UNIVERSAL DECIMAL CLASSIFICATION
REFERENCE NUMBER 384+621.39+654 (43) "1939-1945"

BRITISH INTELLIGENCE OBJECTIVES
SUB-COMMITTEE SURVEYS
REPORT NO. 29

Telecommunications and Equipment in Germany during the period 1939-1945

LONDON: HIS MAJESTY'S STATIONERY OFFICE
1950

PRICE 1s. 6d. NET

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B.I.O.S. SURVEYS

REPORT NO. 29

Telecommunications and Equipment in Germany during the period 1939-1945

PREPARED BY THE GENERAL POST OFFICE

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LONDON

PUBLISHED FOR THE BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE BY HIS MAJESTY'S STATIONERY OFFICE

1950

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TELECOMMUNICATIONS AND EQUIPMENT IN GERMANY

SECTION 1. RESEARCH AND DEVELOPMENT

1. MATERIALS FOR COMMUNICATIONS WORK

1.1. PERMANENT MAGNETS

Research on magnetic materials was hindered by the separation of the industry into organizations under separate ownership for various stages of the manufacture. [32]

The shortage of nickel, cobalt, and tungsten caused a search for alloys using reduced proportions of these metals, and for methods of using scrap castings, etc. Thus there were developed a low-nickel Alni-type alloy and a range of ternary chromium steels to replace tungsten steel. [32] There were also magnets pressed from powder, either sintered or resin-bonded. [26] [32] These pressed magnets are inefficient in magnetic energy per unit volume, and slightly so in energy per unit weight, but they could be formed into complicated shapes, with inserts if required, and they could be made from scrap material or from runners of castings.

Anisotropic materials were produced only on a very small scale. [32] [88]

Of these developments, the only one likely to be of permanent value is the pressed magnet, and its range of application may be smaller than was thought in Germany. [32]

1.2. "SOFT" MAGNETIC MATERIALS

A full range of nickel-iron alloys, similar to those used in Britain and America, was said to have been produced, [1] and to have been available as strip in thicknesses down to 0.015 mm. But as the manufacturer had no knowledge of the effects of mechanical strain on *Mumetal*, [3] the electrical testing of these materials must have been incomplete or careless.

An easily saturable alloy, 5000Z, was produced [1] for a switching application, but does not appear to have been used for other purposes.

Sendust, which is an aluminium-base alloy, was found to have better properties than the available nickel-iron powder cores. *Sendust* was also produced as sheet material for magnetic screening. [1]

1.3. CERAMICS

German ceramic condensers were outstanding before the war for consistency of properties and accuracy of shaping even of thin-walled tubes, probably because of careful furnace control. During the war these qualities were maintained, but not improved on. Few, if any, new materials came into use; there was experimental work, but not of a kind systematically toward particular improvements (this impression may result from the personality of a leading

research worker who described, *inter alia*, magnetic, piezoelectric, and photo-electric ceramics, but had neither brought any of them to readiness for manufacture nor seriously studied the relation of these properties to the constitution of the materials). [26] [47] The possibilities of *high-K* materials were realized, and samples were made, but the work was left unfinished, and some workers believed that the high permittivity resulted from the presence in the ceramic material of conducting particles.

In this field, work in America has overtaken that in Germany during the past few years.

1.4. SEMI-CONDUCTORS

The manufacturing processes for non-linear resistors were well established. [33] The products, however, were as variable as those of American origin. Research work on the manufacture was concerned with applications other than communications.

The effect on electrical properties (especially conductivity) of deviations from exact stoichiometrical composition of materials was studied, but without reaching any generally useful conclusions. Materials so examined included uranium oxides, titanium dioxide [94] and *gamma*-ferric-oxide.

Studies of the structure of the barrier layer in selenium rectifiers were inconclusive ; selenide layers had been shown to exist but their role was not clear. "Artificial barrier layers" of varnish, etc., had been found to give reduction in self-capacitance, but the properties required in the layer were uncertain, and the idea had not reached the production stage. [33]

1.5. SYNTHETIC MICA

From the academic point of view, the synthetic mica problem was solved with the production of a material slightly different chemically but with similar electrical and mechanical properties. [23] The technical process, however, so far as it had been worked out, was very expensive and the product was therefore unlikely to compete, in peace-time conditions, with natural mica.

2. COMPONENTS

2.1. CONDENSERS

The impregnants used for paper condensers are all well-known in Britain, but chlorinated naphthalene and (for power condensers) chlorinated diphenyl are used to a much greater extent than in British practice. [36] Chlorinated naphthalene, which has the advantages of high permittivity and high melting-point (i.e., 90° C.), is considered to be a stable and satisfactory impregnant. The addition of stabilizers, which has been found necessary both in Britain and in America, had not been considered, possibly because of the lower operating temperatures for which German condensers are designed. Efforts were therefore devoted only to maintaining the purity and uniformity of the wax, and to overcoming the risks to the health of operators handling the materials. [36]

There was some use of synthetic waxes, e.g., a synthetic ozokerite, and *Z-wax* (a paraffin wax melting at about 100° C.). [36] Mixtures of *Z-wax* and natural paraffin wax were also used. *Z-wax* is hygroscopic, and additional sealing by some other substance is required when it is used as a condenser impregnant.

Life-testing of condensers was carried out only on a small scale ; its object was to maintain a check on production, not to investigate the causes of failure.

Metallized paper condensers were made by the technique originated in Germany before the war. Modifications were tried—e.g., the use of aluminium or lead instead of zinc (neither of which was successful) and the use of an auxiliary layer of tin between the paper and the zinc. [36] Lacquering of the paper was found to improve the insulation resistance and reduce the liability of breakdown.

Wood-pulp paper is used where British practice would be to use rag paper, [7] [36] but this may be a matter of availability rather than preference on technical grounds. A factory making a widely-used grade of paper was found to use normal equipment and methods, but to have an exceptionally pure water-supply. [7]

By 1942 it had become essential to find a substitute for mica, and polystyrene film (which had already been developed under the name of *Styroflex*) was used for roll-type condensers. [30] [36] [65] Some, at least, of the condenser manufacturers used film which was internally stressed and, after winding the condenser, released the stress by heating to about 90° C. ; the resulting shrinkage sealed the condenser windings. These condensers do not require impregnation, but for tropical use they were sealed (e.g., with glass-to-metal seals).

Polystyrene condensers are unique in their high insulation resistance and small change, with time of charging, of capacitance and insulation resistance. Also their power-factor at audio frequencies is even lower than that of a mica condenser. Nothing comparable was available in Britain or America, but the technique is not likely to be unduly difficult.

2.2. CABLES FOR COMMUNICATIONS

Synthetic materials were used for cable insulation and sheathing. For insulation there were polystyrene, built up as a series of foils, for coaxial cables, [6] [61] and a polystyrene-polyisobutylene mixture (*Oppanol O*). The proposed substitutes for lead as a cable-sheath were not satisfactory ; they included an *Oppanol* mixture, [13] and also aluminium, [13] and steel. [6]

2.3. TELEPHONE INSTRUMENTS

The subscriber's transmitter and receiver were thought in Germany to be worth improving, even if the result was more expensive. The objects were better sensitivity, and more uniformity between different instruments. A balanced-armature receiver seemed likely to meet the requirements, and a regenerative microphone having its diaphragm driven electromagnetically by its own speech current, was being tried. [27]

Pending the introduction of these more sensitive instruments, certain subscribers were allowed to use receiving amplifiers of about 13 db. gain, or receivers for both ears. [28]

2.4. CONTACTS FOR RELAYS, ETC. [41] [61]

The lives expected from contacts on relays, selectors, and vibrators are generally similar to those expected in British equipment, and German and British practices in spark-quenching and in "wetting" are much alike.

The main object of German war-time work on contact materials was at first to find substitutes for platinum-iridium and similar alloys ; later, there was a shortage of platinum, and substitute alloys, which usually contained a

high proportion of gold, were developed. Some of these substitutes were as good as, or even better than, the original materials ; e.g., gold with 5% nickel was found to be an excellent substitute for platinum. This type of research had not been of comparable importance in Britain.

"Plated" contacts—actually made by pressing the materials together at about 10 tons per sq. in. at high temperatures—were used as another method of economizing in precious metals.

A different type of problem was presented by low-voltage vibrator contacts, for which the existing material, tungsten, was unsatisfactory, and a better one had to be found. A partial solution in this case was a sintered silver-tungsten alloy.

The life of materials was judged more from field trials and users' opinions than from laboratory tests. The importance of electrical transfer, rather than mechanical wear, as the cause of contact deterioration was appreciated ; mechanical wear, however, was considered to become important if the transferred material built up as hard needles.

Sintered alloys were developed, following pre-war work in conjunction with an American firm, and gave excellent results, particularly as sliding contacts.

3. SYSTEMS

3.1. SOUND RECORDING

The development of the Magnetophon, [37] [60] a pre-war instrument recording magnetically on plastic tape containing oxides of iron, was continued for both military and civil purposes. The military model, compact and portable, and provided with a device for slow playing-back of recorded high-speed telegraphy, had no British counterpart. The high-quality model used extensively for broadcasting was of as high a standard as any loud-speakers with which it was likely to be used, but was inferior to the best British disc-recording systems. [38] A recent development was the use of an auxiliary supersonic frequency to replace the D.C. biassing in the recording head ; this improved the signal-to-noise ratio. Reduction of hum and rumble is recognized to be desirable, but lack of equipment and qualified staff is preventing any rapid improvement. [38]

The extensive use as recording media of magnetic oxides—at first magnetite, later *gamma*-ferric-oxide—originated in Germany, but the relevant properties of these materials were apparently not studied systematically as they were, during the war, in America.

The Magnetophon was also used for sound analysis, the recording being played back a number of times through filters for various frequency-bands. The filters were of adjustable band-width. This apparatus was applied to the examination of recorded "scrambled" speech, to deduce the structure of the scrambling system in use.

There is interest in stereophonic reproduction, and two experimental systems had been constructed. One, a development of the Magnetophon, uses two channels ; the other has three Class B sound-tracks recorded in the space available on standard sound-film. [81]

3.2. BROADCASTING STUDIOS AND EQUIPMENT

The studios at Hamburg, Berlin, and Frankfurt are well-designed, usually on well-known lines. The large studio at Hamburg is an exception ; the

cause of its good bass absorption is not obvious, and the excellent acoustical properties of this studio are apparently accidental. [38]

Microphones and loud-speakers are of moderate performance, and are not considered satisfactory. Some attempts at improvement are now being made, [38] but will probably leave German products still inferior to the modern British and American types.

4. GENERAL COMMENTS

In Germany, even more than in Britain, there was diversion of effort and materials from long-term research work towards war-time projects, and some of this war-time work was treated in so superficial a manner that the underlying principles were not appreciated. Whereas, in Britain and America, shortages of material led to the development of new and in some cases better materials, in Germany most of the substitutes which were sufficiently developed for practical use were makeshifts having inferior properties, and therefore much of this German work is of little or no permanent value.

In some fields (e.g. paper condensers) [36] there was unjustifiable complacency concerning the existing methods and products, and it was felt that perfection of the product would result merely from maintenance of the existing standards.

Much technical ability had been wasted either for political and racial reasons or by diversion of all available man-power into the armed forces.

SECTION 2. TRANSMISSION

1. INTRODUCTION

The trunk telephone and telegraph network in Germany was not in such an advanced state of development as in Great Britain and investigations into German technique have not yielded anything of outstanding importance. Nevertheless a number of details are of considerable interest.

1 + 1 circuit carrier systems (L-system) on loaded underground cables form a very important part of the trunk network, as would be expected from published literature. On the other hand, the 1 + 3 circuit carrier system (S-system) for loaded cable, which has also been publicized, was still in the experimental stage and no production equipment existed. 12-circuit systems on both loaded and unloaded cables had been planned, but only a few systems had been operated, mainly in France during the Occupation, French factories (L.T.T. and S.E.L.T.) being utilized for equipment construction. The 15-circuit system for open wire lines (*MG 15*) was little used inside Germany but was manufactured for use in outlying satellite countries. A number of wideband cables of interesting construction were laid and equipped between the main centres. These were designed to carry 200 telephone channels, one low grade television channel and one medium grade television channel per pair. Some military carrier telephone systems were in use but are of little interest, except that one multi-circuit type employs upper and lower sidebands of the same carrier for the two directions of transmission.

Multi-channel V.F.T. is operated in much the same way as in this country.

2. GERMAN LOCAL LINE TRANSMISSION STANDARDS [30]

The limit is normally set by transmission considerations ; signalling and dialling by themselves impose a limit of 600 ohms. The normal loss permitted

is 0.45 népers for the average of sending and receiving losses at 800 c/s (not including feeding current loss). Normally 0.6 mm conductors are used up to 2 km and 0.8 mm, thereafter to 5 km. The transmission limits are sometimes exceeded.

3. DEVELOPMENT OF CARRIER SYSTEMS IN GERMANY [30] [67]

Prior to 1934, when the Reichspost commenced development of a coaxial system, all carrier equipment was developed by contractors (S. & H. and A.E.G.), primarily for export, and such systems as were installed by the Reichspost were experimental only, with a view to possible adoption and specification later. The L-system (1 + 1, cable), S-system (1 + 3, cable), *MG 15* (15, open wire) and *MEK 8* (8, open wire) were all used on this basis. All except *MEK 8* (A.E.G.) were S. & H. developments.

Since 1938, the Reichspost has installed all types of systems, as manufactured, to provide service for the Wehrmacht and Luftwaffe. All systems designed prior to 1938, including the coaxial system, have 3 kc/s channel spacing, but after the C.C.I.F. meeting at Oslo (1938), development of a 12-circuit system conforming to the decisions at that meeting (4 kc/s spacing) was commenced by S. & H. to the requirements of the Reichspost.

After conflicting discussions regarding 3 kc/s or 4 kc/s channel spacing, the former was finally agreed for national service. It was decided to use a primary sub-group 12 kc/s wide which could comprise four national channels or three international channels. A standard German system proposed by Siemens & Halske was a primary sub-group 6-18 kc/s, a primary group 54-102 kc/s, and a primary super-group 408-648 kc/s. During the war an "international" committee reversed the Oslo decision of the C.C.I.F. and standardized 3 kc/s channel spacing.

On multi-pair cables a zweiband system and "Mittelton telegrafie" would be operated below 12 kc/s, a 12-24 kc/s group being the basis of 12 circuit and coaxial systems. (In Germany a "zweiband" system is any 1 + 1 carrier system and the special significance given to the word in England is not now recognized.)

All German carrier systems utilize double modulation of each individual channel and the channel characteristics obtained are generally good. The choice of 6 kc/s (L.S.B.) as the first modulation frequency followed the use of the band 3-6 kc/s for the L-system.

Development of a coaxial system was commenced for the Reichspost in 1934 ; it predates both the 12-circuit and *MG 15* systems.

4. THE GERMAN COAXIAL SYSTEM [30] [48]

4.1. ROUTES AND CABLES

The following coaxial cable systems existed in Germany at the end of the war :

Berlin-Munich (being extended to Vienna)
Berlin-Hamburg
Berlin-Frankfurt/Main
Frankfurt-Cologne
Berlin-Hanover
Berlin-Leipzig

All these cables are believed to have approximately the same performance ; each consists of a single coaxial pair surrounded by a layer of voice frequency quads which are used for maintenance and local traffic.

The design of the coaxial pairs normally used is of interest in that the insulation is polystyrene—a material which the Germans produced and used in considerable quantities.

4.2. GENERAL ARRANGEMENT OF CHANNELS

Each cable is arranged to be equipped with 200 telephone channels at 3 kc/s spacing, in the range 90-690 kc/s, together with a subscriber television (*Fernseh*) channel between 1 and 2 Mc/s and a broadcast television channel between 2 and 4 Mc/s. The subscriber television channel (180 lines, 25 frames/sec) was installed and operated over certain routes but was too obsolete to be of interest. Some repeater equipment was installed for the broadcast television channel ; the telephone circuits were in commercial use.

4.3. TERMINAL EQUIPMENT

In common with all other modern German transmission equipment, the units are assemblages of "unit boxes" (baukastens). Equipment for 10 channels fills a standard bay—about 8 ft high and 26 in. wide. All panels are insulated from the bays.

The first modulation is with 6 kc/s (lower sideband) ; the second with 27, 30 . . . 51, 54 kc/s (upper sidebands). The channels are thus assembled as lower sidebands of virtual carriers 33-60 kc/s.

The group equipment for 40 channels occupies one bay and includes separate crystal oscillators at frequencies 150-720 kc/s ; the lower group sidebands in the range 90-690 kc/s are transmitted to line, i.e., erect channel sidebands. The group modulating equipment is double-screened throughout.

4.4. CARRIER GENERATING BAYS

Two carrier frequency generating bays mount the channel frequency generating equipment for one route. A master 60 kc/s crystal oscillator controls a 3 kc/s oscillator via a 57 kc/s difference frequency. The output of the 3 kc/s oscillator passes through a saturated choke and is followed by filters. The 6 kc/s output locks working and spare 6 kc/s oscillators. The 6 kc/s oscillator is connected to amplifiers each of which provides the first modulation frequency for 40 channels. The ten frequencies 27-54 kc/s are selected by filters from the 3 kc/s oscillator supply and each provides the second modulation and demodulation frequencies for 20 circuits without amplifiers, i.e., 200 circuits in all.

4.5. LINE AMPLIFIERS (TELEPHONE CHANNELS)

The normal and reserve amplifiers for each direction (which are identical with those at the main intermediate repeater stations) are mounted on one bay. The amplifier has four stages with a gain of 6.5 népers maximum. A coarse gain adjustment is provided on the feedback of the last three stages and a potentiometer control of 25 steps with a range of 1.5 népers is provided on the feedback of the first stage. The first three stages used pentode valves and the last stage a triode. The amplifier is arranged in double-screened copper-sprayed boxes with an ingenious mechanical arrangement to allow covers to be removed.

4.6. LINE AMPLIFIERS (TELEVISION CHANNELS)

These amplifiers each consist of four stages with push-pull output and no feedback. The maximum gain is 7.5 népers. The amplifiers are double-screened and mains-operated. Switching from normal to spare is manual and is similar to the arrangement for telephone amplifiers.

4.7. REPEATER ARRANGEMENTS

Main repeater stations are spaced at approximately 35.5 km and are large underground attended stations with full battery power supplies, charging plant and standby Diesel generators. Telephone and television channels are repeated at these stations with amplifiers similar to those at the terminal stations.

Intermediate repeater stations at the 17.5 km points are unattended and on some routes are large two-room bunkers buried underground. One room is used to house the equipment proper and the other to house the air conditioning and power plant. These stations are used for television repeaters only, the telephone channels being by-passed. The repeaters are mains-operated.

On the Berlin-Hamburg cable, power for the unattended repeaters is normally derived from the power mains but can be transmitted over the coaxial cable if the supply fails. The power filters for this purpose are in the power room at the attended stations ; they are double-screened and transmit 550 volts 50 c/s A.C. to give 500 volts at the unattended station.

On the Berlin-Frankfurt cable, which was installed after the Berlin-Hamburg route, the power for the unattended stations is transmitted over a separate power cable from the adjacent attended station. No use is made of the coaxial cable for transmission of power, possibly because of the heavy load of the air conditioning plant.

On some routes, control of the unattended station from the adjacent attended station is carried out at 6 kc/s over the coaxial cable but in other installations it is believed that separate pairs in the surrounding V.F. quads are used. In all installations all control of the unattended stations is manual from the attended stations.

4.8. EARTHING ARRANGEMENTS

Double-screening is carried through the whole of the high frequency panels and wiring from the cable proper to, and including, the group modulation equipment. For example, in the telephone and television line amplifiers, anode circuits are decoupled first to the return tube of the coaxial cable ("B" conductor) and are further decoupled to the lead sheath of the cable ("C" conductor).

5. 15-CHANNEL OPEN-WIRE CARRIER SYSTEM [30]

The *MG 15* System is constructed by Siemens & Halske A.G. and provides 15 carrier circuits on an open-wire route, using one pair only. A 1 + 3 system may be used under the *MG 15* system. A 3 kc/s spacing of channels is used, the channel panels being similar to those on the coaxial system.

All channels are initially formed as lower sidebands of a 6 kc/s carrier, and occupy the frequency band 3.3 to 5.7 kc/s. A second modulation places the channels in their correct position in the range 15 to 60 kc/s. For this second modulation, only 12 carrier frequencies are used, 3 being used twice,

one channel being formed as an upper, and another as a lower sideband of each of the frequencies which are used twice.

Group modulation with a carrier frequency of 171 kc/s translates the 15-60 kc/s group to 156-111 kc/s ; this band is transmitted direct to line in one direction and is modulated with 204 kc/s to form a band 48-93 kc/s for transmission in the opposite direction.

An automatic level control is operated by pilot frequencies, this control being essential for high frequency working on open wire circuits.

6. V.F. TELEGRAPH SYSTEM [30] [67] [95]

The system in use has changed little since its introduction as an 18-channel system constructed on the baukasten or "unit box" principle, about 1935. The two principal changes seem to have been the supersession of the sending relay by a static modulator in 1941, and the provision of a centralized grid bias supply instead of mounting small secondary batteries at the foot of the racks. 6- and 12-channel systems, similar in essentials but differing in construction, were in use for several years before 1935. The equipment is manufactured by Siemens & Halske.

Like the British system the 18 carrier frequencies of the system are the odd multiples of 60 c/s between 420 c/s and 2,460 c/s inclusive.

The power transmitted to line is 10 microwatts per channel at a point of zero level on the telephone trunk, as in the British system.

Unlike the British system, the system is designed for operation with tone suppressed during idle periods and is used in this way for systems set up within Germany. The German nomenclature is positive battery for space with tone suppressed. The system will work equally well inverted and the London-Hanover system for example is working with tone on during idle periods, according to C.C.I.T. standard for international systems.

Like the British systems, it employs multi-frequency tone generators. Six 18-channel systems form a generator group on the German system, compared with ten 18-channel systems in this country.

7. FILTERS [30]

No evidence of the fairly advanced theoretical work of Cauer, Piloty, and Feldtkeller is seen in any existing equipment, which mostly employs filter based on Zobel methods. Jaumann (differential) filters are used in V.F.T. equipment.

The core materials used for filter inductors and loading coils are carbonyl iron, nickel iron and a small amount of aluminium silicon iron (*Sendust*). This last material, of Japanese origin, is considered to be superior to nickel iron in certain respects ; it has never been available commercially in England.

For filter capacitors, rolled *Styroflex* units have largely replaced mica. They are smaller and cheaper and have a power factor much the same as mica ; the temperature coefficient is, however, considerably greater. Foil electrodes are normally used but metallizing has been successful. *Styroflex*—thin oriented polystyrene film—has been developed and much used in Germany as a dielectric for both capacitors and cables ; polyethylene is not available in Germany.

8. CABLES [30] [48] [49] [54]

For audio-frequency cables, star-quad construction seems to have become increasingly popular since about 1935. Aluminium conductors have been

generally used owing to shortage of copper ; lead shortage has led to the use of extruded super-purity aluminium sheaths (99.99%), which can be thinner than for lead. A few enamelled pairs are sometimes included to facilitate testing and provide a limited service in case of breakdown.

For 12-channel carrier systems, loaded quad cable with *Styroflex* insulation has been developed. A typical cable has 1.2 mm copper conductors loaded with 1.75 mH coils at 284 metres ; the attenuation was 0.05 népers/km at 60 kc/s, allowing 100-120 km repeater spacing.

The original coaxial cable used copper conductors, the outer conductor being longitudinal copper strips spaced from the inner by elaborate *Styroflex* helices. Later cables preserved the same general construction but employed a copper-clad aluminium inner conductor and an aluminium tube pressed from two flat sheets and lapped. The attenuation of this later cable was about 0.155 népers/km.

9. WIRE BROADCASTING [30]

Considerable wire broadcasting networks were operated by the Reichspost in the large towns. The programmes were distributed to the towns on screened cable pairs and modulated with carrier frequencies of (typically) 155, 220 and 250 kc/s for transmission over subscribers' telephone pairs. The modulating and distributing equipment is located in telephone repeater stations.

SECTION 3. EXCHANGE EQUIPMENT AND MANUFACTURE

1. INTRODUCTION

The improvements actually made and those projected in the manufacture, design, and operation of German telephone exchange equipment during the war and in the few preceding years can best be viewed against the background of the organization of the industry and the general character of the manufacturing methods and of telephone exchange equipment, during this period.

This background is sketched in the following sections 2 to 4.

2. ORGANIZATION OF THE GERMAN TELECOMMUNICATIONS INDUSTRY

2.1. OPERATION

The state-owned public telephone service in Germany is operated by the Reichspost, the telephone exchange equipment being supplied by private firms.

The state-owned railway telephone service is operated independently by the Reichsbahn, the telephone exchange equipment also being supplied by private firms.

2.2. MANUFACTURE

The manufacturing industry is divided into two main groups :

(a) The Siemens group and

(b) The International Telephone and Telegraph group.

Smaller independent firms manufactured subscribers' apparatus and private branch exchanges, including P.A.B.X's, but generally all the public exchange equipment was manufactured by the Siemens and I.T.T. groups.

The Siemens group is German-owned, the Reichspost having a 40% interest.

The I.T.T. group is American-owned and manufactured equipment to Reichspost standards, this equipment being largely identical and interchangeable with Siemens-made equipment.

2.3. RELATION BETWEEN REICHSPOST, REICHSBAHN AND MANUFACTURERS

2.3.1. *Reichspost*

The largest manufacturers of telephone switching equipment by far was Siemens & Halske, with their main factories and research establishments at Berlin. Very close collaboration existed between the Reichspost and Siemens & Halske, and main development work was generally undertaken by Siemens & Halske or one of its subsidiaries.

Details of the other principal telephone manufacturers are given in a Report [17] on "The Manufacture of Line Telecommunications Equipment in Germany", but little development work regarding telephone switching systems was undertaken by these firms. Some development work was also done by the Reichspost engineers as instanced in the trunk switching system, using a form of coded tone frequency for operating purposes and outlined in section 6.3. Frequent interchanges of technical staff between the Reichspost and Siemens & Halske were stated to take place.

The collaboration between the Reichspost and Siemens & Halske, whilst determining the general lines of design and manufacture of telephone exchange equipment in Germany, has not prevented the development, manufacture and supply by Siemens & Halske of exchange equipment for foreign administration based on principles or used for purposes not required by the Reichspost.

2.3.2. *Reichsbahn*

The Reichsbahn is a separate organization concerned only with the German railways but taking a considerable interest in telecommunication switching systems as well as the usual signalling devices for control of train traffic. Siemens & Halske had a very close technical collaboration with the Reichsbahn, and had been largely responsible for the development of the nation-wide automatic telecommunications network covering the whole of the railway system in Germany.

3. MANUFACTURING METHODS

Factories of any considerable size continuing to function after the war are described and features and processes differing from British practice are indicated. [17] [55]

It is quite evident that the factories outside Berlin contributed only a small proportion of the telephone exchange equipment output even during the war. With the loss of the Berlin factories there did not remain in Germany any unit comparable in size with even the smallest of the principal British manufacturers. In the factories visited there was hardly any evidence of the adoption of mass production methods and no methods of production offering any marked advantage over methods in use in Britain were observed.

4. GENERAL CHARACTER OF AUTOMATIC EXCHANGE EQUIPMENT BEFORE THE WAR

4.1. THE TWO-MOTION SELECTOR

The standard numerical selector in Germany is the small two-motion "rectangular" switch in which the complete movement described by a wiper tip from start to finish of a call is a rectangle in elevation view.

For many years Siemens & Halske manufactured the Strowger two-motion selector which differed only in detail from the British pre-2,000 type selector. The original rectangular selector was introduced in 1924. This remained the German standard automatic telephone selector until 1927 when a still smaller selector of the same type was produced.

A feature of the design is economy of space by placing the selector mechanism in front of the contact bank, slightly to one side, instead of above it as in the Strowger type. Saving in weight has also been effected by improvements in design such as the use of a small die-cast frame, and also the absence of a separate release magnet.

Whilst savings in space and weight are advantages, they affect only a small proportion of the total equipment required for a complete telephone exchange and their value as represented by the reduction in the annual charge of exchange buildings is not of primary importance under British conditions.

The movement of the wipers is similar to that of the British Post Office 2,000 type selector. The rectangular selector is certainly very small but there is of course a disadvantage in having the mechanism in front of the bank because the wipers are not so accessible as on the type where the mechanism is placed above the bank. It should be noted, however, that easy interchangeability and simplified adjustment are features of the design and that one mechanism can readily be changed for another by simply withdrawing the one and thrusting the other into its place.

The small design does not permit the fitting of the various auxiliary spring sets found on the British 2,000 type selector and this would appear somewhat to restrict the facilities it can provide. Siemens & Halske claim that the design of the magnetic circuit particularly in the cross-section of the iron cores gives quick operating time for the armature and the speed of the switch on relay interruption is given as 37 steps per second which is rather faster than the 2,000 type selector. Another point concerns the contact banks which had been designed for ribbon cable wiring. This allows inspection of the bank soldering which is a point of some importance in reducing the service difficulties of dry joints.

4.2. RELAYS

The Siemens & Halske flat-type relay was standardized for telephone exchanges in Germany some years prior to the war, and is well-known to telephone engineers. In the opinion of Siemens & Halske engineers and exchange maintenance staff this relay has proved efficient in service and requires very little maintenance. The chief point in its favour, is that because of its simple design, it is much cheaper than the previous knife-edge type, although not quite as efficient. All main parts are press stampings including the core.

After experimenting with a few other designs, including a smaller version of the flat type, it was decided to use the above-mentioned type everywhere possible on automatic exchange equipments, even for line and cut-off relays

and all circuits are designed with this in mind. There are a few exceptions to this rule, the chief one being in the smallest exchanges employing line finders where small line and cut-off relays are used, somewhat similar to the 600 type used by the British Post Office for line and cut-off relays.

4.3. FEATURES OF AUTOMATIC EXCHANGE LAYOUT AND DESIGN

4.3.1. *General*

A point of interest in exchanges of the automatic type as supplied by Siemens & Halske to the Reichspost and elsewhere is that little alteration has been made over a period of many years in the trunking arrangements, circuit principles, and arrangement of racks. Probably the most notable changes were those occasioned by the introduction of the two-motion rectangular selector. Generally, changes in apparatus have been made to obtain improvement in performance or reduction in space while the apparatus itself remains functionally the same, or very nearly so.

So far as could be ascertained no new public automatic exchanges were installed during the war or immediately preceding it, although extensions to existing exchanges took place.

The small two-motion rectangular switch remained the standard numerical selector for public automatic telephone exchanges but this selector has important limitations, as for example that of having only 10 outlets per level, and also its unsuitability as a "drop back" selector. The former limitation of availability is overcome by interposing 15 point "mixing" switches between the outgoing selector levels and the more expensive (e.g. junction) outlets. The absence of the "drop back" feature as is the case of the British 2,000 type selector influences the switching arrangements for satellite exchanges.

The use of 10 outlets per level, as compared with the British practice of 20 outlets per level is largely a question of economics. As the various cost factors influencing a comparison may differ in the two countries, it is not unreasonable to suppose that the practice in each country is the more suitable for its national conditions.

An interesting feature of German practice is the general employment of a double wiper as a single contact with both wiper tips pressing one on each side of a solid bank contact. This is in contrast to British practice of single-sided wiper to bank contact. Both schemes have advantage.

The usual arrangement in all but the smallest exchanges is to provide subscribers' individual line switches. These are 12-point uniselectors having a "homing" position, an "all trunks busy" position and 10 outlets. These outlets are connected to 17-point uniselectors (actually 15 outlets are used) which in turn are connected to the first selectors. This is the well-known Siemens & Halske first and second pre-selector scheme. Where the total number of first selectors is small, the second pre-selectors can be dispensed with. In the smallest public exchanges, as for example rural exchanges up to about 200 lines, 50-point line finders and rotary step-by-step first selectors are employed.

All public exchanges operate at 60 volts, the calling subscriber drawing transmitter current from the first selector and the called subscriber from the final selector. Battery testing is employed throughout and the subscriber's meter is operated by increased current over the "C" wire upon initiation of

release of the connection, although the metering circuit is prepared when the called subscriber answers.

Other features of automatic exchange design generally differing from British practice are the avoidance of storage devices and translators of all kinds ; the avoidance of mixed digit working ; the use of level "1" of first selectors for subscribers' numbers, although usually the last level to be so employed ; no subscribers' line I.D.F., no automatic routiners ; multi-party line working (on the lines of the old British Group Service) and two-party line working with separate metering and secrecy for both schemes, secrecy being obtained in the two-party line case by using a two relay auxiliary equipment at one of the party's premises.

4.3.2. *Rural Automatic Exchanges*

The Reichpost do not favour unattended rural exchange, their practice being to house the equipment in the local Post Office or in a building adjoining. A visiting mechanic attends to the maintenance, being provided on the basis of 1 man per 1,000 lines not including subscribers' apparatus and line maintenance.

The Postmaster or Postmistress carries out mixed maintenance duties and regulates the heating. The need of special casing of the equipment does not arise and open racks are employed.

4.4. SIGNALLING AND DIALLING

4.4.1. *Local Junction Working*

In local automatic areas an interesting but well-known principle to be noted is that for a call from one subscriber to another no matter how many local junctions may be involved in setting it up, there is only one repetition of the impulses sent from the calling subscriber's dial. This repetition occurs at the first selector in the caller's exchange. This avoidance of impulse repetition at tandem exchanges is achieved by using either :

(a) three-wire junctions between exchanges when the distances are short and the traffic substantial,

(b) two-wire junctions which are connected through at tandem exchanges to the two wires of another junction. Repetition of impulses is avoided by locking the selectors used for the connexion at the tandem exchange instead of providing a holding and impulse repeating bridge. The locking condition is broken and the switch is released when the caller clears by virtue of a momentary high voltage applied at the outgoing end to flash over a neon tube and actuate a relay in series with it at the incoming end.

Another point to be noted is that impulsing over junctions is effected over one wire, so halving the resistances in series with the impulse relay as compared with loop dialling.

The application of these principles is stated to provide satisfactory dialling without imposing any resistance limits on local junction line plant which can consequently be the most economical type to comply with transmission requirements. This is a considerable advantage, resulting largely from the adoption at the outset of battery dialling over junctions.

4.4.2. *Toll Junction Working*

On the longer toll ("no delay") junctions up to 60 miles or so the method of signalling and dialling used on the predominantly audio junctions is 50 c/s A.C. This is used on account of interference from adjacent high voltage power lines apparently experienced extensively in Germany. This has led to the practice of dividing the lines into sections by transformers to avoid longitudinal build-up of interference currents so debarring direct current dialling and/or signalling. Another reason is the use of phantom circuits on audio cables for junction working which complicates direct current working. A still further reason is that even where direct current working is possible the 50 c/s A.C. signalling is much less prone to disturbance by varying insulation conditions on the line. When more than two 50 c/s dialling junctions are used in tandem, impulse correction is employed. The possibility of power line interference with telephone line signalling is increasing in Great Britain, and the further study of German methods may give some assistance.

4.4.3. *Trunk Working*

The long-distance network is provided and operated on a delay basis, the calls being booked at record positions and set up as in conventional delay operating practice.

For long-distance signalling and dialling beyond the approximate ranges already indicated for toll working, automatization has not proceeded very far. For carrier circuits 2 V.F. dialling has been used between Berlin on the one hand and Hamburg and Munich on the other. On these routes the standard C.C.I. frequencies of 600 and 750 c/s are employed. It was noted that in modern installations the V.F. relay sets and receivers were mounted on normal exchange type racks but were located in the repeater stations.

4.4.4. *Reichsbahn Switching and Signalling System.*

The German State Railways have a complete automatic switching system which provides telephonic communication over a wide network, embracing the whole of Germany.

The system provides a most extensive working communication network, controlled by automatic switching means. Communication is established by dialled impulses from any one automatic telephone in the network to any other. The system is restricted to railway personnel and over it much of the railway administration work was conducted. It is not used for railway signalling as such, which is effected separately.

The whole scheme is in effect a widespread completely automatic non-director system with conventional two-motion selector switching and signalling including satellite digit discriminating principles and any of the methods of signalling used for nation-wide public telephone systems. Technical features and points of interest are incorporated in the description in one report. [31] These are not of an outstanding nature. The chief matter of interest is in the national policy of fostering the complete independence of the railway and the public telephone systems, both administratively and as regards buildings, lines and equipment.

5. AUTOMATIZATION POLICY OF THE REICHSPOST

The policy of the Reichspost is to convert all manual exchanges to automatic working and to enable subscribers to dial not only all unit fee calls within

linked numbering schemes but also, by employing multi-metering, to dial calls greater than unit fee to subscribers on any other exchange within areas with boundaries up to approximately 50 miles from a town whose location and importance in the area mark it as the main switching centre.

There was no disposition to extend the range of subscriber-to-subscriber dialling beyond this multi-metering range nor any intention of employing automatic ticketing of subscriber-to-subscriber calls. In fact it was stated that the very long and costly lines could be fully exploited only by operator control and that for the longer distance trunk calls the policy was that ultimately all these shall be completed automatically by a control operator without the intervention of any other operator.

In implementing these policies the Reichspost shows no intention of departing from the principles of switching and signalling which have determined the design and layout of German telephone exchanges in the past. Thus, whilst the investigations of new methods of switching and signalling are actively pursued, the use of the step by step principle without translation for subscriber-to-subscriber dialling both within linked numbering schemes and within the extended multi-metering areas promise to remain the guiding principles for the future.

6. RECENT DEVELOPMENTS AND PROJECTS

6.1. AUTOMATIC EXCHANGE DESIGN

6.1.1. *Motor Uniselector Switching*

The Siemens & Halske high-speed motor uniselector was introduced about 1930 and is well known to telephone engineers. It has 51 sets of bank contacts to the half-circle but the wipers being staggered by 180°, successively traverse two series of contacts adjacent to each other in a manner well known so that it can be used as a 100-point selector with a normal position.

Up to the present time it has been used only to a limited extent, but in 1937/38 two trial 600 line automatic exchanges were opened both employing motor uniselectors throughout, i.e. for line finders, numerical and final selectors. One is a Reichspost public exchange at Eisenberg and the other a private exchange in Siemenshaus, the main Berlin office of the Siemens & Halske organization. The latter was inspected and is described in one report. [31] Siemens and Halske and Reichspost engineers were of the opinion that the equipment had worked exceedingly well, but opinions on the suitability of the motor uniselector for replacing the two motion selectors differed.

It was apparent that no official Reichspost policy for the future use of the motor uniselector had been formulated.

6.1.2. *New Switching Schemes*

Neither the engineers of the Reichspost nor Siemens & Halske considered that the cross-bar system was justified for use with direct impulsing systems. They were of the opinion that it is too expensive in these circumstances, although Siemens & Halske agreed that consideration of this system may be warranted by administrations using register systems.

No serious investigations had been made by the Reichspost or by Siemens & Halske into the use of electronic devices such as valves, cathode ray tubes and cold cathode tubes for automatic switching in telephone exchanges, though a number of patents dealing with such systems had been taken out.

6.2. AUTOMATIC TOLL WORKING—SUBSCRIBER-TO-SUBSCRIBER DIALLING

In central and southern Germany, subscriber-to-subscriber dialling with multi-metering had been introduced experimentally in a number of areas of about 100 miles in diameter. This full scale experiment was regarded as having been successful and it was intended to extend the method to suitable areas throughout Germany.

The fees are determined on a time and distance basis. To provide the multi-metering service satisfactorily it is necessary that the junctions between exchanges in the area should be provided on a "no delay" basis, and this is an economic factor which has its influence in selecting and determining the size and shape of the area.

The size of the area within which multi-metering is permitted does not appear to have been influenced by the fear that subscribers would object to the higher fee calls being registered on their exchange line meters and not shown separately in their accounts. In support of this policy it is affirmed that although subscribers can elect to have these calls set up by operators and so assure a separate entry in their accounts, it is found that even in newly-equipped networks the subscribers make about 95% usage of the longer range dialling when it has been in operation only for a few days.

The chief factors in determining the limiting range of multi-metering are economic and the avoidance of complexity. It is stated that within the range of about 100 miles the transmission requirements can be specified without repeaters in the junction lines, this avoids complexity and at the same time ensures that the majority of trunk calls are included in the multi-metering scheme. In fact 85% of the total trunk calls are effected over distances of less than 100 kilometres.

Features of the system are :—

(a) The exchanges in the area are given dialling codes which appear in the directory.

(b) A route-discriminating scheme on the lines of satellite exchange switching is employed at minor switching centres to maintain the code numbering scheme and at the same time to avoid switching through the main centre when local switching using the junction line plant more economically is indicated.

(c) The multi-metering apparatus, which provides for time and zone metering, has capacity for a 12-minute call between exchanges about 120 miles apart involving a fee which requires 60 unit fee registrations on the caller's meter. The speed of registration is 4 units per second so that the time taken in this limiting case is 15 seconds. Registration is effected on the release of the call. The multi-metering apparatus is located in the originating exchange or at the next forward exchange. In the latter case the registration fee impulses are transmitted over the junction to the caller's meter.

(d) Calls are cut off after 12 minutes, a warning signal being given to the subscriber 10 seconds previously.

(e) No multi-fee registration is effected if a caller releases the connection within 10 seconds of the "called" party answering. This is to avoid charging for wrong numbers.

6.3. SEMI-AUTOMATIC TRUNK WORKING

In the field of long-distance trunk working thought had been given just before the war and in the early war years to the methods to be adopted to assure over the whole of the long-distance trunk network that for the great majority of calls the controlling operator should be the only operator employed on a long-distance call. Early in the war years a scheme was propounded and accepted as a basis for development in preference to all other schemes which had been considered. The basis of this scheme is that each trunk terminal exchange in Germany, of which there are about 800, should have the same electrical calling code from any originating trunk traffic operator's position in any trunk exchange.

With this scheme a control operator's position at any originating trunk exchange would be provided with a bank of keys, each key corresponding to an objective distant trunk exchange. The number of keys per position was not settled but 100 was mentioned as a maximum.

Although the control positions of any one trunk exchange would therefore only have a limited number of direct calling keys, the various trunk exchanges throughout Germany each with, say, 100 keys, would between them have keys corresponding to all the, say, 800 terminal trunk exchanges in the country. Each key would send a combination of any number up to 10 different voice frequency currents. The use of 10 different frequencies, the combination of any number of which for one code would be sent simultaneously when the appropriate key was depressed, was one method contemplated. A later and more favoured method is to allocate a period, say of one or two seconds, to cover the duration of the code and to divide this into 10 equally spaced intervals so that if a pulse of a selected signalling voice frequency were sent in any one of these intervals, it would have a different significance from that in any of the other intervals. By employing combinations of pulses in the 10 intervals, the same total number of combinations, namely 1,023, could be produced by this method as by the use of combinations of 10 different frequencies. The preferred method would use only one frequency. A control operator wishing to call a subscriber in a distant town presses the code key corresponding to the appropriate trunk exchange and this will route the call either direct or via one or more intermediate trunk exchanges to the required exchange from which she (at her key switchboard) will receive a signal to send the dial impulses corresponding to the wanted subscriber's number. Alternative routing can be effected automatically if a primary trunk route is congested.

The objective trunk exchanges which are accessible by key depression at any originating trunk exchange would, of course, be chosen to cover the majority of the outgoing trunk traffic from that exchange. For the minority calls to distant trunk exchanges for which no key is provided on the originating trunk exchanges positions, it would be necessary for the controlling operator to depress the key corresponding to the most suitable distant trunk exchange towards that which is ultimately required and then on receipt of the dialling signal to dial say "O" to obtain the distant operator. This operator would then complete the call as though it had originated in her own exchange by depressing the key for the desired trunk centre, and completing by dialling.

When a call encounters busy conditions on both direct and alternative paths it would be automatically routed to an operator at the furthest point reached on the route.

It was visualized that motor uniselectors would be employed for all the selection of trunk lines. Laboratory trials were said to have been made of the principles of this scheme, but it has not been employed in the field. Fuller information of the scheme will be found in one of the reports. [31]

6.4. FOUR-WIRE SWITCHING

No firm solution to the problem of 4-wire switching had been found but much consideration of the problem had been given by Reichspost and Siemens & Halske engineers. It was stated that if and when 4-wire switching was used at manual positions it was intended to use cord positions rather than cordless positions for this purpose. In this connexion, Siemens & Halske had developed a 6-way switchboard plug, and corresponding jack, but these had not been used in practice. [31]

The Reichspost had also propounded a scheme for using carrier frequencies to provide a further speech path over ordinary 2-line wire switchboard plugs and jacks to permit 4-wire switching. This scheme was not considered to be desirable as a permanent standard but its use would perhaps be justified for adapting existing manual switchboards for 4-wire switching.

7. EXAMINATION OF GERMAN DEVELOPMENTS IN RELATION TO BRITISH PRACTICE

It is interesting to review the developments of the German telephone exchange equipment industry during the war in relation to British practice. It is clear, however, that for this period the industry in both countries was operating under the worst possible conditions for useful progress and very little improvement—certainly nothing spectacular—can be expected. This, in fact, is what has happened, but even so it will have been noticed in earlier sections that there have been a few interesting developments and proposals for development in Germany during the war. These are largely projections of the continuous development process which has been going on for many years. It is thought that a brief examination of the development process in the telephone exchange field in the two countries, the resulting difference in practice, and the underlying probable causes, will be interesting in itself and helpful in examining the more recent German developments in relation to British practice.

Both administrations started a programme of automatic telephone exchange installation a few years before the first world war on the common basis of the 10-level 10-point two-motion selector and the 10-point primary and secondary line switch, and gradually differences in practice evolved.

The key to the main differences in practice appears to be the very different attitude of the two administrations, which became apparent at a very early stage, to the compromise any administration has to make between the conflicting principles of simplicity of switches on the one hand and reduced quantity on the other hand. The Germans leaned more to the former and the British to the latter.

This led to the early use of increased availability of outlets in British practice from 10 to 20 on two-motion selectors and from 10 to 25 outlets on the line switch, resulting in the British case in the avoidance of mixing pre-selectors

on selectors 10-level outlets to junction routes and of secondary pre-selectors, both of which were necessitated by the German practice of adherence to 10-outlet leads. Both principles can be defended and in fact each may be the better for the prevailing conditions in its own country. The difference had no marked effect on the general layout of exchange and line plant or the subscribers facilities and numbers scheme for independent automatic exchanges, or for the smaller multi-office linked numbering schemes.

When, however, the automatization of large multi-office areas like London and Berlin had to be faced, the German leaning for simplicity forbade the director whilst the British leaning for overall economy accepted it. Here again both principles can be defended.

This avoidance of the director with its translation feature appears to have become established in the minds of German telephone engineers, and no doubt provides a clue to what at first sight seems to be a lead of German over British switching technique in the adoption of subscriber-to-subscriber dialling within large areas outlined in section 6.2. and the considerable development of the semi-automatic trunk switching scheme outlined in section 6.3., which are probably the outstanding achievements of the German telephone exchange industry just before and during the war.

In deciding the policy of the extent of subscriber-to-subscriber dialling within its own territory, an administration has two alternatives :

(1) To aim at 100% subscriber dialling.

(2) To aim at fairly large areas in the territory within which 100% subscriber-to-subscriber dialling is provided, and to employ controlling operator dialling for all the larger trunk calls between these areas.

The adoption of the first policy involves two things ; a national numbering scheme with translators (directors) and the provision of routes on a no-delay basis. It has been shown that the former is not liked in Germany, and the latter for the longer distance trunk routes is considered to be expensive. A policy decision therefore has been made that a national numbering scheme will not be adopted. This has led to the two developments already mentioned :

(a) Subscriber-to-subscriber dialling confined to areas of a size which permits of an exchange and line network which does not require translators and which is not too big to proscribe multi-metering.

(b) Rapid semi-automatic operation for all the longer trunk calls using 10-character voice frequency exchange identification codes.

The policy decision on the basis indicated was fairly easy to make and cleared the way for active development.

In the British case the determination of the scope of subscriber-to-subscriber dialling on policy grounds is not so simple. There is no ban on the use of translators, and there is no economic objection to providing the longest trunk lines on a no-delay basis. The question is posed therefore whether 100% subscriber dialling with national numbering shall be adopted or whether subscriber dialling shall be limited to suitable areas. This is a very difficult question which for the reasons given did not arise in Germany. It is a question which requires much enquiry and investigation from the engineering, economic service and administration standpoints. This enquiry has been proceeding for some years and is still proceeding.

SECTION 4. TELEGRAPHS

1. OBJECT

This section is a brief summary of the information contained in two reports [25] [64] on the subject of telegraph apparatus in use and/or developed in Germany during the war years 1939/45. The survey includes mention of the principal advances made and provides a critical and comparative analysis of such information, in relation to developments in Great Britain during the same period. Some supplementary information to that given in the reports has been available, mainly as a result of more detailed examination in this country of equipment evacuated from Germany, and this information has been used in the compilation of the present report.

2. TELEGRAPH INSTRUMENT DESIGN

The design of telegraph instruments has with few exceptions remained substantially the same as was known pre-war. [25] [98] Only two new types of instrument were found, namely :—

(a) A lightweight teleprinter weighing 17 kg, i.e. 37½ lb, manufactured by Siemens & Halske, and known as a T-Type 68. [64] This machine was developed for the Wehrmacht to provide a multi-purpose instrument having robustness combined with compactness and minimum weight. It includes a 4-row keyboard, typewheel tape receiver, reperforator and automatic transmitter and an automatic dialling unit for use when required in conjunction with the Teleprinter Automatic Switching System. The dialling unit, automatic transmitter and reperforator units may be omitted if desired. When used as a reperforator the instrument operates as a printing reperforator. Only 15 prototype models were produced. This machine is undoubtedly an interesting development.

(b) A combined transmitting and receiving Hellschreiber instrument with typewriter keyboard for field force use. This machine was manufactured in quantity by Siemens & Halske and is known as the Feldschreiber.

The principal developments which occurred in contemporary British designs were as follows :—

(a) Messrs. Creed & Co. developed the Teleprinter No. 10X which is a tape-receiving teleprinter of radically new design employing the principle of aggregate motion selection. This instrument is compact, light and very silent in operation and has a margin of 45% with orientation. It was developed just prior to the war and primarily for use on ticker services. Its principal application during the war was to R.A.F. teleplotter service in fighter operations rooms.

(b) Messrs. Creed also developed in the late stages of the war a printing reperforator Model 85 (transmitting and receiving models). This machine was intended for use by the Services for tape relay systems.

(c) The Great Northern Telegraph Co. developed an elegant range of markedly improved types of Morse instruments, namely Model 309, Undulator, Model 112, Wheatstone transmitter and Model 451 receiving reperforator.

(d) For certain special purposes the reception of telegraph signals and their conversion to other codes was effected by means of equipment using electronic switching techniques developed for the purpose. There does not appear to have been any corresponding types of equipment in Germany.

Many minor changes in the design of components of German telegraph instruments were noted but as in the British case these were imposed mainly as the result of shortages of materials normally used or as the result of efforts to simplify bulk production processing. A notable development in this connexion was the use of pressure die-castings, and in this respect the Germans appear to have made considerably greater use of this method than in British practice. In all cases the components produced in this manner are ones in which the component is only lightly stressed.

German designs do not appear to have made use of any forms of self-lubricating bearings, whereas in British designs increasing attempts have been made whenever possible to incorporate this type of bearing to reduce lubricating maintenance problems.

3. PICTURE TELEGRAPH EQUIPMENT

There were no advances in picture telegraph technique [102] in Germany during the war, apart from preliminary development work for special applications in which the use of television technique was proposed for the transmission of telegraph messages. In Great Britain the use of sub-carrier F.M. was introduced immediately before and during the war for use on radio circuits. The Germans do not appear to have considered the use of this method. Also, in developing systems in Great Britain crystal oscillators were employed for the apparatus necessary for speed control and this was the first occasion of their use for this purpose as far as is known.

4. TELEGRAPH SERVICES

The technical methods of operating telegraph services in Germany during the war years had not changed substantially from the position as known in 1939. There had been a considerable expansion of the Automatic Teleprinter Switching System (i.e. Telex Service) using the Siemens Fernschreib Wahlamter TW.39 system. [99] The assembly and component design of this equipment is excellent and the circuit design appears to have overcome the shortcomings inherent in the earlier equipment employed, namely the Siemens TW.35. No points of outstanding novelty or originality were discovered.

Full details of the Automatic Teleprinter Switching System are given in Siemens Fernemelde Technik TE.13/49—Fernschreib Wahlamter TW.39, [100] and one report [25] describes a number of the most interesting features incorporated in the equipment.

In Great Britain the proposed conversion of the Public Telegraph Service from point-to-point teleprinter working to automatic switching had been halted by the outbreak of war in 1939. Manual switching, employing multiple type switchboards, was introduced as a war-time expedient in the later stages of the war. Very extensive use, however, of manual teleprinter switchboards, providing intercommunication and broadcasting facilities, was made in this country from the outset of the war for the defence teleprinter network of the Fighting Services.

The development of manual teleprinter switchboards in Germany was comparatively slight as a result of the automatic switching service provided by Telex. The facilities provided in German switchboards were, however, similar to those adopted in this country, but British equipment was in general more compact and catered for a greater range of capacities.

The design and production of miniature electrical components in Germany was in advance of British practice. The Siemens & Halske telegraph relays (based upon Carpenter patents) were notable examples in this respect.

5. TESTING EQUIPMENT

No novel forms of testing equipment employing new principles were found. Two items of testing equipment appear to have been employed in conjunction with the automatic switching network, i.e. :

(a) A "Test Transmitter" for testing the receiving mechanism of a teleprinter by means of a continuously repeating test message having graded degrees of distortion, i.e., 0, 10%, 20%, 30% and 40%.

(b) An "Automatic Distortion Indicator" for testing the transmitter of a teleprinter. This device is a development of the tester described by Schallerer in Telegraphen-Fernsprech-Funk-und-Fernseh-Technik, Part 2, 1935. [101]

These two items appear to have been of particular value in connexion with the automatic telegraph switching network since the testing facilities were readily available to a large number of teleprinters.

In Great Britain a very novel and interesting development was the Telegraph Distortion Monitor developed by the G.P.O. for the purpose of providing a continuous check of the grade of service on a working telegraph channel operating on a short wave radio link. This device will provide an alarm when a predetermined degree of distortion occurs and will also count the number of signal elements whose length is less than a preset percentage of a unit signal element.

SECTION 5. SUBSCRIBERS' APPARATUS

1. SUBSCRIBERS' INSTRUMENTS [27]

The design of German telephone instruments [121] appears to have been dictated by considerations more of cheapness in manufacture and less of satisfying appearance than in the case of their latest British equivalents.

The instrument body is usually a sheet-metal pressing, and the moulded parts—handset and receiver rest—have projecting ribs along the mould joint lines for ease in removing the "flash". All telephones are of the "handset" type, with capsule-type insets for both transmitter and receiver.

Research and development work came practically to a stop before and during the war. The latest important decision of policy [104] had been that in view of the small cost of transmitters and receivers in relation to the total cost of a subscriber's line, improvements in the performance of these items would be worth-while even at the price of a relatively large increased cost for the individual items, and work along these lines had been started. (See sections 2 (Transmitters) and 3 (Receivers) below.)

In the meantime, it was proposed to control the production [109] of the existing "cheap" designs more closely, and to use the "Reference Equivalent Meter" [108] to segregate items of "good" or "outstanding" performance from the remainder, for allocation to compensate for inefficient junctions or local lines. [110]

The line balance in German telephones was formerly a 240 ohm non-inductive resistor which, with the transformer ratio of the induction coil used, gave the least side-tone when connected to a 600 ohm non-reactive line. To give the least side-tone when connected to long underground lines, telephones are now provided [107] with a balance consisting of a 600 ohm non-inductive resistor shunted by a 0.3 microfarad condenser. The latter is disconnected for overhead and short underground lines.

2. CARBON TRANSMITTERS

The majority of German transmitters have carbon diaphragms with the front electrode moulded integrally with the diaphragm (S).*

In the latest type, this electrode is a blunt cone cut back to leave only five narrow radial strips in the form of a star, and the back electrode is a concave star with a lacquered aluminium insulating cap to concentrate the current to the useful part of the diaphragm chamber. [103] Volume and quality were claimed to be independent of position, but packing troubles are still experienced. Carbon granule production is wholly empirical [17] and different sizes of granules are selected to give a high resistance for central battery or a low resistance for local battery working.

At the 1938 C.C.I. meeting Siemens & Halske made extravagant claims for a transverse current transmitter, i.e., one in which both electrodes are fixed, and the moving element is insulated. [103] Excellent freedom from non-lineality was in fact obtained, but the output was about two népers down in volume and the item was thus unfit for service.

The Reichspostforschungsanstalt were attempting to regain the lost two népers partly by better receivers and partly by providing the transmitter with an iron diaphragm driven electromagnetically to give a form of regeneration. The intention was to connect the driving coil in place of the normal anti-side-tone balance, and to polarize the magnetic system by the transmitter feeding current.

3. RECEIVERS

Capsule receivers (S) had been standardized to avoid the variations of sensitivity inevitable with detachable diaphragms, but the latest type in service does not incorporate any other improvements over previous designs, and is inferior to British types such as the B.P.O. Receiver Inset No. 2P.

The Reichspostforschungsanstalt had done some work on a receiver with a thin steel conical diaphragm, using several pairs of poles arranged alternately in a circle to increase the force on the diaphragm while avoiding high flux densities in it. Trouble was experienced with instability of the airgap, and it was concluded that a large gain of sensitivity could be obtained in a magnetic receiver only by the use of a balanced armature design.

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*Specimens of items marked (S) may be inspected at the Engineer-in-Chief's Pattern Room, G.P.O. (Castle House), Aldersgate Street, London, E.C.1, where they are held under the title of "German Subscribers' Apparatus".

Tilting rectangular balanced armatures were employed for the transmitters and receivers of the early Siemens & Halske sound-powered telephones. The latest Type 70 employs a circular armature clamped round its periphery and coupled by a central driving rod to a light aluminium double-conical diaphragm (S). A balanced concentric magnetic system is employed and the design appears to be much in advance of previous types both in performance and ease of manufacture. Work had been started to develop a similar but lighter unit, which was expected to have applications as a receiver in an ordinary telephone, giving a probable improvement of about 0.5 néper in volume over the existing receivers.

4. CAPACITORS

The condensers used in German telephones employ either metal foil with separate kraft paper dielectric, or metallized kraft paper, and their manufacture follows well-known lines. [7] [24] [30] [36]

5. MISCELLANEOUS TELEPHONE INSTRUMENTS AND FACILITIES

Operators' headsets having a light capsule transmitter supported by an arm from the earpiece (S) were used by the German Armed Forces, but supplies had not been sufficient to allow the Reichspost to replace earlier types by these, as it desired to do.

Receiving amplifiers were not in general use, except by the Army, as a maximum gain of 1.5 népers was specified to avoid loss of secrecy through cross-talk and this could in practice be secured by the use of a sensitive auxiliary receiver (S) either of the balanced armature type or employing a Rochelle salt piezoelectric crystal and matching transformer. One form of receiving amplifier employed a mechanical system consisting of a crystal receiver assembled in one unit with a carbon transmitter, but this gave results of inferior quality.

Some tests had been made by the Reichspost with the Lorenz system of subscriber-to-subscriber 1 + 1 carrier working [111] [112] commonly distinguished in Great Britain (though not in Germany) [30] as the "zweiband system". To avoid the frequency conversions from "audio" to "carrier" necessary in this system, the Reichspostzentralamt had an alternative scheme [105] for feeding one subscriber's transmitter directly with carrier frequency in place of the normal D.C. and thus employing "carrier" from end to end in one direction and "audio" from end to end in the other direction.

6. DIALS AND OTHER IMPULSING DEVICES

The latest German dial, designed just before the war but still in very limited use, is an improvement on their earlier types (S) in following the British (and American) practice of running the governor at a high speed. It has a 3-tooth fibre impulse wheel, and a lost-motion period which can be either after or (by fitting a special cam) before the train of impulses. The design is notable for its simplicity, and for the use of synthetic resin mouldings both for the main body and the finger plate (S).

For operators' positions a dial mechanism is mounted in a geared assembly including a finger-plate which is part of the curved surface of a cylinder and which moves nearly vertically in front of the operator. This facilitates use and lessens fatigue.

Electrical keysenders are sometimes used at Private Branch Exchanges, but mechanical keysenders and autodials are unknown—the operators' dial largely eliminates the need for them.

7. COIN-COLLECTING TELEPHONES

Wall-mounting coin-collecting telephones are generally similar to British types, but incorporate an air-dashpot to prevent impulsing from the receiver-rest, armoured handset cords, and special lock-screws to the transmitter and receiver caps. A 3-minute cut-off of local dialled calls is contemplated. Multi-fee working is used in Bavaria.

A coin-collecting table telephone is available for local calls from subscribers' premises but has a complicated and flimsy mechanism (S). Trunk charges are booked, after releasing the normal electro-mechanical trunk-barring feature with a special key.

8. SUBSCRIBERS' INTERCOMMUNICATION SYSTEMS

Subscribers' intercommunication systems [27] could be rented from the Reichspost, but were mostly purchased privately, subject to Reichspost approval of the design (which would then be included in the "Reichspost Catalogue of Systems"), [106] and maintained either by the subscriber's own staff or a contractor.

Private Manual Branch Exchanges [121] [123] were regarded as obsolescent except for 50- and 100-line lamp signalling switchboards. The latter are generally similar to the B.P.O. P.M.B.X. No. 1A but use 4-way plugs and cords and give a local transmitter-feed to the extension during exchange calls. They may be installed either singly or in suites of up to eight positions with a series multiple. [121] [124]

Series Systems (*Reihenanlagen*) [121] [125] are generally similar to the B.P.O. House Exchange System, but obtain secrecy on exchange calls by a series connexion of the line instead of a parallel connexion with guard relays, and are consequently much simpler. Sizes range from one exchange line with one internal extension to five exchange lines with 15 internal extensions : external extensions may also be connected, via a special manual switching unit. [125] For installations of one exchange line with a single external extension the Reiha-apparat is replaced by the "Zwischenstellenumschalter" [121] [126] which is generally similar to the B.P.O. extension plan 7 system but employs a wall-mounted relay-set (S) in place of a multi-contact switching key. Exchange calls may be signalled automatically to the extension if not answered at the main station, and direct access to the exchange is available from the extension. Signalling and speaking current for these systems is provided over the B wires of the exchange lines via special feeding bridges at the exchange and subscriber's premises, [121] and impulsing is then effected over the A wires to earth.

Private Automatic Branch Exchanges [121] [122] of all sizes from one exchange line with three extensions have been popular in Germany, and use switching equipment generally similar to British types. Facilities which have been standard in Germany for many years, though they are only now being introduced in Great Britain, include the use of cordless attendant's cabinet for answering incoming exchange calls, and the ability to effect local enquiries or the transfer of an exchange call automatically by means of a "call-back and transfer" circuit. Direct dialling to extensions from the public system is

provided in some areas and special facilities such as immediate access, conference, staff locator, and fire alarm, were permitted on privately-owned-and-maintained installations.

Heat Coils of various ratings (or in the larger sizes electro-magnetic circuit breakers) are used for apparatus protection [121] to the exclusion of fuses. The latest heat coils are reset after functioning either by reversal in the holder, or by fitting a fresh fusible metal disc (S).

Plugs are similar to British types, but may have a central fourth conductor. They are provided with a helical spring cord guide which was abandoned in Great Britain many years ago (S). No moulded plugs were seen.

9. FLAMEPROOF EQUIPMENT

The principles of intrinsic safety, i.e., the design of apparatus so as to be incapable of producing incendiary sparks, are not used in Germany. Apparatus for use in inflammable atmospheres is of the type known in Great Britain as "flameproof", i.e., enclosed by a metal case strong enough to withstand an internal explosion and having wide-flange joints to prevent its propagation to the outside. Apparatus for use in coal mines is tested and certified [113] by the Berggewerkschaftliche Versuchsstrecke of Dortmund-Derne [119] and for other industries by the Chemisch-Technische Reichsanstalt. Full details of the requirements and testing procedure are contained in the appropriate sections of the Vorschriftenbuch des Verbandes Deutscher Electrotechniker. [113] [116]

In Germany, flameproof enclosure is insisted on only for those parts, such as moving contacts, which are considered dangerous in normal working and not necessarily for such parts as terminals, primary cells, and bell coils nor hence, presumably, for the connecting wires between different telephones, etc.

In common with British practice, telephone handsets and cords are also unprotected, but German practice [121] is normally to fit special lock-screws to the transmitter and receiver caps to prevent unauthorized removal with its risk of sparking at the inset contacts.

One of the two manufacturers visited [118] made electrical connexions through the wall of the flameproof enclosure by brass bars moulded into a synthetic resin plug (S) which was afterwards sealed into a tapped hole in the wall by synthetic resin cement and an S.R.B.P. nut. This appears an improvement on British practice.

10. PRIVACY EQUIPMENT

Little use was stated to have been made in Germany of telephone privacy equipment, doubtless owing to the general atmosphere of mutual suspicion coupled with recognition of the fact that unless a very elaborate system is used "scrambled" speech can be understood, at least in parts, by a practised listener even without special equipment. Secret teleprinters [25] were used where a high degree of security was required.

Siemens & Halske had made less than 1,000 frequency inversion sets, using a carrier of 2,100 c/s for the Wehrmacht, 3,000 c/s for the Reichspost, and 2,700 c/s for the Nazi Party.

Split-band working with 2, 3 or 5 bands interchanged either automatically or at the will of the user had been used on a few radio-telephone links by the German Navy and diplomatic service. Study of the frequency spectrum of

recorded split-band speech to locate the band boundaries with a view to decoding had been undertaken by the Physikalische Technische Reichsanstalt.

The Wehrmacht had ordered 2 pairs of "time-scrambling" equipment based on a 1918 Danish invention by Tigerstedt, but it is uncertain if the second pair was delivered.

The Luftwaffe had ordered 40 pairs of "wobble-frequency" equipment for use on decimetre-wave beam radio circuits, but except for experimental prototypes these were never delivered because of air raid disturbance. This was a frequency inversion system using a modulating carrier of 40-60 kc/s wobbled through a range of 3 or 4 kc/s under the control of two rotating variable condensers, to a prearranged programme repeating itself every 15 minutes. Band inversion was used to avoid an excessive total side-band width.

11. OTHER SUBJECTS

One report [27] contains some notes on the following matters which came to the notice of its authors during their visit, but which are not directly concerned with subscribers' apparatus :—

Electro-Acoustic Measuring Apparatus and Laboratory Technique (see Section 1 (Research and Development) of this Survey).

Condenser Microphones for Explosion Measurements.

Atlas-Werke A.G., Bremen.

Deafness and Hearing Aids.

Manufacture of Rochelle Salt Crystals (see Section 7 (Radio) of this Survey).

SECTION 6. POWER

1. POWER PLANT

No specific investigation into the German practice in providing power supplies for telecommunication services was made by either British or American observers.

From pre-war technical literature it appeared that general practice in Germany did not differ appreciably from current British and American practice, and the absence of any particular comment by observers who visited Telecommunications Establishments supports this view. There is, however, some interesting information available on some aspects of power plant obtained as a result of investigation on other allied subjects, e.g. secondary batteries.

The very complete investigations made into the secondary battery industry [10] [15] show that the Germans were not in advance of the British in lead-acid secondary cell technique. A new storage battery with a cell voltage of 3 to 4 volts, invented by Dr. Fredrich Croy, was investigated in some detail. [59] The object of the invention lies in the use of metallic mercury or the amalgam of another metal as the cathode, a lead oxide grid similar to the positive plates of the lead battery as the anode, and a solution of sodium sulphate-sodium hydroxide as the electrolyte. This battery is still in the experimental stage and considerable development is required before a practical battery emerges. The Germans have made some progress in the development of lightweight alkaline secondary batteries, using sintered plates. It appeared that this process was in the development stage, the batteries concerned being those for

miners' hand lamps, train lighting and traction purposes. The use of sintered plates dispenses with the usual heavy metal grid used in British manufacture. The production of stationary batteries was unexpectedly high during the war, the reason for this not being clear.

On the electrical control side of power plant, the most marked difference between German and British practice is in the use of small circuit-breakers. [45] [52] The German designs are not new but the circuit-breakers are of excellent construction. British manufacturers have full details of these circuit-breakers and it is expected that they will be developed for general use in Great Britain. A particularly interesting example is the German circuit-breaker for house lighting and small motor installations. It is unique in that it provides both magnetic and thermal overload protection in a small enclosure which can be inserted into a standard screw type fuse socket.

On the machine side a compensated A.C. generator developed by Professor Dr. Ing. Humburg, was of particular interest. [14] The particular machine inspected was rated 30 kVA 380 volts, 3-phase, and was used in considerable numbers by the German Army for Diesel-operated field supplies of A.C. The compensation adapts itself automatically to both power load and power factor. Voltage variation was claimed to be less than $\pm$ 2%. Generally, loads imposed by telecommunication equipment are fairly steady with the exception of W/T transmitters and it would appear that these special machines would offer little advantage for stationary equipment.

Mechanical rectifiers or contact convertors are still in the development stage ; one installation operating at 1,500 amps 600 volts, was operating on the street-car system in Hamburg. [53] It is claimed that a 2,000 kW contact convertor weighs 2.5 tons as against 23 tons of an equivalent synchronized convertor. The contact convertor would, therefore, appear to have advantages and might repay further development work.

The air conditioning and refrigeration industry had nothing new to show investigators and observers expressed the opinion that Germany lags behind America by 5 to 10 years. No reference is made to the application of air-conditioning or refrigeration to telecommunications buildings, and it is doubtful whether air conditioning was used to any great extent in apparatus rooms or switchrooms. There seems to have been some attempt to control humidity in some apparatus rooms, [41] but nothing very elaborate was attempted. There is no reference to any special precautions taken to exclude dust from apparatus rooms.

SECTION 7. RADIO, INCLUDING BROADCASTING, WIRE BROADCASTING AND TELEVISION

1. ORGANIZATION OF GERMAN RADIO DEVELOPMENT

The German radio industry was co-ordinated for the war effort by the Speer Ministry, and the Telefunken organization [76] was an important instrument in the execution of Government policy as it co-ordinated for the Ministry much of the Academic Research, the Operational Research, and Production chains for the country. Most of the H.F. research was done by this, and other, similar, large firms. Isolated problems were undertaken by Universities [87] and by small free-lance laboratories [69] [77] working as independent units.

The Telecommunications Research Section of the Deutschen Reichspost [86] undertook pure research into S.H.F. problems, propagation, and cosmic ray and ionospheric phenomena, and the development of ultra-sonics and the application of pulse modulation technique to multi-channel telephony. The national co-ordination of the work seems to have been incomplete, however, due possibly to difficulties of communication between the hundreds of small units into which the industry gradually dispersed on account of Allied air attacks. There are frequent mentions of such dispersals throughout the reports.

2. BROADCASTING

Little information on the German broadcast system appears in the reports, possibly because of the greater interest displayed in Germany in the wire-programme services. The broadcasting studios at Munich are briefly described [12] but although at the time of the visit only the skeleton remained, it is clear that they were not outstanding examples of studio construction. Reverberation data was found in some of the records which survived the raids.

Upper Austria had three synchronized broadcasting systems briefly described. [97] Each consisted of a main station with two cable-connected slave stations, the three being kept in synchronism by automatic capacitor-trimming of quartz crystal oscillators.

Visits to the 100 kW broadcast transmitters at Hamburg and Munich are reported ; [5] these equipments were supplied by Telefunken and Lorenz respectively. A 1,000 kW Lorenz L.F. transmitter, which was erected at Calbe for communicating with U-boats is mentioned. [5] It used four RS-300 tubes in parallel push-pull and could be tuned from 15 to 60 kc/s. The station was apparently quite successful as it could be heard by U-boats submerged in the Caribbean Sea.

The German radio industry obtained some small assistance from factories in occupied territory and a survey of the activities of some of these is given. [70] [72] [73] [75] Components and equipment for use in broadcast and Services radio work comprised the bulk of the useful output.

3. WIRE PROGRAMME SERVICES

The wire broadcasting system was regarded by the Reichspost as the most important method of distributing radio entertainment and in a 10-year programme they aimed at covering all potential listeners. [50] The network was developed more thoroughly in the north of Germany than in the south, but one type of system was used throughout and arrangements were made for three programmes to be distributed. At a central station these were used to modulate carrier frequencies of 155, 210 and 260 kc/s and the signals were transmitted together, via broad-band amplifiers over cable pairs including subscribers' telephone lines, and filters were provided to separate the telephone and programme channels. The terminal amplifiers included a standard amount of pre-equalization to give some correction for the characteristic of subscribers' lines. The received signals usually extended from 30 to 8,000 c/s. For toll cable connexions between distributing centres, loaded audio cables were used having cut-offs around 9 to 11 kc/s. These cables had amplifiers at 70-kilometre intervals with line output levels of +0.7 népers with reference to one milliwatt. Open wire links for long-distance programme distribution by single channel carrier were under trial when the war ended. [50]

4. TELEVISION AND WIDEBAND TRANSMISSION

A public television service continued in Germany until 1943 and cinema television was used throughout the war for troop entertainment. [71] The Berlin-Leipzig telephone-television service, [35] which employed 200 lines on the video channel and coaxial cable transmission with a band from 1.3 to 2.5 Mc/s, was also in operation. It would appear that 200-line definition formed the basis for the proposed German television network although experiments had started on 441-line definition using a 4 Mc/s band-width ; a 1,029-line system was in the early stages of development. [35]

In general technique, German television was somewhat behind that of the United Kingdom when, in 1939, development was stopped in order that the personnel could concentrate on service developments such as guided missiles. The trend of the television and coaxial cable developments up to the time they were stopped on account of the war can be discerned in detail from several good German papers. [62] Code-modulated telephony, wideband time-division multiplex systems, and a combined television and telephone service were being designed. A rotating electron-beam vacuum tube switch had been developed for use in some of these projects.

Iconoscope development [19] had been encouraged for use in guided missiles and work had just commenced on the orthicon when the war ended. [93] Considerable laboratory progress appears to have been made in photo-emission technique, particularly in the application to photo-cells and photo-electric multipliers. The Weiss pattern was preferred in the latter and lives of 1,000 hours were stated to have been obtained. This appears to compare favourably with the situation in the United Kingdom at that period.

5. RADIO COMMUNICATION IN THE SUPER HIGH-FREQUENCY RANGE

In the field of S.H.F. radio communication it appears that there were no outstanding developments in Germany and that the technique in 1945 was behind that of the United Kingdom. It seems that multi-channel systems were being developed, [20] and in particular centimetre-wave multi-channel pulse modulated radio equipment was being designed but was never actually in operation. Research was started on the use of magnetrons as sensitive detectors in the S.H.F. band, and on wide-band tunable Klystron oscillators for the ranges 3.8 to 5 cm and 1.7 to 2.1 cm, and radio interferometers for wavelength measurements in the range 6.8 to 0.37 cm were constructed, at the Physikalische-Technische Reichsanstalt, Heidelberg. [63] An interesting 32-channel electron switch was under consideration for a time-division multiplex system. [26] Telefunken did useful work on S.H.F. directional aerials and the theoretical work of Dr. Kurt Fränz in this connexion is summarized. [57] The Institutes of the Bevollmächtigter für Hochfrequenz-Forschung were the controlling authorities for a wide range of research in the fields of radar and signals, and an account of their work, including countermeasures against Allied radar, is given. [89] The Ferdinand Braun Institute worked on navigational aids and anti-jamming measures ; [89] the Ernst Orlich Institute on anti-jamming, C.W. radar, and infra-red systems ; and the Ernst Lecher Institute on centrimetric aerials, local oscillators and crystal valves. The last-named Institute was also working on countermeasures against Allied radar.

6. RADIO-SONDE TRANSMITTERS

Lightweight radio-sonde transmitters for sending signals from meteorological balloons were in use in Germany towards the end of the war. The Marine Laboratory at Greifswald had developed a frequency-modulated radio-sonde using a capacitor with temperature-sensitive dielectric as its source of signal control. [68] At Stuttgart a 2-valve radio-sonde which receives conventional radar signals and re-transmits them after an amplification of "20,000 times" was under development. This device was extremely light and cheap to make and was intended for use in balloons engaged in wind current determinations.[83]

7. APPLICATIONS OF ULTRASONICS TO PHYSICS AND BIOLOGY

Siemens-Schuckertwerke did much work in applying ultrasonic vibrations to various physical and chemical processes. [44] They found that most of the effects were not frequency-dependent, and that those frequencies could be chosen which were most convenient from the point of view of design, e.g. magneto-striction was employed between 10 and 25 kc/s, piezoelectric oscillators between 300 and 400 kc/s and a generator based on the Galton whistle at 15-20 kc/s. The applications were most diverse, and included emulsification of liquids, disinfection of water and milk, coagulation of smoke, dust precipitation, and the hastening of crystallization in sugar refining. Interesting engineering applications were the degassing of transformer oil and the use of ultrasonic vibrations instead of a flux in soldering and welding. In the latter application the work to be joined was placed on a supersonically vibrating anvil and it is claimed that this was sufficient to make the use of any form of flux unnecessary. [44]

8. PIEZOELECTRIC CRYSTALS

A small amount of raw quartz had been obtained from the Ukraine, but the chief source of the pre-war stock of raw material for piezoelectric purposes had been Brazil. The production of quartz piezoelectric elements rose from a pre-war total of 10,000 per annum to a peak of 400,000 during 1944, being spread over 10 firms, chiefly Telefunken, Zeiss, and Steeg & Reuter. Zeiss produced some 10,000 quartz BT plates for oscillation directly at 60 Mc/s, by wringing them on to optical flats and hand-lapping with rouge, and it is interesting to note tourmaline plates up to a frequency of 400 Mc/s had been produced by skilled operators. Scarcity of quartz brought about a reduction in size of plates and stimulated attempts to synthesize quartz in autoclaves. Substitutes for quartz, including $NH_4H_2PO_4$ and KH_2PO_4, were crystallized from solutions and nepheline from melt, but no synthetic piezoelectric circuit elements had come into use except Rochelle salt, which was used for audio frequency work, e.g. gramophone pickups and microphones. One authority stated that in the crystal growing process hairs were superior to threads or wires as supports for the crystal seeds, and that most crystals needed to be annealed after removal from solution. [58]

Crystals for optical work, notably in the infra-red and ultra-violet portions of the spectrum, had been grown from melts, e.g. rock salt up to 12 in. diameter [16] and lithium bromide, iodide and chloride up to 5 in. diameter and 8 in. long. [21]

9. QUARTZ CLOCKS

German workers were among the first to make use of quartz crystal vibrations for time-keeping purposes. The investigations of the Physikalische-Technische Reichsanstalt in this field were well known before the war, and an up-to-date account of the work is given in a report (in German) by Dr. Adelsberger. [63] The quartz clock equipment made commercially by Rohde & Schwarz appears to have given good service at the Deutsche Hydrographische Institut. [42] A feature of the Rohde & Schwarz clock is the locked tuning-fork oscillator used to divide the 100 kc/s crystal oscillator output down to a frequency suitable for phonic motors. This method of division seems to have been reliable.

10. HIGH-FREQUENCY HEATING

Eddy-current heating was used, with powers up to 200 kW and frequencies usually in the range 100 to 300 kc/s ; the most popular size of generator was 20 kW. Its main application was to be the hardening of gear wheels. In this process either the whole gear could be hardened at once, or each tooth could be treated separately. For treating a whole gear wheel 130 mm in diameter and 12 m in axial length a power of 200 kW at a frequency of 250 to 300 kc/s was required, but for dealing with one tooth at a time a power of 20 kW sufficed.

Dielectric heating had been tried for wood drying, wood gluing in aircraft construction, tobacco drying, and killing lice in garments. Its main uses were for wood gluing and lice killing. For wood gluing a power of 20 kW at 6 Mc/s was used. For lice killing, the clothing was sprayed with water and conveyed through an electric field at the rate of 400 kg per hour, the power and frequency used being 30 to 40 kW and 25 Mc/s respectively. [34]

11. VALVES

The valve industry in Germany was widely dispersed as a defence measure although the major part of the work was in the hands of only a few large firms. Towards the end of the war much of the valve manufacture was being transferred to underground factories, and a large plant equipped with machines taken from Philips Valve Works in Holland and staffed by female slave labour was opened near Hamburg shortly before the end of the war. Telefunken were closely concerned with many major developments. For example, they proposed in 1938 a programme of rugged valve development for a proximity fuse in A.A. shells, but work did not actually commence until 1941. These valves were experimentally tested up to 30,000 *g* by means of an air gun, details of which are reported, but apparently no operational use was made of them. [18]

A range of metal-ceramic enclosed valves somewhat resembling the American "lighthouse valve" was developed, notably by Telefunken, for use in concentric line circuits at decimetre wavelengths ; the manufacturing processes are reported in some detail. [2]

Siemens were interested in the production of cold-cathode tubes, and used this principle in a range of diodes, triodes and tetrodes.

Considerable effort was expended by Germany on the production of special alloys for use in electric lamp and valve manufacture, and tungsten, tungsten-molybdenum, and molybdenum alloys for use in the lamp industry were

manufactured and processed by Metallwerke Plansee. [29] The drawing of the wire into filaments was also carried out by this firm.

German valve technique and the apparatus used in the industry appear to have been basically similar to those in the United Kingdom. As the war developed production gradually swung over to "preferred" types, and interesting developments occurred as the result of shortage of nickel. Anodes of iron, plated with aluminium or thorium, were extensively used, and it appears that thorium in particular gave an improved vacuum. Thorium powder was made into sheets, rod, and wire by Telefunken who were possibly the only firm in the world to do this. A getter material, called *Ceto*, composed of thorium, aluminium, and cerium, was extensively used in the form of a paste applied to the surface of metal components and also to the insides of envelopes. [9]

Metal-ceramic valves were produced for operation as amplifiers at wavelengths down to 20 cm and good signal/noise ratios were claimed for them. In preparing the metal-ceramic joint the ceramic was coated with molybdenum-iron paste which was then fired and afterwards coated with nickel, and the joint to the metal envelope was made with silver. [2] 56]

Klystrons incorporating modified Housekeeper seals were made to operate in the wavelength range 6 to 12 cm. Other Klystrons were developed for use at 3 cm in which the gun was located with an accurately ground ceramic disc. [8]

12. CERAMICS

The German ceramic industry, already in an advanced state of development before 1938, was a valuable asset during the war, and in the early days was undoubtedly ahead of the United Kingdom in applying ceramic techniques to communication equipment. The manufacture of ceramic materials and components was spread over a number of firms whose various activities are individually reported in detail and at some length. [43] Data is given on the composition, manufacture, testing, and properties of various ceramic materials, and research on these materials, and on synthetic mica is also described. Numerous examples are given of the applications of ceramic materials to radio components with, in some cases, excellent detailed drawings. [43]

13. RADIO-FREQUENCY TEST EQUIPMENT

Although isolated examples in the field of radio instrument design were unusual or novel the general standard of technique was behind that of the Allies. Cathode-ray tube displays were strongly favoured for production testing of transmission equipment. Such means were employed for the testing of electric wave filters, and in one instance [39] the same equipment could be used as a panoramic receiver. One television test equipment employed a sweeping oscillator covering an 8 Mc/s band, with cathode-ray tube display. [40]

Signal generator designs were largely conventional. Frequency modulation signal generators were built by Siemens & Halske and Telefunken [40] but merit no special attention.

An interesting precision R.F. impedance bridge was developed by Siemens & Halske, Berlin, using as a means of balance the temperature-resistance effect in an arm carrying superimposed D.C. [39] Siemens & Halske (Munich) also designed radar test equipment in the 30, 10 and 3 cm range and their factory had a maximum manufacturing output of 1,000 test sets per month.

According to one short report, [82] thermistor research was also included in this laboratory's programme.

Spectrographic monitoring equipment for use in radio monitoring stations was seen at Linz, Austria. [96] In conjunction with a panoramic receiver this equipment records on photographic film the reception characteristic of incoming radio signals and is adapted for checking frequency stability and field strength. Several sets of this equipment were in routine use in Germany.

14. RADIO COMPONENTS INDUSTRY

A comprehensive survey of the radio components industry was made [23] and the production and development work of some fourteen firms covering a wide field is described in outline. Much attention had evidently been given by German industry to the production of components of high stability, particularly those for use in communication systems. The report states that, electrically and mechanically, the best firms were ahead of the United Kingdom in this field.

15. CONCLUSION

The reports give the general impression that in the early stages of the war Germany was well advanced in materials research and could as a result produce outstanding designs in some details of radio equipment. In the general development and engineering of H.F. communication systems, however, the Germans displayed less initiative and originality than the Allies so that, as the war advanced and their efficiency decreased due to inadequate co-ordination of associated branches of industry, they fell behind in communications technique.

REFERENCES

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[1]	8	Manufacture and Application of Specialized Magnetic Materials Generally. 8s. 6d. (8s. 9d.).
[2]	30	Telefunken Metal/Ceramic Radio Valves. 3s. 0d. (3s. 2d.).
[3]	36	Magnetic Materials and Beryllium. 2s. 6d. (2s. 8d.).
[4]	65	Philips Valve Works, Hamburg, Hammerwerke (Valve Works), Minden. C. H. Müller, A.G. (X-Ray Tube Factory), Hamburg. 1s. 6d. (1s. 7d.).
[5]	153	Miscellaneous German Radio and Communication Targets. 1s. 6d. (1s. 7d.).
[6]	179	German Cable Industry. 12s. 6d. (12s. 10d.).
[7]	226	Metallized Paper Capacitors. 6s. 6d. (6s. 8d.).
[8]	248	The Radio Valve and Lamp Industry in Vienna. 2s. 0d. (2s. 2d.).
[9]	276	Telefunken Gesellschaft für Drahtlose Telegraphie m.b.H., Berlin. Valves : Thorium Metal, Zirconium and other Special Metals. 2s. 0d. (2s. 2d.).
[10]	384	German Battery Electric Vehicles and the German Storage Battery Industry. 5s. 0d. (5s. 2d.).
[11]	393	Development and Production of Electrical Components, Especially of Relays by Siemens & Halske and other German Firms. 2s. 0d. (2s. 1d.).
[12]	407	D.R.P. Broadcasting Studios, Munich. Acoustics of the Studios. 6d. (7d.).
[13]	411	Miscellaneous Electrical Factories in the British and American Zones. 3s. 6d. (3s. 8d.).
[14]	414	Prof. Dr. Ing. Humburg, Technische Hochschule, Hannover. Variable Speed Constant Frequency Generator and Compensated A.C. Generators. 6d. (7d.).
[15]	467	German Secondary Battery Industry. 2s. 0d. (2s. 1d.).
[16]	468	The Manufacture of Synthetic Crystals in the Plant of I.G. Farbenindustrie, Oppau-Ludwigshafen. 1s. 0d. (1s. 1d.).
[17]	486	The Manufacture of Line Telecommunications Equipment in Germany. 3s. 6d. (3s. 8d.).
[18]	501	Rugged Valves and Mechanical Tests for Valves and Components. 3s. 0d. (3s. 2d.).
[19]	530	Photo Surfaces. A Report on German Developments of Photo Cells, Electron Multipliers and Television Pick-up Tubes. 6s. 0d. (6s. 2d.).
[20]	551	German Wireless Communication mainly with Reference to Centimetre and Decimetre and Pulse Technique. 2s. 0d. (2s. 1d.).

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[21]	552	Report on the Investigation on the Production of Synthetic Crystals in Germany and Copenhagen. 1s. 6d. (1s. 7d.).
[22]	557	Visits to Radio Targets in Germany. 1s. 6d. (1s. 7d.).
[23]	563	The German Radio Component Industry. 6s. 6d. (6s. 8d.).
[24]	567	Resistors and Fixed Capacitors Produced in Germany. 7s. 6d. (7s. 9d.).
[25]	583	Design and Operation of Telegraph Apparatus and Teleprinter Switching Systems in Germany. 4s. 6d. (4s. 8d.).
[26]	587	German Naval Mining Relays and Moulded Powder Permanent Magnets. 5s. 6d. (5s. 8d.).
[27]	606	The Design of German Telephone Subscribers' Apparatus. 5s. 6d. (5s. 8d.).
[28]	622	Investigation of Cold Cathode Tubes Made by Siemens Reiniger Werke, Rudolstadt. (Part II). 3s. 0d. (3s. 2d.).
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[33]	725	German Research on Rectifiers and Semi-Conductors. 4s. 6d. (4s. 8d.).
[34]	866	High Frequency Heating. 3s. 0d. (3s. 2d.).
[35]	867	Television Development and Application in Germany. 7s. 0d. (7s. 3d.).
[36]	893	Impregnants Used in German Paper Capacitors. 15s. 6d. (15s. 10d.).
[37]	951	The Magnetophon Sound Recording and Reproducing System. 10s. 0d. (10s. 3d.).
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[39]	1228	H.F. Instruments and Measuring Technique. 3s. 0d. (3s. 2d.).
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[50]	290	Wire Programme Services of the Reichspost. 1s. 6d. (1s. 7d.).
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[52]	512	Survey of Low Voltage Air Circuit-Breaker Practices, Germany. 3s. 0d. (3s. 2d.).
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[88]	XXXI-4	Cobaltine Alni-Steel Magnets. 3s. 0d. (3s. 2d.).
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[95]	57	12-Channel Long-Distance V.F. Telegraph System. 1s. 6d. (1s. 7d.).
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The undermentioned, though not specifically mentioned in this report, also have a bearing, directly or indirectly, on the subject matter.

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The most useful approach to these documents, many of which may comprise hundreds of folios, is by way of the Summary Sheets (bearing the same reference FD numbers), obtainable from the Board of Trade, German Division, Technical Information and Documents Unit, 40 Cadogan Square, S.W.1, at the cost of a few pence. The documents themselves, together with unpublished reports and such other new documents which may be received subsequent to the publication of this Survey, can be viewed by appointment at the same address, and there are arrangements for obtaining photostat and microfilm copies.

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[114]	ditto /2	,,	Vorschriften für Schlagwettergeschutzte / Explosionsgeschutzte Elektrische Betriebsmittel VDE 0170/V.43 / VDE 0171/V.43
[115]	ditto /3	,,	
[116]	ditto /4	,,	Leitsatze für die Bestimmung der Zindgruppe und Explosionskasse von Gasen und Dampfen VDE 0173/V.43
[117]	ditto /5	,,	Merkblatt über Anforderungen an Werkstatten, die Schlagwettergeschutzte und Explosionsgeschutzte VDE 0191/V.43 NOTE.—The above are separately-issued sections of the "Vorschriften-buch des Verbandes Deutscher Elektrotechniker".
[118]	ditto /6	ditto (2)	A 48-page illustrated catalogue of flame and explosion proof telephones and signalling equipment, issued by the firm Funke & Huster.
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Printed in Great Britain under the authority of HIS MAJESTY'S STATIONERY OFFICE
by Cheltenham Press Ltd., Cheltenham.