order. British Post Office Engineers had planned for the conversion of the area to automatic working to be completed over a 4-year period ending in 1943, but by April of that year, owing to hostilities only 9 of the 31 director exchanges envisaged were in service.

As part of this programme the Ericsson company was asked to supply the joint trunk, central and tandem exchanges, together with the service P.A.B.X., all of which were to be installed in Lancaster House, an imposing six-storied building near the city centre accommodating, also, telegraph and repeater plant.

The general arrangement of the telephone exchange equipments throughout the building is as follows :—

Basement : Cable chamber.

Ground Floor : M.D.F., testing equipment and central automatic exchange.

First Floor : Tandem exchange, trunk exchange apparatus racks and telephone power plant.

Second Floor : Service P.A.B.X.

Third Floor : Directory enquiry bureau and service observation room.

Fourth Floor : Central exchange meter racks and trunk exchange apparatus racks.

Fifth Floor : Manual switchroom.

MAIN DISTRIBUTION FRAME.

The M.D.F. consists of two parallel structures, each of 110 verticals, with a mezzanine platform (Fig. 1) and an overhead jumpering field for interconnections. The frame nearest the outer wall carries protective equipment for most of the junction lines, the remainder, together with the subscribers' circuits, being accommodated on the inner frame.

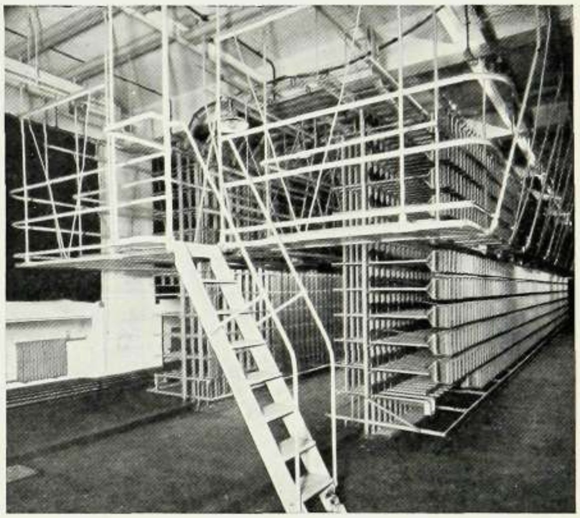


Fig. 1—Main Distributing Frames with Mezzanine Platform

The following list of the principal M.D.F. circuits will give some idea of the large number of cables entering the building :—

	Circuits	
	Initial	*Ultimate*
Subs. lines ord. & 2/10 PBX (central)	8,900	9,300
Subs. lines over 10 PBX (central)	1,040	1,040

	Circuits	
	Initial	*Ultimate*
O.G.J. from selector levels (central)	1,000	1,200
I.C.J. (central)	1,400	1,600
PBX power leads (central)	800	900
O.G.J. from selector levels (tandem)	800	2,000
I.C.J. (tandem)	800	2,000
O.G.J. from selector levels 2V.F. (trunk)	740	1,000
I.C.J. (trunk)	3,000	5,000
Thro' junctions, thro' circuits and private wires	5,400	8,100
Junctions to repeater distribution frame	1,500	2,000

Fig. 2—Test Desks, Trunk Test Racks and Test Jack Frames

TESTING EQUIPMENT.

Fig. 2 shows the line-up of the test desks with the test jack frames, and the trunk test racks in the background. The 5 two-position desks are provided with no less than 40 equipments for dealing with alarms extended from other exchanges. Of the 10 trunk test racks, 5 are " demand ", 3 are " toll " and 2 are " fault record " positions. They combine the features of the test desk and the T.J.F., and each canopy above the equipment panels carries 20 patching cords for making up temporary alternative routes for interrupted trunk lines. The necessity for providing " plugging up " facilities is obviated by the provision of push keys which control the free line signal and apply a " busy " condition to the O.G.J. multiple.

CENTRAL EXCHANGE.

The central exchange and the service P.A.B.X. both employ the B.P.O. " 2,000 " type selector in association with subscribers' uniselectors, the former exchange being designed for a multiple capacity of 10,000 lines and a present equipment of 9500 lines with uniselector circuits for 7,440 subscribers, 240 of which are barred trunks.

In passing it may be remarked that the exchanges in Lancaster House were installed prior to the development of the new group selector rack with grading facilities at the rear, thus separate trunk distributing frames were provided.

Due to the high percentage of private branch exchanges in the area, all final selectors are of the P.B.X. type, the first 9 racks being equipped for large type P.B.X. groups cabled from 7 levels of the second numerical selectors.

In addition to 8 automatic routiners, ample equipment has been provided for service observation, traffic recording and other services which are features of the modern telephone exchange.

Following is a list of the major items of equipment which were supplied for the central exchange :—

Uniselector racks	38
1st code selr. racks	38
2nd ,, ,, ,,	6
1st num. ,, ,,	18
2nd ,, ,, ,,	21
Final ,, ,,	39
I.D.F. verticals	76
T.D.F. bays	28
Director racks	9
" A " digit selr. racks	3
Jacked-in relay sets	800 approx.
2-motion selectors	6,400 ,,

POWER PLANT.

The telephone power plant on the first floor (the repeater equipment has its own source of power) supplies all the telephone equipment in the building and operates on the divided battery float system. It consists of two 25-cell batteries each having a capacity of 10,200 ampere hours, two motor generator sets each capable of developing 220 amperes at 51 volts, and a control panel.

The main discharge conductors of 27 sq. in. cross-section, carry a load of 4,152 amperes and with their subsidiary branches, which are of 21, 12 and 6 sq. in. cross-section, distribute power from the batteries to the automatic equipment.

A total weight of 55 tons of copper is used for the distribution system, also, the cells (Fig. 3) are some of the largest to be found in telephone exchanges or power stations in this country and weigh, complete with acid, $2\frac{1}{4}$ tons each, giving a total weight for the two batteries of $112\frac{1}{2}$ tons.

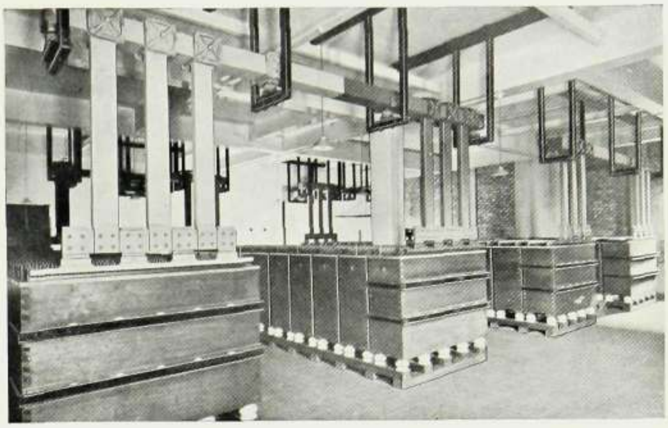


Fig. 3—Part of the Telephone Battery Room

Each motor-generator set consists of a 172 h.p. motor operated from the 400 volt, 3-phase, 50-cycle supply and coupled to a shunt-wound generator connected to a filter unit of 3 choke coils. A shunt condenser of 4,000 micro-farads ensures the elimination of " ripple " from the exchange equipment.

Ringing current is generated from a mains-operated $\frac{3}{4}$h.p. motor direct coupled to an alternator having an output of 300 watts at 75 volts. A 50-volt battery-driven dynamotor of the same output is also provided and is automatically switched in should the mains-operated machine fail.

TANDEM EXCHANGE.

Tandem exchange equipment was installed in two stages, a certain amount of equipment having to be brought into service early to meet the opening requirements of three new local exchanges ; however, at the final cut-over there were some 700 first and 500 second selectors and approximately 500 auto/auto relay sets with impulse regenerators.

Initial trunking allowed for 4 exchanges (including central) to be served from tandem first selector and 36 from second selector levels, excluding the service P.A.B.X. which has its own group of level "9" switches.

The usual "T.I.M.", etc. services are available to subscribers *via* "O" level second selectors, and engineering services are routed through a small group of level "01" third selectors.

Four hundred tie circuits are cabled from each side of the tandem I.D.F. to the I.D.F's for central and trunk.

JOINT TRUNK EXCHANGE.

The trunk exchange equipment went through many vicissitudes during its prolonged installing period.

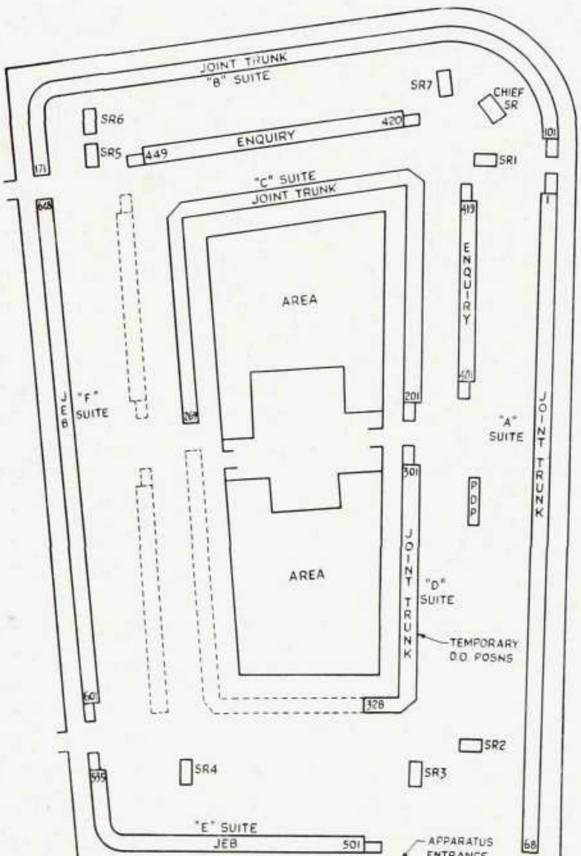


Fig. 4—Layout of the Manual Switchroom

Some of the sections were used in making up a trunk "Q" switchboard which was located in the basement for use in connection with A.R.P. services and has since been dismantled; others were transferred to Liverpool relief exchange which was hurriedly brought into service when two exchanges in the area were "blitzed".

Lancaster House itself sustained two direct hits from bombs and great credit is due to the British Post Office engineers and all associated with the installation of the exchanges in the building for the way in which difficulties were surmounted during this period.

Figs. 4 and 5 indicate the general arrangement of the manual switchroom and it will be obvious that considerable work was entailed in installing the 366 sections and associated desks, each one having to be hauled up 120 feet from ground level to the apparatus entrance.

Referring to Fig. 4, the joint trunk suites "A" to "D" and the incoming jack-ended junction suites "E" and "F" are composed of standard 3-position sections, with pneumatic tubes; The enquiry suites consist of small single-position sections and the whole of the boards are of the sleeve control type.

It is interesting to note that there are approximately 20,000 local calls per day in the Liverpool area and, due to the delayed automatization previously mentioned, a very large proportion of these calls were of necessity routed *via* the "O" level; thus the traffic on the joint trunk positions was much heavier than was originally anticipated, with the result that an inordinate amount of work was entailed in the preparation and handling of tickets quite

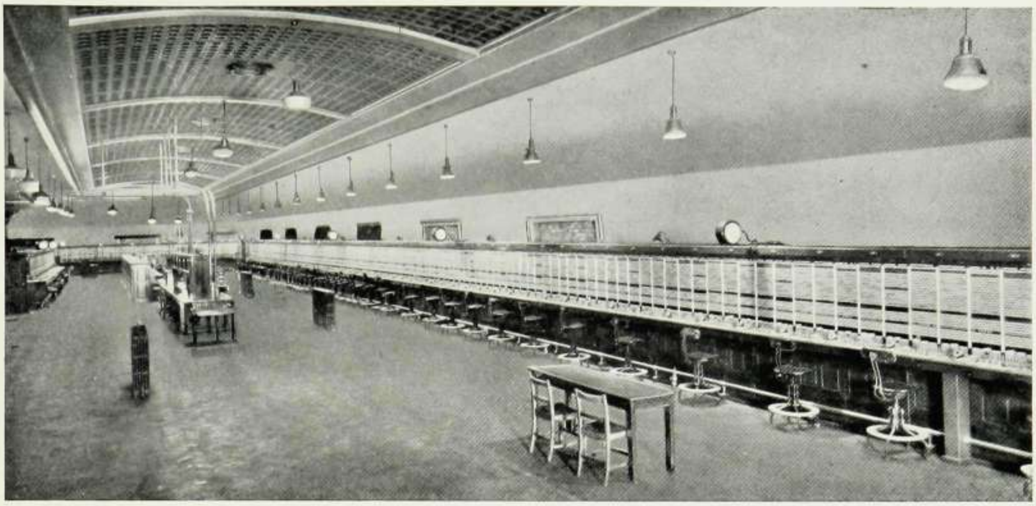


Fig. 5—View of the Manual Switchroom taken from SR.2 on Fig. 4

apart from actual operating. To overcome this, Post Office engineers have extended dialling-out facilities in the area and have achieved a reduction of no less than 35% of the busy hour traffic through the trunk positions.

Owing to local conditions, it was found impracticable to extend the manual positions at five C.B. exchanges in the area to provide dialling-out facilities and it became necessary to establish a central switchboard for this purpose. As the "D" suite at Lancaster House was being installed at the time, ready-made equipment was to hand; thus on these positions, cord circuit equipment was increased from 11 to 15 circuits and external cabling was arranged to allow for segregated incoming and outgoing terminations, the trunk multiple being used for the latter. Access to these positions is obtained by dialling the first three letters of the required exchange name, the operator completing the call on an order-wire basis.

Ultimately this switchboard will become redundant but arrangements are such that its restoration to normal trunk working can be rapidly effected.

Details of the circuits on the various switchboard suites are as follow :—

POSITIONS	SERVICE	CIRCUITS				CORD CCTS. PER POSN.	18-MIN. C.T.I's PER POSN.
		ANS.	O.G.J. MULT. F.L.S.	O/G SERV. MULT. NON-FLS	O/G TRK. MULT. F.L.S.		
"A" Suite 1-68	Joint Trunk	960	1,600	200	480	11	6
"B" Suite 101-170	,,	,,	,,	,,	,,	,,	,,
"C" Suite 201-269	,,	,,	,,	,,	,,	,,	,,
"D" Suite 301-328	,, *	,,	,,	,,	,,	15	Wiring only
"E" Suite 501-533	J.E.B.	,,	,,	,,	,,	16	—
"F" Suite 601-648	,,	,,	,,	,,	,,	,,	—
401-419	Enquiry	400				8	—
420-425	Enq. & Ser. PABX	400 Ord 120 PABX	380	100	—	11	—
426-449	Enquiry	400				8	—

* "D" SUITE, TEMPORARY "DIALLED-OUT" POSITIONS.

	ANS. MULT		O.G.J. MULT	O/G SERVICE MULT.		O/G TRUNK MULT.
	REGULAR	SER. P.A.B.X.		SUITES A-F	ENQUIRY	
PANEL REPETITION	12	6	5	5	4	5

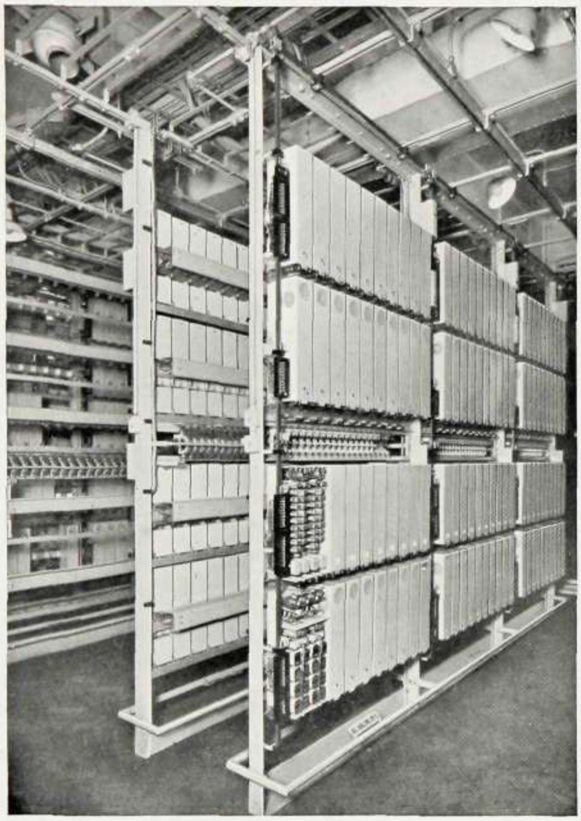


Fig. 6—Trunk 2 V.F. Relay Set Racks

An indication of the amount of traffic through the trunk exchange is given by the fact that more than 2,000 M.B. relay sets were provided, including 600 for "O" level circuits, 560 B/W junction circuits and 300 I/C junction circuits. In addition, there are nearly 1,000 2V.F. relay sets (*see* Fig. 6) and 500 code selectors.

Observation Equipment.

Lancaster house is an observation centre and has a separate room on the third floor reserved for this function. Simultaneous observations can be made by 6 operators on either automatic or C.B. service, the equipment being arranged in two suites, each consisting of one control and three operating panels with an 8-digit number display for checking dialled digits.

Each suite has 25 incoming junctions and the usual provision is made for calls to be directed to a disengaged operator.

Directory Enquiry Bureau.

The directory enquiry bureau equipment, which consists of 14 operators' positions, 2 monitors' positions and a supervisor's desk, handles all directory enquiries.

Each operator has access to the complete directory record contained on 3 double-tier revolving drums arranged in the manner shown in Fig. 7. Incoming calls are routed *via* an allotter to a disengaged operator and provision is made whereby, if all operators are engaged, the calls are queued and as operators become available, are passed on in the order of their origination.

Outgoing lines are connected to the bank of a transfer uniselector through which it is possible to call the monitor, supervisor, or a distant exchange.

Service P.A.B.X.

The service P.A.B.X. has equipment for 600 multiple numbers, 400 of which are provided for the Liverpool Telephone Manager's Office and 200 for the Postmaster Surveyor's Office.

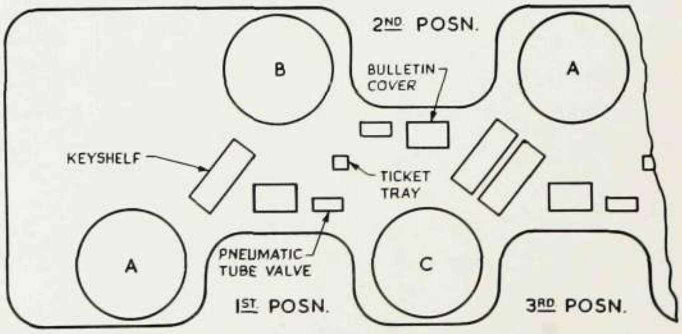


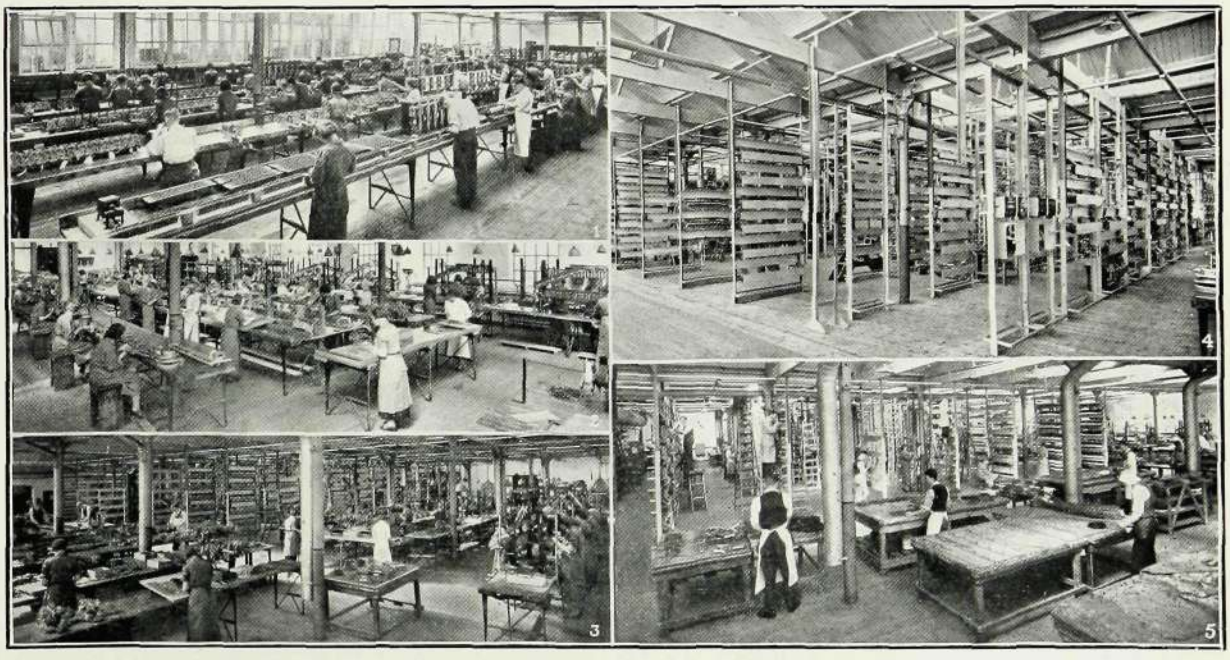
Fig. 7—Arrangement of the Directory Enquiry Positions

Trunk or toll calls are routed *via* level 6 of the first selector, to the joint trunk operator but direct junctions are provided from levels 8 and 9 respectively, to Warrington P.B.X. and Manchester service P.A.B.X. Level " O " calls terminate on the trunk enquiry suite P.A.B.X. positions.

Incoming calls from subscribers within the director area proceed *via* tandem selector levels 93 and 94, all other calls coming in through the service P.A.B.X. operator.

CONCLUSION.

Since the cut-over of the exchanges in Lancaster House there has been some advance in the automatization of the Liverpool area but there still remains much to be done before the final stage is reached. It can, however, be stated that the completion of the joint trunk, central and tandem exchanges constituted a forward step of some magnitude toward the ultimate goal.



A View of some of the Ericsson Shops Engaged in Manufacturing Automatic Telephone Exchange Equipment

The Ericsson "Alnico" Magnet Heavy Duty Hand Generator

IN the January 1938 issue, a description was given of the development and characteristics of alnico hand generators, with some account of their advantages over earlier types.

Since that date, some progress has been made in the adaptation of these generators to specific requirements and the purpose of this article is to describe the alnico generator which has been specially designed for heavy duty, to replace the Ericsson 5-magnet tungsten steel unit.

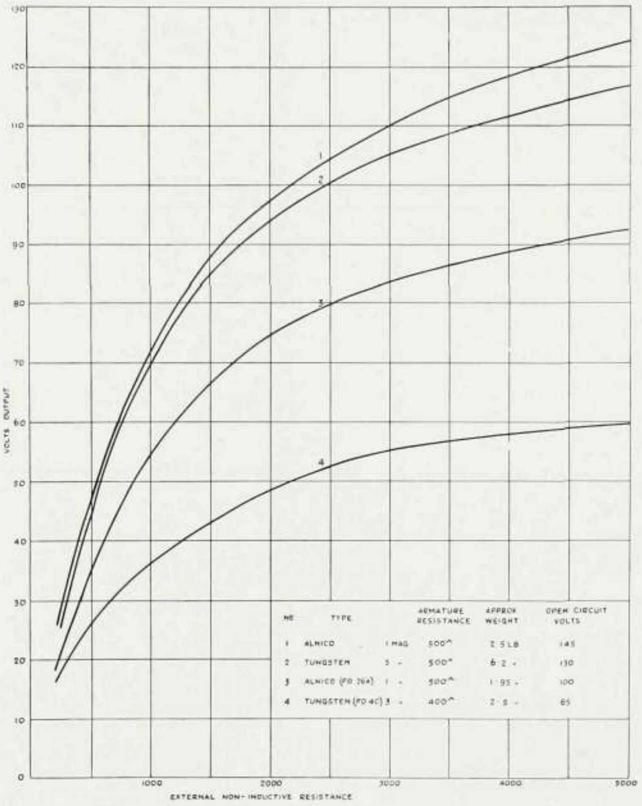


Fig. 1—Volts Output Curves for Various Generators

The new generator is constructionally similar to the standard alnico and as far as possible piece parts have been made interchangeable with those of the smaller machine, incidentally, some improvements on the prototype have been made and are incorporated in all alnico generators, e.g., the pressed up brass cheeks which incorporated the feet have been replaced by zinc alloy die cast end cheeks with detachable brass feet (*see* Fig. 2) and the spindle bearing at the handle end has been lengthened. The former change simplifies the adaptation of the generator for different types of mounting and the latter change ensures a longer life by virtue of the increased bearing surface.

The heavy duty generator is designed to meet high resistance or long line conditions and is particularly suitable for party-line working.

The output is 40% greater than that of the standard alnico for only 29% additional weight which has resulted from the length being increased by $\frac{1}{2}''$.

Comparison between the heavy duty alnico and the 5-magnet tungsten generators reveals that the latter is almost three times the weight and size of the former and the volts output is slightly lower as can be seen in Fig. 1, curves 1 and 2.

The watts output curve is similar in form to that of the generator P.O. No. 8A shown in the previous article already mentioned and reaches a peak of almost 5 watts with an external resistance between 1,000 and 1,500 ohms, dropping down uniformly to approximately 2.5 watts at 5,000 ohms.

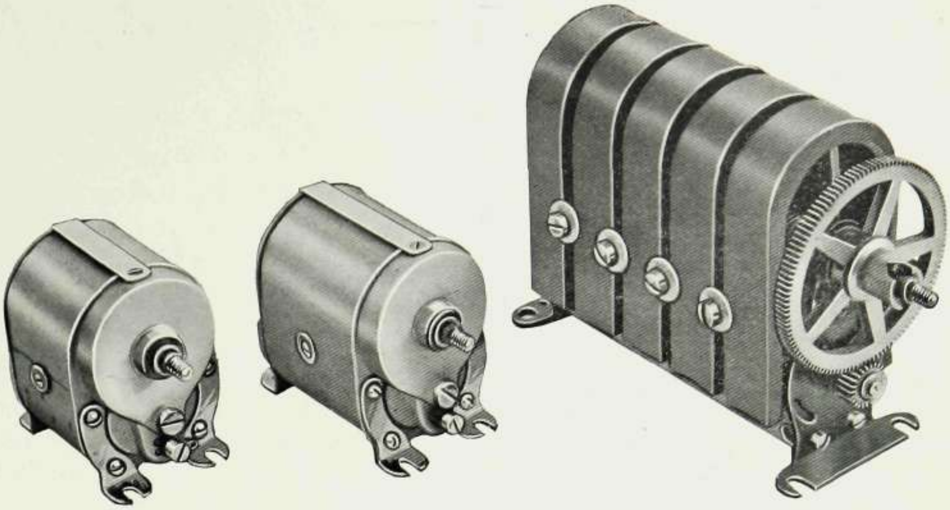


Fig. 2—A Comparison. Standard and Heavy Duty Alnico and Old Type Five-Magnet Generators

The saving in mounting space achieved with the alnico generator over the tungsten steel type is more than ever noticeable in the heavy duty model as may be seen in Fig. 2. The actual sizes without the handle are as follow :—

Generator	Length	Width	Height
Standard Alnico	$3\frac{3}{8}''$	$2\frac{3}{16}''$	$3''$
H.D. Alnico	$3\frac{7}{8}''$	$2\frac{3}{16}''$	$3''$
5-Magnet	$7\frac{3}{4}''$	$2\frac{7}{8}''$	$5\frac{1}{4}''$

When required in the form of a separate unit, the generator can be housed in a moulded bakelite case (Fig. 3) which has accommodation also for a condenser. Originally designed for the small model, the case has been improved and adapted to suit either type of alnico generator. It is neat and compact, the overall dimensions being approximately $5\frac{1}{4}''$ x $4\frac{1}{4}''$ x $4\frac{5}{8}''$ high, and is fitted with screw terminals to simplify the wiring of external connections.

The new model is designed to ring 32, 1,000 ohm or 40, 2,000 ohm magneto bells connected in parallel. Alternatively, it will ring a single magneto bell of 1000 ohms resistance over a longer length of line than it is possible to conduct a normal telephone conversation.

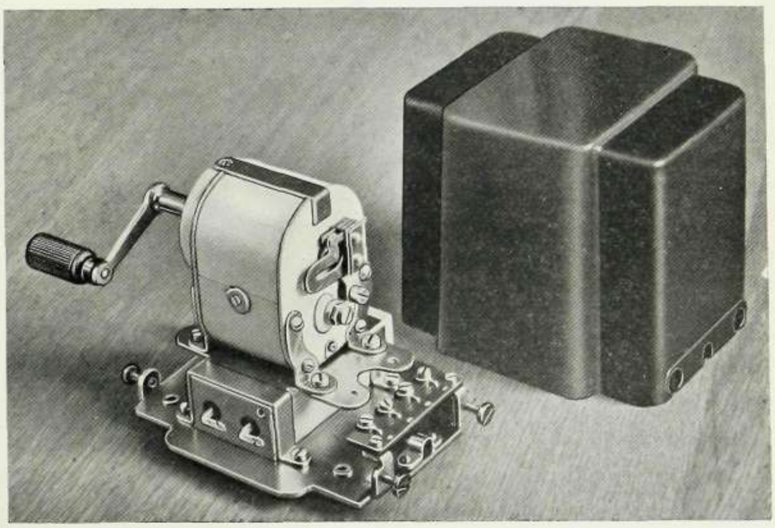


Fig. 3—Alnico Generator in Case, with Cover removed

The Three-Channel Carrier System

THE Three-Channel Carrier System for open wires has been developed as an economic solution to the problem of increasing the number of channels over long distance trunk circuits.

As its name implies, it offers three speech circuits on one open wire pair, in addition to the normal physical circuit.

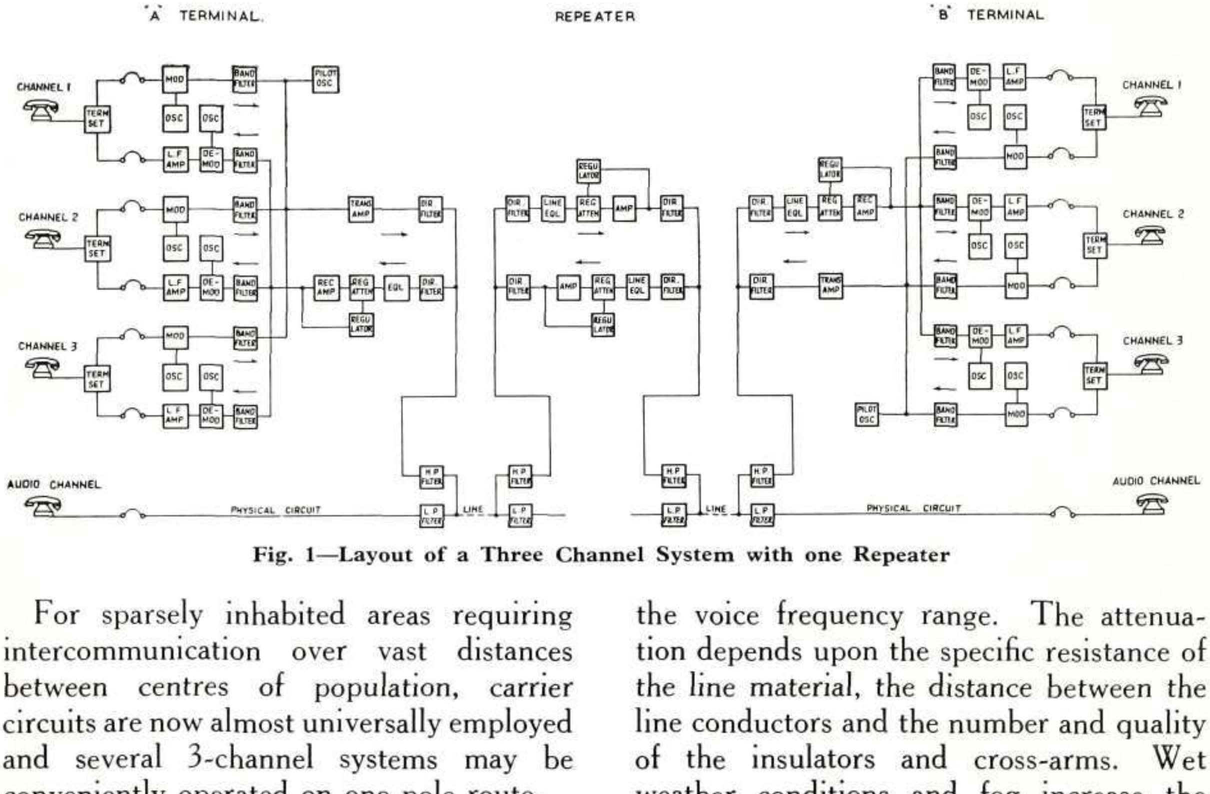


Fig. 1—Layout of a Three Channel System with one Repeater

For sparsely inhabited areas requiring intercommunication over vast distances between centres of population, carrier circuits are now almost universally employed and several 3-channel systems may be conveniently operated on one pole route.

With only terminal equipment, distances up to 300 miles (500 km) can be covered, given suitable conductors. This distance can be extended by introducing intermediate repeaters, up to 300 miles extra coverage being added for each repeater. Fig. 1 shows the schematic arrangement of a 3-channel system with one repeater.

LINES.

The normal open wire lines of copper or bronze twisted or transposed, usually offer, even in their original condition and in any case after simple preparation, satisfactory transmission properties within the whole of the required frequency band. The line attenuation is appreciably higher for carrier frequency currents than for those within the voice frequency range. The attenuation depends upon the specific resistance of the line material, the distance between the line conductors and the number and quality of the insulators and cross-arms. Wet weather conditions and fog increase the attenuation whilst ice and snow multiply it many times.

Electrical interferences of varying intensities are induced in open wire lines by such outside sources as long wave radio transmitters, power lines and atmospheric disturbances. These interfering currents give rise to background noise in each channel and set a lower limit to the volume level in front of the receive terminal and in front of each repeater. Increase in receiver amplification obviously cannot improve this signal-to-noise ratio. On the other hand, the highest transmitted power to line is limited by crosstalk to other circuits in the vicinity and by the power handling capacity of the output circuits and line filters.

Experience has shown that suitable levels are + 17.5 db (+ 2 nepers) for transmit and —25 db (— 3 nepers) for receive. Under favourable conditions the receive level may fall to — 34 db. These figures are with respect to one milli-watt in 600Ω.

FREQUENCY BANDS.

Three-Channel systems utilize six frequency bands in the range between 6 and 30 kc/s. Only single sidebands are transmitted and the carrier frequency is suppressed. Three bands are used for each direction of transmission on the same line pair. The audio frequency band utilized in each channel is from 300 to 2,700 c/s and is amplitude modulated to its appropriate carrier frequency band in individual oscillators and modulators. At the receive terminal, each received sideband is demodulated by a corresponding oscillator and demodulator.

FREQUENCY ALLOCATION.

In order to provide facilities for operating several 3-channel systems on one pole route with the minimum of inter-system crosstalk, two separate 3-channel systems have been designed. They are similar with regard to performance and operation but the frequency bands have been arranged to ensure minimum overlapping whilst keeping within the same overall frequency range. Actually, in both systems there is an upper and a lower group of three channels, each group being used for transmission in one direction.

The Ericsson systems provide a further facility for the reduction of intelligible crosstalk. In each system the transmitted sideband may be completely inverted by a simple operation. This results in the carrier frequencies being moved from the lower side of the band to the upper side, and *vice versa*, and so causes the opposite sideband, the frequencies of which are inverted, to be selected. It is found that intelligible crosstalk is reduced to mere background noise by this procedure. Fig. 2 shows the complete layout of the frequency bands of the two systems with and without inverted sidebands.

2 WIRE / 4 WIRE TERMINATIONS.

As may be seen from Fig. 1 the audio side of each channel is connected to a terminating set. This comprises a hybrid transformer with padding and switching arrangements for the conversion from 2 to 4 wire working. Facilities are provided for the connection of each channel to the following :—

Switchboard	2 wire
Audio toll circuit	2 wire
Audio trunk circuit	4 wire
Another carrier system	4 or 2 wire

Starting from the terminating set, the transmit side of the carrier channel passes through a volume limiter comprising a set of biased dry rectifiers and functioning as an amplitude clipping device on peaks of high speech power. This ensures that when all channels are brought together after modulation the common amplifying equipment will not become overloaded.

The volume limiter is followed by a band filter which selects the frequencies between 300 and 2,700 c/s which will form the effective transmitted speech band.

MODULATOR AND OSCILLATOR.

Each audio frequency band must be converted to its appropriate carrier frequency band for transmitting over the line and each received carrier band must be re-converted to audio frequency before being passed into the terminating network.

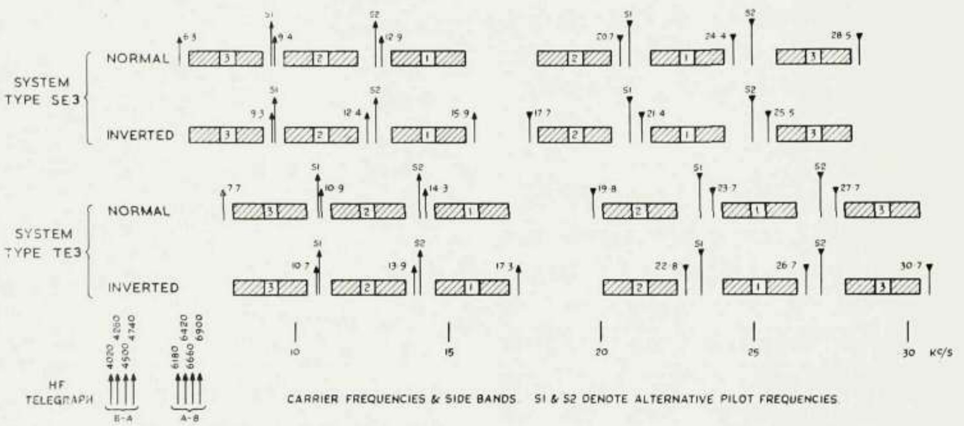


Fig. 2—Frequency Allocation of Ericsson 3-Channel System

Both modulator and demodulator for one channel, together with their associated oscillators, are mounted on one panel and the frequency determining coils and condensers are in a thermally insulated box to avoid rapid temperature changes. The temperature coefficient of capacity is arranged to be as nearly as possible equal and opposite to the temperature coefficient of inductance, so that a very low frequency drift over a wide temperature range is achieved ; in addition, the frequency of the oscillators is rendered nearly independent of valve potential changes by amplitude stabilizing lamps. Although facilities are provided for easily checking the synchronism of the oscillators from both ends of a system, it is found that adjustment of frequency is rarely necessary.

The modulator and demodulator use similar components and each comprise a metal rectifier balanced ring bridge together with associated input and output transformers. The carrier frequency is largely balanced out.

A simple change in strapping between accessible wiring tags will change the frequency of the oscillators by 3 kc/s resulting in a change from the upper to the lower sideband, or *vice versa*, as previously described, *see* Fig. 2.

BAND FILTERS.

The modulator output consists of two sidebands of the carrier frequency and the required sideband is selected by the modulator band filter.

The outputs of the three transmit band filters are connected in parallel and the three carrier channels now pass together through the remaining apparatus to line. The attenuation of the filters outside their respective bands is determined by the allowable inter-channel crosstalk. By reason of the fact that the carrier may be shifted from one side of the pass-band to the other, and as the suppressed sideband is on the same side as the carrier, it is obvious that the attenuation must be high on both sides of the pass band.

The Line Amplifier.

After passing through the modulator band filters, the now combined carrier channels are at a low level and must be brought up to sufficient power to provide the required line level and also to compensate for the slight extra losses in the directional and line filters. Where several channels are to be amplified simultaneously in a common amplifier, it is necessary that a very low order of amplitude distortion be introduced as otherwise crosstalk will occur between the channels. It is also necessary that variation in power supplies and changes in valve characteristics have negligible effect on gain. For these reasons the line amplifier is of the degenerative or negative feedback type with a maximum output power of approximately one watt; it employs two valves and is heavily degenerative over the entire carrier frequency band. A similar amplifier is used on the receive side and in addition a spare is provided which may be plugged across to either the " transmit " or the " receive " position in the event of a fault occurring in either. The same facilities are provided at each repeater.

Directional and Line Filters.

As may be seen by reference to Fig. 1 the " transmit " channels are separated from the " receive " channels by the directional filters. Each filter has a high attenuation in the pass-band of the other so that the transmit frequencies at high level are not fed back through the receive circuit.

The carrier system proper, terminates at this point and the directional filters could be connected straight to the line provided that no other service was operating on the same pair, but in practice it is usually found that in addition to the carrier system, a physical circuit at normal voice frequencies is operated on the same pair of wires and sometimes, also, a H.F. telegraph system.

In order to separate these circuits from the carrier system, line filters are provided and connected as shown in Fig. 1. They usually comprise one high pass and one low pass filter and serve to separate the frequencies below about 3 kc/s from those above. The impedance presented to line is 600 ohms balanced to earth.

Pilot Oscillator.

It will be noticed from Fig. 1 that the input circuit of the transmit amplifier also includes the pilot oscillator. This oscillator is designed to give a constant output within close tolerances and has a frequency which falls between two of the transmitted channels (*see* frequency allocations in Fig. 2). Its function is explained later in connection with the regulator.

Line Equalizer.

At the receive terminal or repeater the directional filter is followed by a line equalizer. This comprises three units which are connected in series and can be set to give an attenuation slope (in steps of approximately 2 db up to a maximum of 20 db) between the upper and lower limits of the received band. This slope is made approximately equal and opposite to that of the line loss of the particular line concerned.

REGULATOR.

Line attenuation changes occasioned by variations in temperature and weather conditions are monitored by a pilot frequency of constant amplitude transmitted in each direction. This pilot is filtered out of the main circuit at the output of the receive amplifier and after passing through a constant gain amplifier, is used to give an indication of the line attenuation and may also be used for the automatic or manual setting of a regulator for maintaining the total attenuation between the transmitter and receiver at a constant level. The Ericsson automatic regulating equipment is entirely electronic and has no moving mechanical parts.

The output from the pilot circuit is rectified and the resultant D.C. passes through the regulator circuit which includes an element so arranged that its resistance varies with the current passing through it, making attenuation adjustment practically instantaneous and continuous. In this way, variation of overall line loss is reduced to very small proportions, even when several repeaters are operated on one line.

LOW FREQUENCY AMPLIFIER.

The receive band filters correspond to the transmit band filters at the further end of the line and similarly, the demodulator and associated oscillator correspond to the transmit modulator and oscillator. After being demodulated, the audio level is too low to send directly into the hybrid, and so, after passing through a simple low pass filter, it is amplified by a single valve amplifier giving a gain of approximately 30 db. In this amplifier also, some equalization is provided to compensate for the overall filter characteristics.

RINGING FACILITIES.

Ringing over each channel is effected by the transmission of a frequency at 500 c/s which may or may not be modulated at

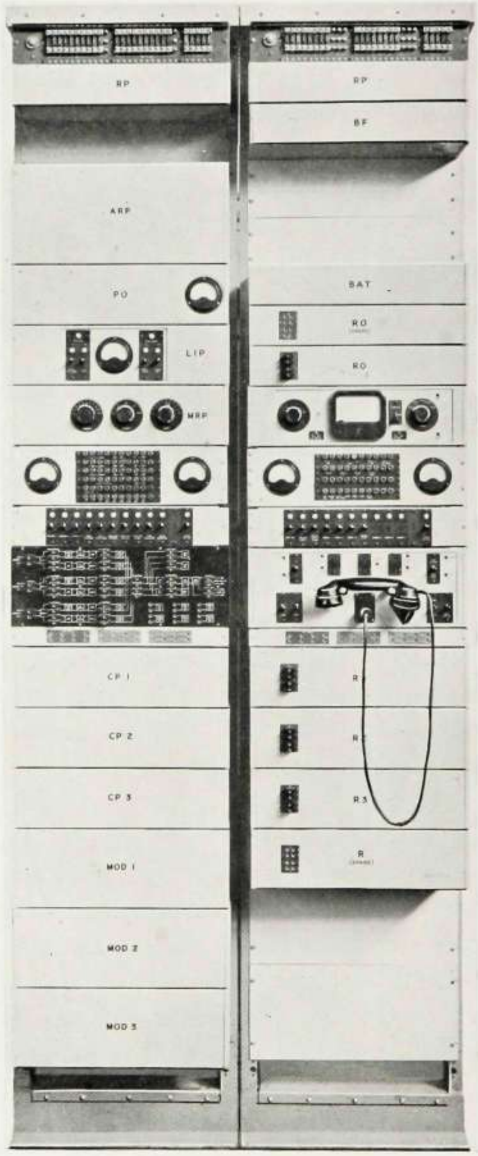


Fig. 3—Three-Channel Terminal Equipment

20 c/s. At the receive end the signal is converted in a ringer circuit to the required low frequency ringing current.

Repeater.

The repeater contains those elements of the terminal equipment necessary for providing gain and equalization each way. The amplifiers are similar to the transmit and receive amplifiers and one spare is provided. Automatic regulation for each stretch of line is effected as described for the terminal units.

Special Features.

The Ericsson three channel system follows orthodox design but incorporates features which are novel and afford certain advantages over some existing systems.

The apparatus is panel mounted in the usual fashion but each panel is connected into the main bay wiring *via* a plug and jack which have been specially designed to eliminate risk of contact faults.

Valves of low power consumption have been chosen and as far as possible, apparatus has been designed to economise in mounting space. Fig. 3 shows the arrangement of equipment for a single terminal but only three bays are required to accommodate two terminal equipments.

The individual valve power supply is checked from a centrally situated test panel by the simple operation of push button keys, and anode currents and filament voltages are read directly on associated instruments.

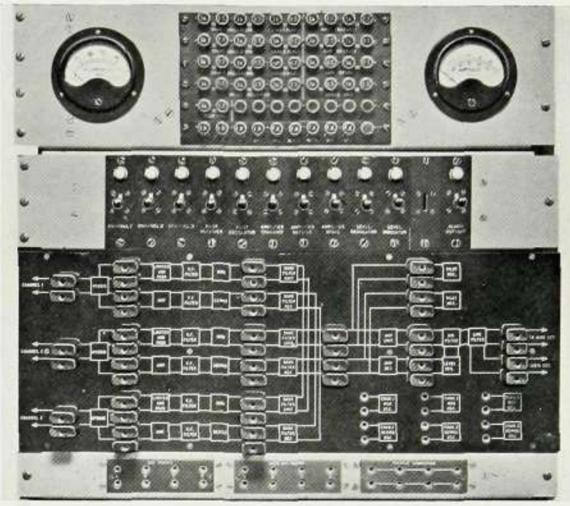


Fig. 4—Enlarged View of Test Field in Fig. 3

All suitable points in the circuit where " level " measurements may be desirable, are connected directly to a " U " link panel where a transmission measuring set and test oscillator may be plugged in for checking circuit losses. Fig. 4 shows an enlarged view of this " U " link panel surmounted by the battery cut-off keys and lamps and the test panel.

The Production and Applications of Quartz Crystal Plates

THE present considerable use of quartz plates in the science of telecommunications has arisen from the demand for electronic oscillators of very high stability and frequency, and for wave filters with very sharp cut-off characteristics.

The behaviour of a crystal plate may be compared with that of the string of a musical stringed instrument. When struck mechanically, the string vibrates at a frequency dependent upon its nature and dimensions. The crystal plate vibrates similarly at a frequency dependent upon its physical dimensions, but requires for the driving force a voltage alternating at the natural mechanical frequency of the plate. If the driving frequency is changed slightly, the mechanical vibration is rapidly reduced in amplitude, also if a crystal plate is given an electrical impulse, as in switching on a circuit, it will vibrate and generate an oscillating voltage across its electrodes. The highly selective response indicates that a crystal behaves as a simple resonant circuit the inductance and capacity of which can be readily calculated from its dimensions. The main characteristics of the equivalent electrical circuit are (for practical crystals), very high inductance, very low capacity, and a resistance far below that of a coil of the same inductance. The frequencies used in the coaxial multi-carrier telephone system are such that the crystals required have dimensions suitable for mass production methods.

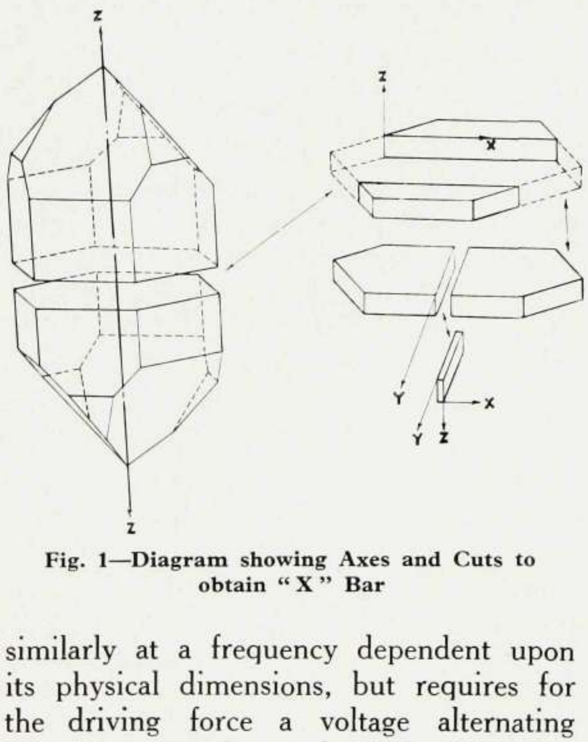


Fig. 1—Diagram showing Axes and Cuts to obtain "X" Bar

The raw material, if perfect, would be a transparent hexagonal prism with opposite sides parallel and terminated by a pyramid at each end. Such a crystal has three electrical (X) axes, three mechanical (Y) axes and one optical (Z) axis. The Z axis is parallel with a line joining the points of the pyramids, Y is at right angles to Z and to a prism face and X is at right angles to Z and parallel to a prism face. The fact that there are three sets of parallel prism faces makes it obvious why there are three sets of X and Y axes and it will also be clear that in any one set, X, Y and Z are mutually at right angles (*see* Fig. 1).

For cutting purposes, only one set of axes is used, i.e., that which ensures the most economical use of the raw material.

A perfect crystal may be formed of either right-hand or left-hand quartz ; thus when a beam of plane-polarized light is passed through the crystal along the Z axis, the plane of polarization is rotated clockwise for right-hand and anti-clockwise for left-hand quartz. Unfortunately in practice both forms are found in the same crystal, giving "optical twinning". The electrical axis may also be reversed in different parts of the same crystal, causing electrical twinning.

As untwinned raw material is very rare and as a finished plate must contain no twinning, it is easily appreciated why only about 2% of the original weight appears in the finished product.

Optical tests reveal the presence of optical twinning but to test for electrical twinning the crystal surface must be etched with hydrofluoric acid. This dissolves the surface and forms myriad patterns of minute pyramids from which light is reflected. The surface has the appearance, when twinned, of patches of light and shade which change to shade and light as the plate is moved. When the whole plate appears either light or dark it is satisfactory.

The properties of a crystal plate depend principally upon the dimensions and the orientation of its edges relative to the X, Y, Z axes. In order to produce consistent crystals it is necessary to know the exact positions of the axes. In any crystalline structure the atoms of its chemical elements lie in parallel planes which are fixed distances apart. The distance between these atomic planes is comparable with the wavelength of X-rays, which may be diffracted by the atomic layers. Only at what is known as the "Bragg" angle is a detectable reflection obtained. The actual angle between a cut surface and an atomic plane is therefore determined (to an accuracy of one minute) by obtaining a reflection from the atomic plane and from this it is possible to locate the axes.

The next essential is the precision cutting of the raw material, the various stages of cutting being carefully checked to prevent wastage. Fig. 1 illustrates the way in which the quartz is cut to obtain a bar crystal.

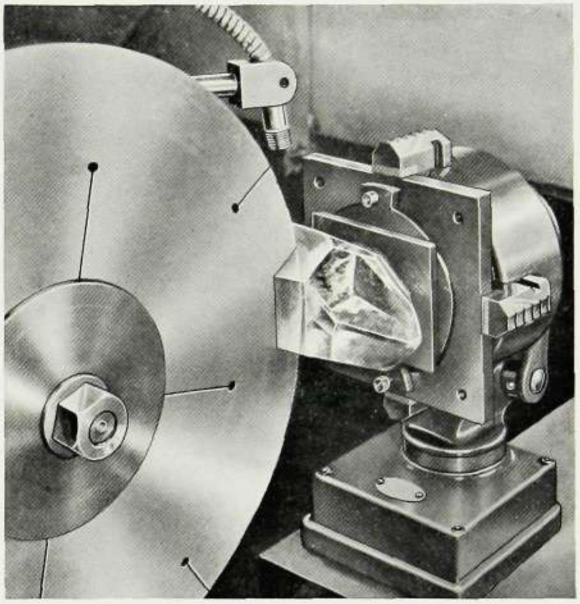


Fig. 2—Cutting "Z" Slabs

For normal production methods the limiting dimensions of plate attainable are set by the strength of the material and the operations involved. Generally speaking, difficulties increase rapidly as the thickness decreases below 0.015". The plates used in normal telecommunication work usually present no difficulties.

The only materials used in cutting and grinding are diamond dust and carborundum. The rim of the cutting wheel (Fig. 2) is impregnated with diamond powder for a radial distance of $\frac{1}{8}'' - \frac{1}{4}''$

according to the diameter. This rim is usually thicker than the non-impregnated part of the disc and is made from a soft metal such as mild steel or copper; although bakelite can be used, short "saw" life renders this material uneconomical.

To obtain slabs of crystal suitable for cutting into plates, a smooth face is first ground on one of the natural prism faces. This enables the crystal to be fixed to a ground glass plate by a thin film of wax, giving a very strong joint; the assembly is then mounted in a jig which is adjusted by means of a polarized light system so that a nearly correct cut can be made and checked by X-ray reflection. The error is measured and the machine jig is reset accordingly.

Similar operations are carried out on the slabs to divide them up into plates which are then ground down as nearly as possible to the final size. The first grinding operation is on the thickness. The plates are placed in cut out spaces, normally of pentagonal shape, in a thin bakelite plate which rests on a cast-iron lapping plate. A second lapping plate with the centre cut out, is placed upon the crystals which are then driven round slowly and eccentrically, thin carborundum paste made with water being poured through holes in the upper plate. The rate of grinding is very consistent and the amount removed can be regulated by time measurement. The tolerance on dimensions is usually a fraction of one thousandth of an inch and the surface finish is such a fine matt that when seen by light at glancing incidence, it appears to be polished.

When ground to final thickness and finish, the plates are made up with molten wax, into rectangular blocks of up to fifty, the assembly then being ground or lapped as before, until the edges are of the required dimensions. The plates are next separated and chemically cleaned prior to undergoing further treatment relative to their particular application.

Crystals can be broadly classified as either high or low frequency. The line of demarcation between the two groups is very indeterminate but is in the region of 400 kc/s. Most of the lower group are required to be clamped at a point on a particular line, whilst those in the other group are usually assembled between stainless steel electrodes which, however, still permit freedom of movement over a limited space.

Frequencies up to about 15 mc/s can be attained with crystals of the higher group, the upper limit being set mainly by the difficulty of producing plates which at 15 mc/s have a thickness of approximately 0.008". If higher frequencies are required, tourmaline is used but the material is not suitable for mass production.

As the temperature of a crystal changes, its natural frequency varies due to changes in the dimensions and elastic constants. A crystal, also, has more than one mode of vibration and if at some particular temperature its fundamental frequency approaches a harmonic of the frequency of another mode of vibration, there is a rapid change in frequency accompanied by a sudden drop, or complete cessation in activity or output.

As the fundamental frequency depends upon the thickness, and the interfering frequencies upon the length and width of the plate, it will be obvious that the dimensions must be precisely determined and maintained in production.

The necessary fine limits cannot be achieved by a grinding process, because the tolerable frequency error represents an infinitesimal variation in the thickness of a

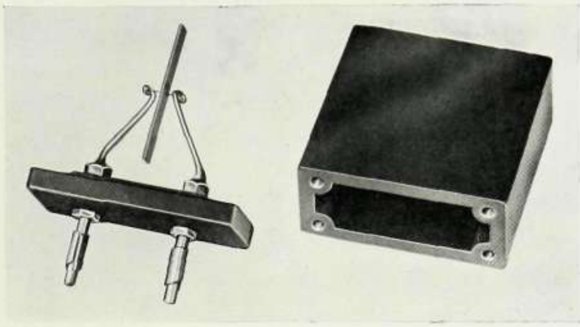


Fig. 3—Bar Crystal and Holder

plate, therefore, the last few millionths of an inch are removed by slowly dissolving the plate in a bath of ammonium bifluoride.

The process can be timed reasonably accurately and has the advantage, over earlier finishing methods, of eliminating the changing of frequency with age.

When very close to the final frequency, the plate must be tested in the holder in which it will be used—Figs. 3 and 4 are typical examples. The final error is usually trimmed out in the actual working circuit by means of a small condenser.

Lower frequency crystals are nearly all bar shaped and oscillate in a longitudinal direction, i.e. the length increases and decreases at the natural frequency. A bar oscillating in this mode has a nodal line (a line of no movement) passing through its geometrical centre but at an angle to its width depending on the width-length ratio. This is due to quartz having different elasticities in different directions.

The crystal may be supported along its nodal line by means of a knife-edge clamp, by point contacts along the line, or by a single contact at the centre. Clamping is often effected by means of hemispherical contacts which serve also as connecting leads to the faces of the bar. Since there is no electrode, in this case, equal in area to the bar, the surface of the bar is coated by the sputtering process with a very thin film of gold, which forms an excellent untarnishable electrode having a resistance of only a few ohms.

Development of soldering technique has produced an improved method of bar mounting (Fig. 3). By firing a silver spot on the nodal centre of the surface of a bar, a wire may be soldered to it. The resultant joint is often so strong that at breaking stress the wire will pull a piece of quartz away from the bar before the metal-crystal joint breaks. After wires have been attached, gold is applied and the crystals are ground down to the length which will give the desired frequency.

Some of the circumstances in which quartz crystals are utilized might now be

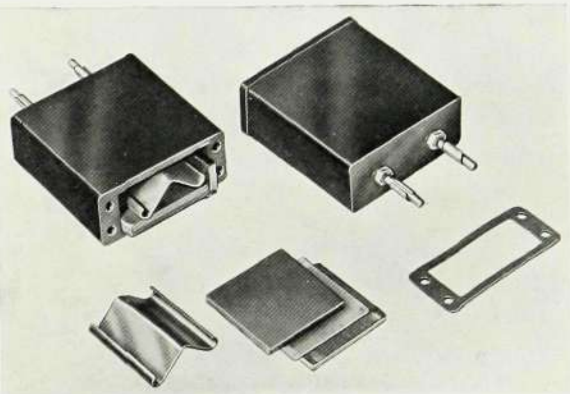
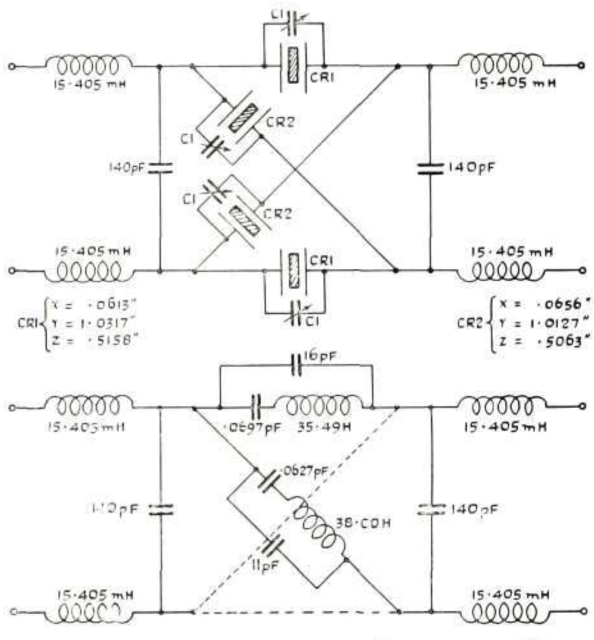


Fig. 4—Typical Assembly of a High Frequency Plate Crystal

considered. High frequency plates are used in large numbers in service types of portable transmitters and, to a lesser degree, in fixed frequency broadcast transmitters, the latter requiring crystals of very fine quality. Lower frequency crystals are used for resonators in carrier telephony filters, intermediate frequency filters, and to a smaller extent, and again of a much finer quality, for the frequency and time measuring equipment employed in astronomy.

The advantages of a crystal over a coil and condenser circuit are more demonstrable in the lower frequency group.



SINGLE SECTION OF BAND PASS FILTER [100·6 – 103·7 KC/S]

Fig. 5—Typical Crystal Resonator and Equivalent Coil-Condenser Circuit

Not only does the crystal enable electrical circuits to be used which would be impossible with a coil and condenser arrangement but it has, also, stability and constancy. A typical example of the substitution of crystal resonators for coil condenser combinations is shown in Fig. 5.

The principal limitation with crystal filters is in the band width obtainable, but in the case of carrier telephony channels this constitutes no difficulty. Filters can, however, be constructed having a band width sufficient to pass only a single frequency with allowances for the instability of that frequency.

Frequency measuring equipment suitable for telecommunication work, usually consists of a low temperature coefficient quartz bar mounted in an oven of constant temperature. This oscillator has a frequency of 50 or 100 kc/s, and drives multivibrator oscillators of 50, 10 and 1 kc/s, these figures being exact fractions of the crystal frequency.

The 1 kc oscillator usually drives a synchronous motor clock which can be checked against time signals derived from astronomical observations.

Crystals can now be made so nearly perfect that when working in a precisely regulated temperature, they are for all practical purposes completely stable, having a variation of only 1 part in 100 million; e.g., a clock controlled by such an oscillator would lose or gain only one second in about 3 years (100 million seconds) hence, so-called quartz crystal clocks have now been installed in observatories as standard time keepers.

There are also other uses for quartz crystals, outside the telecommunications industry. For instance, a plate oscillating at a supersonic frequency can be used for sending mechanical vibrations through liquids for the purpose of producing very fine emulsions or for destroying bacteria such as exist in milk. The voltage produced through the compression of a crystal is also utilised in calculating transient pressures developed in gun barrels, air turbines, bomb blast etc.