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Technical Note No. R.D. 228
Part 1

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ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH

# REPORT ON GERMAN RADIO COMPONENTS

- by -

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# Examination of German Components

## SUMMARY

At the request of D.C.D. (letter dated 31st March, 1944, Ref. GB.41310) an examination has been made of German radio components with a view to ascertaining techniques, materials, processes, etc., about which information might be desired at the conclusion of the European War.

Components were extracted from captured German equipment and crashed aircraft. These were subjected to functional tests in accordance with the relevant British specifications, and to an examination of their design and construction.

The conclusions reached as a result of this investigation are set out at the end of each section and the recommendations made are underlined. They can be found on the following pages.

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## 1. INTRODUCTION

At the request of D.C.D. (letter dated 31st March, 1944, Ref. GB.41310), an examination has been made of German radio components with a view to ascertaining techniques, materials, processes etc., about which information might be desired at the conclusion of the European War.

The conclusions are set out at the end of each section and the recommendations are underlined

The components investigated were extracted from German equipments obtained:-

(1) From captured enemy stations and aeroplanes on the fighting fronts.

(2) From crashed enemy aircraft in Britain.

As a consequence, it is impossible to state the history of these equipments prior to their acquisition. A crashed aircraft may have been exposed to bad atmospheric and climatic conditions for varying periods before removal of the radio apparatus and consequently, electrical tests may be inconclusive if the results indicate imperfections in performance, unless faulty construction is obvious. However, any positive results, i.e. any results which indicate very good performance, may be considered as conclusive. In general, therefore, favourable test results may be considered more conclusive than the failures detected.

In many instances it was impossible to examine components electrically because of mechanical damage.

## 2. CHASSIS AND ASSEMBLY PROCESSES

### 2.1. General

2.1.1. General examination of the construction of chassis and assemblies shows that the chassis are extremely light and the assemblies neat.

2.1.2. The chemical composition of the chassis has been determined (Ref. 2). The material was found to be a magnesium alloy. It is generally produced in the form of a die-casting (See Plate 4., Items 1 and 2, Plate 7, item 7).

These die-castings are produced with extreme accuracy, and those produced by different manufacturers and in different years are entirely interchangeable. However, this entails several disadvantages. The system, once employed lacks adaptability, and moreover makes it very difficult to service equipment of this type in view of the cramped nature of the final assembly. A feature of the German production system appears to be the extensive use of subassemblies. In the event of breakdown, a complete section of the apparatus may be replaced and could be returned to a maintenance unit for skilled servicing. This naturally entails the provision in the field of a fairly large supply of replacement units instead of individual components.

2.1.3. It is interesting to note that "tropicalisation" of components is not consistently carried out in Germany. This is borne out by the fact that there appear to be two classes of finish - very good and very bad. In a particular set, while there are many components with very desirable "tropical" properties, associated components may be extremely poor in climatic performance.

2.1.4. Every component in a give piece of equipment is identifiable by a transfer mark, and electrically identical points are always marked with the same number.

2.1.5. It is interesting to note also that every nut used in assembly is locked with a hard lacquer which makes it difficult to "unlock" the assembly. (See Plate 7, Item 8.2, Plate 10, Item 3.1).

2.2. Conclusions

A knowledge of the German methods of die-casting would be of great interest.

The locking lacquer referred to in 2.1.5. could probably find applications in British equipments and its composition and properties might be usefully investigated.

3. CAPACITORS

3.1. Paper Dielectric Capacitors

3.1.1. General

The two main types are:-

(a) Rectangular capacitors (e.g. Plate 5, Items 5, 7, 8, 10).

(b) Tubular capacitors, (e.g. Plate 5, Item 9, Plate 7, Items 1, 2, 4).

Capacitors of type (a) are produced with many different capacities and for various voltages. The normal method of construction is to spot weld a lid and a base to a tube of rectangular cross-section and finally to tin the whole assembly (See Plate 5, Items 5, 7).

The "rolled seam" method of construction is used occasionally for units of large size.

In type (a) also, it is interesting to note that the mounting holes are very often asymmetric to save mounting space (See Plate 5, Item 7.1). On occasion, capacitors are retained by sliding a base clamp over projections on the case (Plate 4, Item 9.2). No riveting is used and the units, which are usually small, are retained solely by mechanical pressure. A further method is to rivet a base plate on to the capacitor, and to drill and tap holes in it by means of which the capacitor is then fixed to the chassis without any projecting lugs. (See Plate 4, Item 6.1). Yet another type of retaining clip is shown on Plate 5, Item 11, a spring steel clip drilled and tapped at the base.

In type (b), the most common type of mounting for metal cased tubular capacitors is the stud type (See Plate 10, Item 10). The insulated tubular type is normally mounted on a ceramic plate or a bakelised paper tag-strip. The insulating material is either bakelised paper (See Plate 10, Item 9), or glazed ceramic (See Plate 6, Items 4 and 5). One disadvantage in the construction of the latter type is that whenever a number of these units is mounted side by side, steps must be taken to prevent the ends from touching. This is done by means of an insulating sleeve of lacquered fabric, cellulose acetate or polyvinyl chloride.

Composite units have been noted on some occasions, consisting of a paper tubular capacitor in series with a coiled up spaghetti resistor. These units are probably used for spark quenching.

3.1.2. Experimental results

The electrical properties of various types are tabulated below. It will be seen that some types give excellent performances after climatic conditioning. In the table of results the methods of construction and the manufacturers of the components are indicated, where known. References to the photographic plates are also included.

The categories of tests carried out viz :- "A", "B", "C", are the categories prescribed in the Inter-Service Specifications (BS/RC Series) and the climatic cycles are in accordance with these specifications.

The most satisfactory types are the following:-

(i) Glass or glazed ceramic cased paper tubular capacitors with metal end pieces, which satisfactorily passed as Category A, B and C components. (Plate 6, Items 4,5). The working voltages of these capacitors go up to 600V. D.C.

(ii) The rectangular metal cased type with glass or glazed ceramic terminations. The sizes do not differ materially from similar British capacitors. Voltages in this type go up to 1000V. D.C.

(iii) Variation of (ii), (Plate 5, Items 5, 7) with ceramic block end pieces and metal insets to take the leads to the unit. (Plate 5, Item 8).

(iv) The glass sealed tubular (metal cased) type (Plate 10, Item 6).

| Sample No. | Description | Manu-facturer | Wkg. Voltage | Nominal Capacitance µF | Dimensions cm. |
|---|---|---|---|---|---|
| 1 | Ceramic cased paper tubular capacitors with metal ends | Siemens-Halske | 250 | 0.02 | 2.8 x 0.76d. |
| 2 | | " | " | " | " |
| 3 | | " | " | " | " |
| 4 | | " | " | " | " |
| 5 | | " | " | " | " |
| 6 | | " | " | " | " |
| 7 | | " | " | " | " |
| 8 | | " | " | " | " |
| 9 | | " | " | " | " |
| 10 | Glass cased paper tubular with metal ends | " | 500 | 0.1 | 2.29 x 1.52d. |

| Sample No. | Foil Thickness | No. of papers | Dielectric Constant | Dielectric Thickness | Plate Reference |
|---|---|---|---|---|---|
| | microns | | | microns | |
| 1 | 16 | 2 | 3.3 | 18 | Plate 6 Items 4 and 5 |
| 2 | 16 | 2 | 3.1 | 18 | |
| 3 | 18 | 2 | 3.3 | 18 | |
| 4 | 14 | 2 | 3.4 | 16 | |

Category "A" Tests

| Sample No. | Power Factor % | | Capacitance µF | |
|---|---|---|---|---|
| | As Recd. | After climatic cycles | As Recd. | After climatic cycles |
| 1 | 0.40 | 0.50 | 0.019 | 0.019 |
| 2 | 0.40 | 0.50 | 0.020 | 0.020 |
| 3 | 0.45 | 0.30 | 0.017 | 0.018 |

Insulation Resistances on all samples $>10^5$ megohms at all stages of test.

Category "B" Tests

| Sample No. | Power Factor % | | Capacitance µF | |
|---|---|---|---|---|
| | As Recd. | After climatic cycles | As Recd. | After climatic cycles |
| 4 | 0.40 | 0.30 | 0.019 | 0.019 |
| 5 | 0.40 | - | 0.014 | - |
| 6 | 0.40 | 0.30 | 0.019 | 0.020 |

Insulation Resistance on all samples $>10^5$ megohms at all stages of test.

Category "C" Tests

| Sample No. | Power Factor % | | Capacitance µF | |
|---|---|---|---|---|
| | As Recd. | After climatic cycle | As Recd. | After climatic cycle |
| 7 | 0.40 | 0.30 | 0.018 | 0.019 |
| 8 | 0.40 | 0.33 | 0.020 | 0.020 |
| 9 | 0.43 | 0.37 | 0.020 | 0.020 |

Insulation Resistance on all samples $>10^5$ megohms at all stages of tests.

| Sample No. | Description | Manu-facturer | Wkg. Voltage | Nominal Capacitance μF | Dimen-sions (cms.) | Plate Reference |
|---|---|---|---|---|---|---|
| 11 | Rectangular Metal cased, paper, terminations on ceramic bushes | L. B. | 1000 | 0.1 | 7.0x1.9x 3.55 | Plate 5, Item 7. |
| 12 | | " | 500 | 0.5 + 0.5 | 5.7x1.9x 1.9 | |
| 13 | | " | 750 | 0.05 | 7.0x1.9x 1.52 | |
| 14 | | " | 1000 | 1 | 12 x 3.18d. | |
| 15 | Metal cased tubular paper, ceramic terminals. | " | 250 | 1 | 2.8x1.52d. | Plate 5, Item 9. |
| 16 | | " | 250 | 1 | 2.8x1.52d. | " " |
| 17 | | Siemens | 500 | 0.5 | 3.18x2.54d. | Plate 7, Item 1. |
| 18 | | " | 500 | 0.5 | 3.18x2.54d. | " " |

| Sample No. | Foil Thickness microns | No. of Papers | Dielectric Constant | Dielectric Thickness microns |
|---|---|---|---|---|
| 17 | 12 | 4 | 4.1 | 15 |
| 18 | 12 | 4 | 3.7 | 17 |

Category "B" Tests

| Sample No. | Power Factor % | | Capacitance μF | |
|---|---|---|---|---|
| | As Recd. | After Climatic Cycles | As Recd. | After Climatic Cycles |
| 11 | 0.5 | 0.46* | 0.116 | 0.118* |
| 12 | ( 0.5 | 0.45* | 0.552 | 0.586* |
| | ( 0.5 | 0.46 | 0.576 | 0.587 |
| 13 | 0.48 | 0.41* | 0.056 | 0.059* |

| Sample No. | Insulation Resistance Megohms | | | |
|---|---|---|---|---|
| | As Recd. | After Dry Heat | After 1st Humidity | After L.T. and 2nd Humidity |
| 11 | 30000 | 50000 | 50000 | 50000* |
| 12 | 40000 | 60000 | 50000 | 25000* |
| 13 | 40000 | $10^5$ | 70000 | $10^5$* |
| | | | | |

* The Low Temperature Test in this case was made at -60°C.

Category "C" Test

| Sample No. | Power Factor % | | Capacitance μF | |
|---|---|---|---|---|
| | As Recd. | After climatic cycle | As Recd. | After climatic cycle |
| 14 | 1.00 | 1.0 | 0.989 | 0.992 |
| 15 | 0.50 | - | 0.093 | - |
| 16 | 1.00 | 0.80 | 0.095 | 0.096 |
| 17 | 0.50 | 0.43 | 0.516 | 0.522 |
| 18 | 0.55 | 0.42 | 0.490 | 0.496 |

| Sample No. | Insulation Resistance Megohms | | | |
|---|---|---|---|---|
| | As Recd. | After Dry Heat | After 1st Humidity | After L.T. and 2nd Humidity |
| 14 | 4,000 | 2,000 | 1,600 | 1,100 |
| 15 | 7,000 | 12,000 | 8,000 | 10,000 |
| 16 | 7,000 | 8,000 | 7,000 | 52 |
| 17 | 18,000 | 30,000 | 20,000 | 20,000 |
| 18 | 20,000 | 20,000 | 1,200 | 18,000 |

| Sample No. | Description | Manufacturer | Wkg. Voltage | Nominal Capacitance μF | Dimensions cm. |
|---|---|---|---|---|---|
| 19 | Metal cased, paper glass seal, | V.T.T. (Wien) | 150 & 350 | 1 + 4 | 4.45x4.45x 5.85 |
| 20 | | V.T.T. (Wien) | 150 & 350 | 1 + 4 | 4.45x4.45x 5.85 |
| 21 | Metal cased, paper ceramic ends (units between terminals and case) | Hydra Werk | 30 | 0.5 + 0.5 | 5.7x2.8x 2.54 |
| 22 | | Hydra Werk | 30 | 0.5 + 0.5 | 5.7x2.8x 2.54 |
| 23 | | Siemens | 350 | 4 | 4.56x6.85x 4.6 |

| Sample No. | Foil Thickness microns | No. of papers | Dielectric Constant | Dielectric Thickness | Plate Ref. |
|---|---|---|---|---|---|
| 19 | 20 | 4 | 6.4 | 24 | Plate 5, Item 5. |
| 20 | 20 | 4 | 6.4 | 25 | " " |
| 21 | 8 | 2 | 3.6 | 5 | Plate 5, Item 8. |

Category "B" Test

| Sample No. | Power Factor % | | | |
|---|---|---|---|---|
| | As Recd. | After Dry Heat | After 1st Humidity | After climatic cycle |
| 21 | 0.60 | 0.70 | 0.69 | 0.73* |
| | 0.59 | 0.72 | 0.67 | 0.51 |

| Sample No. | Capacitance μF | | | |
|---|---|---|---|---|
| | As Recd. | After Dry Heat | After 1st Humidity | After climatic cycle |
| 21 | 0.53 | 0.49 | 0.49 | 0.49* |
| | 0.49 | 0.50 | 0.50 | 0.50 |

| Sample No. | Insulation Resistance Megohms | | | |
|---|---|---|---|---|
| | As Recd. | After Dry Heat | After 1st Humidity | After climatic cycle |
| 21 | 3600 | 5800 | 3800 | * 3800 |
| | 3800 | 3900 | 3800 | 2800 |

Category "C" Test

| Sample No. | Power Factor % | | Capacitance μF | |
|---|---|---|---|---|
| | As Recd. | After climatic cycle | As Recd. | After climatic cycle |
| 19 | 1.80 | 1.35* | 0.97 | 0.97* |
| | | | 3.75 | 3.79 |
| 20 | 1.40 | 1.35* | 0.98 | 0.98* |
| | | | 3.85 | 3.75 |
| 23 | - | - | 3.85 | 3.94 |

| Sample No. | Power Factor % | | | |
|---|---|---|---|---|
| | As Recd. | After Dry Heat | After 1st Humidity | After climatic cycle |
| 22 | 0.72 | 0.68 | 0.72 | 0.87 |
| | | 0.68 | 0.89 | 1.30 |

* The Low Temperature Test [illegible]

| Sample No. | Capacitance µF | | | |
|---|---|---|---|---|
| | As Recd. | After Dry Heat | After 1st Humidity | After climatic cycle |
| 22 | 0.46 | 0.50 | 0.50 | 0.50 |
| | 0.49 | 0.47 | 0.47 | 0.47 |

| Sample No. | Insulation Resistance Megohms | | | |
|---|---|---|---|---|
| | As Recd. | After Dry Heat | After 1st Humidity | After climatic cycle |
| 19 | 1,500<br>1,000 | 5,500<br>3,300 | 1,800<br>1,500 | 1,100*<br>1,060 |
| 20 | 700<br>120 | 2,800<br>340 | 1,100<br>110 | 700*<br>90 |
| 22 | 7,100<br>8,300 | 5,800<br>5,800 | 1,900<br>5,800 | 1,800<br>5,800 |
| 23 | 2,600 | 2,000 | 3,100 | 2,800 |

* The Low Temperature Test in this case was made at -60°C.

### 3.1.3. Construction

It is noticeable that German manufacturers frequently use an impregnant probably incorporating chlorinated napthalene. The impregnants in metal cased paper capacitors consist almost invariably of chlorinated napthalene wax. This is used very rarely in this country due to its corrosive action, but it is suspected that the German compound of chlorinated napthalene is less injurious. This statement is based upon commercial experience before the war.

Chlorinated napthalene of British manufacture is dangerous in view of the liberation of free chlorine. German waxes of this type appear to be used with a reasonable degree of safety up to 1000V. D.C.

The advantage to be gained in using chlorinated napthalene is that the capacity may be increased by as much as 30% for a given size.

The paper used is of extremely fine quality possibly made from wood-pulp, and is extremely thin, viz:- 5 to 20 microns.

The impregnating process is very efficient and considerable difficulty was experienced in separating adjacent papers and foils.

The foils used are also very thin and range from about 8 to 30 microns.

There are other interesting details of construction. The units, in multi-unit types are almost invariably screened from one another by a plate in the metal case. Where necessary the foil is soldered to the case internally and each unit is screened, in addition, by a covering of thicker foil which serves as a connection and also as a protection to the unit. (See Plate 6, Items 7,8,9).

In general the units are very neatly assembled internally and the finished units are fairly robust.

As described in 3.1.1. the method of sealing the metal cases is normally by spot welding and solder dipping. The boxes or cases are not normally painted but are metal sprayed. There are many different designs or terminations of which the following are the most frequently encountered.

(i) This type consists of a cylindrical bushing of some moulding material similar to bakelite, mounted on a bakelised fabric insulating plate.

The soldering lug is mounted on the bushing and connected to the capacitor plates by a wire. This type is very unsatisfactory under climatic conditioning and is inferior to any type in service in this country.

(ii) On some paper dielectric capacitors soldering lugs (of tinned steel) are simply clamped on to a board of bakelised fabric or paper which forms the end plate of the unit. This construction does not provide good insulation and is unsatisfactory.

(iii) This consists of a glazed ceramic bush bonded at its lower end to the metal case. A soldering lug is soldered to the metallised upper end and the connecting wire passes through a central hole in the bush. (See Diagram I). The only possible weakness lies in the reaction of the ceramic-metal combination to thermal stress, but electrical tests do not disclose any such tendency in the temperature range demanded by British Specifications.

(iv) The further type of glazed ceramic termination consists of flat end plates to the metal casing (Plate 6, Item 8.1). This entails soldering a bevelled silvered ceramic edge about 1/16" to 1/8" width and about 1/2" to 1½" length. In the end plate a hole with silvered edges is provided into which a metal terminal is inserted and soldered to the metallised ceramic plate.

This process is used in America by the Corning Glass Works, New York, (Ref.3), although the process is comparatively new in that country, while in Germany the process appears to be widespread and common. Experimental work on this type of terminal is being carried out by British manufacturers.

The process of ceramic-metal bonding is also applied to the paper tubular type where a ceramic tube has silvered ends, and the metal end-pieces are soldered to it, providing an airtight seal.

(v) The processes described above are similarly applied to glass. An interesting feature of these terminals is an iron alloy sleeve passing through and moulded into the glass, (see Diagram 2). The coefficient of thermal expansion of the iron alloy is equal to that of the glass. This eliminates the danger of rupture due to differential expansion. The capacitor leads pass through this sleeve and are soldered to it outside the unit. The climatic performance of the glass terminals is as good as that of the ceramic terminals.

(vi) Insulated paper tubular capacitors are sometimes constructed in glass cases with silvered ends to which the terminations are soldered. This is interesting owing to the excellence of the seal and the satisfactory electrical performance.

The temperature range as marked on the components for both ceramic and glass seal types is either -40 to +70°C. or -60 to +80°C. and both limits are met satisfactorily. With the exception of (i) and (ii), all types of termination withstand climatic conditioning without deterioration.

3.1.4. Metallised Paper Types (See Plate 4, Items 6, 8, 9)

This type of capacitor does not utilise the normal method of interleaving paper dielectric and metal foil. In this instance, the electrode consists of metal sprayed on to the paper as a thin film about 4 microns thick. The metal normally used is aluminium. If the applied voltage exceeds the rated voltage, the heat generated at any weak spot in the paper converts the aluminium to aluminium oxide which is an insulator and so prevents the unit becoming short circuited. The metallised paper is usually subjected to voltage stress prior to assembly and these weak points "blown out", aluminium oxide being formed in their place. The breakdown voltage is low. The type is also constructed in this country (Ref.4). It is noteworthy, however, that units with working voltages up to 750V. have been found where an extra layer of paper is interposed between the metallised papers.

The patent rights of this method of construction are held by Bosch, (a German manufacturer) and the German type of metallised paper is superior to that used in this country.

Test results are given below.

| Sample No. | Description | Manufacturer | Wkg. Voltage | Nominal Cap. | Dimensions |
|---|---|---|---|---|---|
| | | | | μF | cm. |
| 27 | Metallised paper, fabric insulation | Bosch | 120 | 0.5 | 3.25x1.05x3.3 |
| 28 | Metallised paper, Ceramic Insulation | Bosch | 250 | 1.0 | 3.25x2.54x3.3 |
| 29 | | Hydra Werk | 250 | 0.5 | 3.25x1.05x3.3 |
| 30 | | Bosch | 250 | 0.1 + 0.1 + 0.1 | 3.25x1.52x3.3 |

| Sample No. | Foil Thickness | No. of papers | Dielectric Constant | Dielectric Thickness | Plate Ref. |
|---|---|---|---|---|---|
| | microns | | | microns | |
| 27 | 4 | 1 | 2.4 | 7 | Plate 4, Item 6. |
| 28 | 6 | 1 | 2.5 | 7 | Plate 4, Item 9. |
| 29 | 6 | 1 | 3.1 | 7 | Plate 4, Item 8. |
| 30 | 10 | 1 | 3.0 | 12 | - |

Category "C" Tests

| Sample No. | Power Factor % | | Capacitance µF | |
|---|---|---|---|---|
| | As Recd. | After climatic cycle | As Recd. | After climatic cycle |
| 27 | 2.70 | 4.00 | 0.497 | 0.510 |
| 28 | 0.70 | 0.84 | 1.100 | 1.190 |
| 29 | 0.65 | 0.75 | 0.500 | 0.517 |
| 30 | (0.70 | ( 1.50 | ( 0.100 | (0.103 |
| | (0.70 | (11.7 | ( 0.105 | (0.103 |
| | (0.75 | ( 4.30 | ( 0.102 | (0.099 |

| Sample No. | Insulation Resistance Megohms | | | |
|---|---|---|---|---|
| | As Recd. | After dry Heat | After 1st Humidity | After L.T. and 2nd Humidity |
| 27 | 10 | 1 | 1 | 1 |
| 28 | 900 | 850 | 1,500 | $10^5$ |
| 29 | 400 | 250 | 200 | 200 |
| 30 | (7,000 | 12,000 | 12,000 | 1 |
| | (7,000 | 12,000 | 16,000 | 1 |
| | (7,000 | 12,000 | 11,000 | 1 |

### 3.1.5. Comparison of Physical Dimensions

In general, capacitors of German origin are smaller than those of British manufacture. For instance:-

German paper tubular capacitor in ceramic case:-

Capacity : 0.05 µF

Voltage : 750V. D.C.

Volume : 2.7 ccs. approx.

British waxed paper tubular capacitor:-

Capacity : 0.02 µF

Voltage : 750V.D.C.

Volume : 7.5 ccs. approx.

or:-

German metallised paper capacitor (rectangular case):-

Capacity : 0.5 µF

Voltage : 250V. D.C.

Volume : 11.3 ccs. approx.

British paper-foil capacitor (rectangular case):-

Capacity : 0.2μF

Voltage : 350V. D.C.

Volume : 20 ccs. approx.

The volumes stated do not include the terminations.

3.1.6. Conclusions

(i) The most notable feature of capacitor construction is the use of glazed ceramic or glass insulated terminals sealed into the case.

In view of the great advantages of hermetically sealed capacitors, and the fact that the production of glass-to-metal and ceramic-to-metal sealed capacitors in this country is in its infancy, it is most desirable that all aspects of the German technique should be explored directly the opportunity offers.

(ii) The apparently improved form of chlorinated napthalene wax merits attention as it appears satisfactory during climatic tests in accordance with British Specifications.

It appears that some means is adopted for inhibiting the release of free chlorine. This should certainly be investigated.

(iii) The paper used in capacitors is of a very high grade and appears to be manufactured from wood-pulp. After extraction of the impregnant it still possesses water-resisting properties characteristic of well dried and well impregnated papers of British manufacture.

(iv) The metallised paper type of capacitor is worthy of attention and any improvements in metallising technique would be useful for British Manufacturers.

3.2. Electrolytic Capacitors (See Plate 6, Items 1, 2, 3, Plate 9, Item 5)

3.2.1. General Types in Use

The tubular metal cased electrolytics and rectangular metal cased electrolytics as used in this country are also found in German equipments. It is interesting to note that very few high voltage electrolytics have been found. Some of these were inspected, but were not available for investigations.

The tubular type is not remarkable in any way in physical dimensions or physical properties. The capacitors have a base stud fitting and the case is constructed of aluminium or an aluminium alloy. The terminal is fixed by a ring of rubber or rubber-like material and the sealing is excellent.

The rectangular cased electrolytics examined have two peculiar features. One is that the case is constructed of tinned steel. This is discouraged in this country because of the electrolytic action within the component causing corrosion where dissimilar metals are in contact. However, in this application the case does not form one of the electrodes and so, if the insulation between the units and the case is sufficient the difficulty due to the corrosive effect of the contents may be overcome. Otherwise it is difficult to understand why the case is not constructed of aluminium. The glass seals and terminals are interesting as they provide an excellent 'tropical' construction.

3.2.2. Experimental Results

The results of climatic tests (in accordance with I.S.C. Tech.C. Spec. BS/RC.S/130.4) are shown below. The performance of the rectangular cased type with glass seals is satisfactory and it will be noticed that the sample tested was a reversible electrolytic. The results of the tubular type were excellent and the low temperature performance is remarkable.

| Sample No. | Description | Manufacturer | Wkg. Volt. | Nom. Cap. μF | Dimensions cm. | Plate Ref. |
|---|---|---|---|---|---|---|
| 24 | Tinned steel case, glass seals, reversible. | Jaroslow | 8 | 150 | 4.45x1.9 x 5.7 | - |
| 25 | Aluminium case } Rubber or rubber like seals | Siemens-Halske | 8 | 30 | 5.1 x 1.77d. | Plate 6 Item 2. |
| 26 | | Siemens-Halske | 8 | 25 | 3.8 x 1.77d. | Plate 6 Item 3. |

| Sample No. | Power Factor % | | | |
|---|---|---|---|---|
| | As Recd. | After dry heat | After 1st Humidity | After climatic cycle |
| | 15.0 | 15.3 | 15.0 | 14.0 |
| 24 | 16.5 | 17.1 | 17.0 | 15.0 |
| 25 | 5.0 | 5.8 | 6.0 | 8.5 |
| 26 | 8.0 | 8.0 | 8.0 | 9.0 |

| Sample No. | Capacitance μF | | | | | |
|---|---|---|---|---|---|---|
| | As Recd. | After dry heat | After 1st Humidity | After L.T. and 2nd Humidity | At L.T. -40°C | After Low Pressure |
| | 167 | 146 | 150 | 153 | 80 | 158 |
| 24 | 170 | 155 | 154 | 155 | 122 | 156 |
| 25 | 44 | 43 | 44 | 34 | 42 | 44 |
| 26 | 31 | 32 | 32 | 26 | 30 | 33 |

| Sample No. | Leakage current in mA. | | | | | |
|---|---|---|---|---|---|---|
| | As Recd. | After dry heat | After 1st Humidity | After L.T. and 2nd Humidity | At L.T. -40°C | After Low Pressure |
| 24 | 0.05<br>1.1 | 0.01<br>0.8 | 0.01<br>0.9 | 0.01<br>0.5 | 0.01<br>0.03 | 0.01<br>0.5 |
| 25 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 26 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |

3.2.3. Conclusions

In view of the undoubted superiority of German electrolytic capacitors over those of British manufacture, a comprehensive investigation of their manufacturing technique should be made. In particular it is obvious that we have much to learn from them about the composition of the electrolyte used, about the degree of purity of the foils and other materials employed.

The British manufacturers consulted on this point are in agreement with this view.

3.3. Ceramic Dielectric Capacitors

3.3.1. Fixed Capacitors

The subject of fixed ceramic capacitors is dealt with in detail in Ref. (4). (See Plates 1, 2; Plate 4, Items 10,11, 15). No further distinctive types are apparently in use, the only remarks being that the disc type of ceramic capacitor has been found in equipments. The practice of protecting capacitors by a ceramic case is still common and the stacked type of tubes are still in evidence. The most notable feature of assemblies of ceramic capacitors is the temperature compensating assemblies described in Ref. (4) above. (See Plate 4, Item 11).

3.3.2. Trimmer Capacitors

This type of capacitor is also described in the report above and the only development appears to be the use of a high permittivity ('K') ceramic in this type of construction. The value of 'K' is about 90. (See Plate 3, Plate 4, Item 14).

3.3.3. Conclusions

Details of the German methods of metallising, and of the use of high-permittivity ceramic would be useful.

3.4. Mica Dielectric Capacitors

3.4.1. Type similar to British type (See Plate 10, Item 11)

This type of moulded case, stacked mica capacitor is not used extensively but is similar to the type manufactured in this country.

3.4.2. Mica capacitors enclosed in ceramic case (See Plate 7, Item 5).

This type of capacitor is of the silvered mica construction and is completely enclosed in a glazed ceramic case. A ceramic end piece with metal insert for the lead is soldered on to the previously silvered ceramic tube which encloses the capacitor unit. The seal is very good and this type of capacitor successfully passed all the climatic tests applied to it. The one disadvantage is that the capacitor is bulky but this may be outweighed by its ability to withstand severe tropical conditions. (For example. A rectangular ceramic case, dimensions 2.4 x 4.4. x 5.5. cm. contained 2 units 0.006475 μF. The working voltage is not stated. The tolerance marked is ±0.1%). Test results (on a different unit) are shown below.

| Sample No. | Description | Manu- facture | Wkg. Voltage | Nom. Cap. | Dimenions | Plate Ref. |
|---|---|---|---|---|---|---|
| | | | | μF | cm. | |
| 31 | Ceramic cased, mica dielectric. | -- | 250 | 0.005 | 3.25 x 2.54 x 1.05 | Plate 7 Item 5. |

Category "A" Test

| Sample No. | Power Factor % | | Capacitance μF | |
|---|---|---|---|---|
| | As Recd. | After Climatic Cycle | As Recd. | After Climatic Cycle |
| 31 | 0.15 | 0.37 | 0.005 | 0.005 |

| Sample No. | Insulation Resistance Megohms | | | |
|---|---|---|---|---|
| | As Recd. | After Dry Heat | After 1st Boiling | After L.T. and 2nd boiling |
| 31 | 40,000 | 25,000 | 2,500 | 2,000 |

3.4.3. Unprotected Mica Types

A third type, viz. an unprotected stacked mica capacitor was found and is probably used in low frequency circuits. This type is, however, not very satisfactory and has no 'tropical' proofing. (See Plate 6, Item 6). An unprotected variable mica is illustrated in Plate 10, Item 7.

3.4.4. Conclusions

Apart from the unusual methods of sealing employed, mica capacitors as such show no features of special interest.

The investigation yields no evidence as to a possible shortage of mica in Germany.

3.5. Variable Air Capacitors

3.5.1. Tuning Capacitors (Plate 7, Items 7, 8, 9, Plate 9, Items 1 and 2).

The typical German make of tuning capacitor has several noteworthy features. The Capacitors are extremely light and appear to be made of magnesium alloy and ceramic material. The rotor is normally constructed with a ceramic spindle and alloy vanes. The spindle traverses the whole length of the unit. The various rotor vanes or sets of rotor vanes are apparently a push fit on this rod, the interior surface of the rotor bush being splined, presumably to assist in the assembly operation. The vanes all appear to be die-cast and subsequently machined for obtaining the required dimensions accurately. The rotor vanes are apparently die-cast in one piece with the bush. The vanes may be of the order of 1/16" thick and in some instances have a groove (depth 1/8") round the periphery of the vanes. This allows for minor adjustments of capacitance by bending the edge of the vanes.

The whole assembly is constructed so that each capacitor unit in a multi-ganged capacitor, is screened from its neighbour. The whole housing assembly is die-cast and relatively few machining operations are in evidence. (Plate 7, Items 7 and 9).

The connections to the rotor emerge by way of spring contacts through ceramic inserts in the metal housing of the capacitor and these inserts are robustly sealed in the unit. (Plate 7, Item 8). It is possible that the method of construction of the completely screened unit might be adapted to provide a complete hermetic seal.

The exact procedure for the assembly of the rotors would be of particular interest and the type of ceramic insert in the base, which allows for complete screening, is also worthy of attention. The weak point in construction appears to be the neck of the ceramic spindle as it emerges to the driving handle as several units were broken at this point (Plate 7, Item 9.4.).

3.5.2. Parallel Plate Trimmer Capacitors

There were several parallel plate trimmer capacitors consisting of brass plates supported on a ceramic frame. The construction is very rigid and strong although the total capacitance variation is small. (Plate 4, Item 13).

3.5.3. Concentric Trimmer Capacitors

A concentric type of air dielectric was found, of a similar type of construction to the parallel plate type (3.5.2.). The advantage in this is that the variation of capacitance would be linear with angular rotation of the inner cylinder. (Plate 4, Item 12).

3.5.4. Conclusions

Details of the processes of manufacture of tuning capacitors would be useful and the methods employed in the production of completely sealed units should be studied.

## 4. RESISTORS AND POTENTIOMETERS

### 4.1. General

The notable feature of the German equipments at hand for investigation was the absence of carbon rod resistors. Vitreous types and carbon-film (cylindrical as well as helical) resistors are used. On some occasions completely unprotected units (resistance wire wound on a ceramic former) have been noted and lacquered wire-wound resistors are also encountered. Taking the average of a random selection, it can be seen from Plate II that small units are, on the whole, used more extensively than in this country. The largest carbon (film) type observed is 1¾" long.

### 4.2. Carbon Film Types

The units numbered 10-21 incl. are of this type. Visual inspection does not indicate any features of great interest. They differ from the common types of British manufacture by the absence of colour coding, the numerical resistance values being marked on the units. Sometimes the selection tolerance is also marked. Some of the resistors are fitted with a varnished fabric (or less frequently a p.v.c.) sleeve, so as to prevent resistors which are not mounted on a terminal strip from coming into contact with other components. As a protection from the effects of high humidity the fabric is useless, if not actually harmful. (See units 11, 12, 13, 14, 15). Three manufacturers were noted, namely Siemens-Halkse (e.g. unit 10), R.E.A.W.D. (e.g. unit 16) and Hoges.

### 4.3. Vitreous Types

Unit 1 shows a vitreous resistor of somewhat peculiar design. It has a comparatively large surface area, which together with the unusual method of mounting should give this resistor a high wattage rating. The method of mounting is as follows:- The magnesium alloy tube (Plate 11, Item 1) is permanently riveted to the chassis. The cylindrical ceramic former fits over this tube and the resistor is clamped by the spring (Plate 11, Item 1.2.). This should provide very good facilities both for heat conduction through the metal and for air circulation. It may be of interest to note that all ceramic parts encountered are marked "Rosenthale", one of Germany's best known firms for table and artistic porcelain.

Units 2, 3, 4, 7 and 9 are similar to types used in British equipments and show no remarkable features.

### 4.4. Unprotected Types

Units 5 and 6 (Plate 11) consist of ceramic rods, wound with bare Eureka wire. Unit 5 also has a tapping. In view of this entire lack of any form of protection from the effects of high humidity, the reaons for using a resistor of this type are not appreciated. These resistors sometimes occur side by side with protected types. Plate 8, Item 6, shows a completely enclosed assembly of miniature resistors. They are wire-wound and insulated with one lapping of silk.

### 4.5. Potentiometers

Potentiometers are, on the whole, used less frequently in German equipments than in equipments of British make. The design of those encountered is of no special interest and all the samples tested failed under climatic conditions (See Plate 13, Items 3, 4 and 5). It is believed that German potentiometers have the reputation of being a frequent source of failure.

4.6. Experimental Results

The results of measurements (to Inter Service Spec. BS/RC.S/110.1) carried out on some of the types here described are given below:

4.6.1. Tests on Vitreous Resistors

| Rating | Type | Wattage * |
|---|---|---|
| | Plate 11 - Item 1 | 15 |
| | Plate 11 - 2 | 5 |
| | Plate 11 - 3 | 8 |
| | Plate 11 - 7 | 4 |

* Assessed on the basis of a 180°C. temperature rise for full load.

| Plate Ref. | Initial Res. ohms. | % Change due to 30 min. full load | % Change due to 15 min. 100% overload | % Change due to climatic conditioning | % Change due to second loading |
|---|---|---|---|---|---|
| Plate 11-1 | 13400 | +0.15 | - | 0.0 | +0.07 |
| 11-7B | 13830 | +5.40 | - | +10.0 | -0.61 |
| 11-2A | 18.[illegible]3 | +0.45 | -0.37 | +0.16 | +0.10 |
| 11-2B | 18.89 | -0.16 | +0.32 | 0.0 | +0.10 |
| 11-2C | 25.54 | +0.24 | +0.04 | 0.0 | +0.12 |
| 11-2D | 26.05 | +0.38 | - | 0.11 | +0.11 |
| 11-2E | 4130 | 0.0 | - | -0.17 | +27.6 |
| 11-3 | 45400 | +0.04 | - | | - |
| Tolerances allowed by British Specs. | | ±1% | ±1% | ±0.5% | ±0.5% |

4.6.2. Carbon Film Types

| Plate Ref. | Unit | % Change due to loadings 0.4 watts for 24 hours | % Change due to climatic conditioning |
|---|---|---|---|
| Plate 11 Item 12 | A | 0.4 | -0.6 |
| | B | 0.6 | +1.0 |
| | C | 0.3 | +0.5 |
| | D | 0.0 | -1.0 |
| | E | 0.2 | -1.0 |
| Plate 11 Item 11 | A | -0.7 | +17.5 |
| | B | 0.6 | +5.8 |
| | C | +1.7 | +10.4 |
| | D | 0.5 | -42.3 |
| | E | -2.7 | -35.2 |
| Tolerances allowed by British Specs. | | ±0.5% | ±0.5% |

4.6.3. Lacquered Wire-Wound Resistors

| Plate Ref. | Unit | % Change due to loading | % Change due to climatic conditioning |
|---|---|---|---|
| Plate 11 Item 19 | A | +0.20 | +1.0 |
| | B | -0.50 | +4.3 |
| | C | +0.25 | +0.8 |
| Plate 11 Item 9 | A | - | +1.8 |
| | B | +0.30 | 0.0 |
| | C | - | +0.4 |
| Plate 11 Item 16 | A | +0.42 | +0.0 |
| | B | - | 0.1 |
| | C | - | Unstable |

Tolerances allowed by British Specns. are the same as for vitreous resistors.

* Assessed on the basis of a 60°C. temperature rise for full load.

It can be seen that with the exception of 2 units which may have been slightly damaged, all the vitreous resistors are well within the limits alllowed by British Specifications. Nearly all the carbon film types, however, suffer considerably during climatic conditioning and are not satisfactory when loaded for prolonged periods. The load characteristics of lacquered wire wound resistors are satisfactory, but these resistors are unsatisfactory after exposure to high humidity.

4.7. Conclusions

Amongst the types of resistor investigated none show any feature of special interest, and it is thought that they are in no way superior to those used in British equipments. An interesting fact is the relatively rare occurrence of high wattage carbon resistors (say 3-4 watts) and the apparent total absence of carbon rod types.

## 5. ELECTRICAL RELAYS

### 5.1. General

The electrical relays available for examination fall into five distinct types but it is not supposed that these are the only types in use in German equipment.

A general purpose type is shown in Plate 12, Items 6 and 7. It is enclosed in a metal can but no attempt is made to make this can watertight and it does not appear to serve any other purpose than that of protection from dust. The particular model is fitted with heavy duty contacts. The terminals, both of the relay coil and the contacts, are taken out through laminated paper boards of a type which would not be approved for this purpose in accordance with British specifications.

The coil bears the usual marking, e.g.

I - 630 - 9500 - 0, 11 CuL.

which means that the coil consists of one winding whose resistance is 630 ohms consisting of 9,500 turns of 0.11 mm. dia. enamelled copper wire. Most coils, whether on relays or transformers, have been found to bear markings of this type. If there is more than one winding on any former each winding is specified in the same manner. The letter L refers to the insulation (e.g. lacquered or enamelled in this case). S indicates a lapping of silk, SS two lappings of silk. W.D. denotes resistance wire. The coil is protected by a layer of (non-impregnated) paper covered by a transparent cellulose film. This particular unit works very satisfactorily between 10 and 60 volts. It is manufactured by Siemens-Halske.

A more complicated relay unit (damaged) is shown on Plate 12, Item 5. It is not at present understood for what purpose an assembly of this kind could be used. The relay is of the polarised type. A 'make' contact is mounted on each side (5.1 and 5.2) and in addition, two 'make-and-break' contacts (5.3 and 5.4) are coupled to the centre link of the magnetic circuit (5.5). One contact (5.6) is so mounted as to operate whenever the relay is energised independent of polarity. The unit is in no way protected from the effects of humidity. It bears no Maker's Trade Mark.

Plate 14 (Items 1 and 2) shows a composite relay assembly consisting of two general purpose relays, together with mountings for components (3.1). The assembly is mounted in a metal case (magnesium alloy moulding) and protected by a cover of the same material (Plate 14, 3.2 and 3.3). The terminals are taken out through laminated paper boards. A thin sheet of impregnated fabric is mounted between these boards and is designed to fit more or less tightly round the contact terminals at the point where these pass through the laminated paper board, Plate 14 (3.4). While this device probably offers a certain amount of protection from dust it appears wholly inadequate as protection from the effects of high humidity.

A special feature of Item 1, Plate 14, is the anti-chattering device. It appears from the method of mounting as if this protection was added as an afterthought. It consists of a simple spring (1.1) which engages the movable link (1.2) and prevents the closing of the contacts (1.3) when the unit is subjected to vibrations. When the relay coil is energised the forces induced are sufficient to overcome the restraining action of the spring. The unit is manufactured by Siemens-Halske.

Plate 13, Item 1, shows a polarised relay-micro-switch notable for its flat shape and the attached plug. The gap between the movable link of the magnetic circuit (1.1) and the contacts (1.2 and 1.3) can be adjusted by means of the knobs (1.4 and 1.5) on either side.

The coils are marked in the manner already described. Bakelised fabric and laminated paper are again used as insulators. The coils are protected by means of impregnated paper.

Item 2 on Plate 13 shows a heavy duty circuit breaker manufactured by Bosch. One assembly consisted of a general purpose unit, Plate 14, Item 2, with a pair of heavy duty contacts completely enclosed in a metal can and worked by means of a connecting link. The can is presumably for screening purposes.

## 5.2. Indicating Devices

In addition to the electrical relays described, two types of indicating devices were available for investigation. They are shown in Plate 14, Item 4, and Plate 8, Items 2 and 5. These units are used in complete equipments in much the same way in which signal lamps are normally used.

The indicating device consists of a relay (Plate 14, Item 4.1) moulded into a plastic case fitted with a transparent window. A thin metal plate is fixed to the movable link (4.2) painted with alternate stripes of black and luminous paint. When the relay is energised the luminous strips appear behind the transparent window. The units are completely sealed and intended for operation on a 24 volt supply. Manufactured by Siemens.

## 5.3. Experimental Results

The relay units were tested for

(i) Their performance under vibration (as in Inter Service Spec. BS/RCS/130 clause 2.1.3.) (W.T. Board Spec. K.101).

(ii) The effect of 'bumping'.

(iii) The effect of humidity on the insulation resistance.

(Measurement of insulation resistance before and after Climatic test as detailed in W.T. Board Spec. K.110).

Test Results on Relays

| Plate Ref. | Vibration at frequencies between 10 and 100 c.p.s. | Effect of 1 hrs. 'bumping' bumps/min. | Insulation Res. Tests Megohms | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Contacts | As Recd. | After Dry Heat Cycle | After 1st Humidity Cycle | After 2nd Humidity Cycle | After 24 hrs. Recovery |
| Plate Item | | | | | | | | |
| 14 - 2A | Chattering with some spurious contacting between 2700 and 2910 c.p.s. | | 1 - 2 | $>10^5$ | $>10^5$ | $>10^5$ | 2800 | $>10^5$ |
| | | | Coil E | 63000 | $>10^5$ | 1500 | 150 | 3800 |
| 14 - 2B | No chattering or spurious contacting | | 1 - 2 | $>10^5$ | $>10^5$ | 9750 | 120 | 15500 |
| | | | Coil E | 6000 | $>10^5$ | 130 | 4 | 1800 |
| 14 - 1 | No chattering or spurious contacting | Satisfactory, no deterioration | 2 - 3 | 9750 | $>10^5$ | 750 | 2.0 | 6500 |
| | | | 3 - E | 38000 | $>10^5$ | 65 | 2.50 | 4850 |
| | | | 4 - 5 | 2500 | $>10^5$ | 100 | 18 | 4850 |
| | | | Coil E | 2500 | 9750 | 2 | 0.80 | 1450 |
| 13 - 1A | Some chattering with some spurious contacting at frequencies between 2700 and 2850 c.p.s. | | 1 - 2 | 1450 | $>10^5$ | 4.00 | 9.00 | 19 |
| | | | 3 - E | 26000 | $>10^5$ | 0.40 | 0.50 | 650 |
| | | | 5 - E | 26000 | $>10^5$ | 0.30 | 6000 | 2450 |
| | | | 7 - 8 | $>10^5$ | $>10^5$ | 0.25 | 3.00 | 600 |
| 13 - 1B | No chattering or spurious contacting | | 1 - 2 | 1006 | 26000 | 4.00 | 4.00 | 18 |
| | | | 3 - E | 32500 | $>10^5$ | 160 | 30 | 650 |
| | | | 6 - E | 33500 | $>10^5$ | 1000 | 78 | 2450 |
| | | | 7 - 8 | $>10^5$ | $>10^5$ | 2500 | 14 | 600 |
| 14 - 4A | No chattering or spurious contacting | | Coil E | 38000 | $>10^5$ | 78 | 970 | 155000 |
| 14 - 4B (damaged) | No chattering or spurious contacting | | Coil E | 65000 | $>10^5$ | 19 | 16 | $>10^5$ |
| 14 - 2 | Continuous chattering and spurious contacting at frequencies between 3450 and 3550 c.p.s. | | 2 - 3 | $>10^5$ | $>10^5$ | 2600 | 230 | 2600 |
| | | | 4 - 6 | " | " | 0.98 | 180 | 26000 |
| | | | 7 - 9 | " | " | 600 | 195 | 26000 |
| | | | Coil E | 15000 | " | 110 | 9 | 28000 |

It will be seen that mechanically the relays stood up well to the 'bumping' test (120 bumps per minute) but that types as shown on Plate 13, Item 1; Plate 12, Item 6; Plate 14, Item 2, are unsatisfactory under vibration.

All types show a very marked deterioration of insulation resistance during climatic conditioning and particularly the type shown in Plate 13, (Item 1) a slow recovery from the effects of high humidity.

### 5.4. Conclusions

The points of interest noted on the relays under investigation are:-

(i) The anti-chatter device of the type shown on Plate 14, Item 1.

(ii) The compactness of the assemblies consisting of the relays of the type shown on Plate 14, (Items 1, 2, 3).

(iii) The flatness of the polarised relay-micro-switch (Plate 13, Item 1).

(iv) The method of coil marking.

The two types of indicator unit are interesting on account of their unusual application and their small size.

With the possible exception of the indicator units (one of which was damaged when received) the relays are not 'tropical'. No special processes and techniques requiring further study are in evidence.

## 6. COVERED WIRE AND INSULATING SLEEVING

### 6.1. General

It was observed that in the German equipment available for inspection covered wires are used almost exclusively in preference to insulating sleeving. The use of insulating sleeving is in most cases confined to very short lengths of wire, often on component assemblies or as an additional protection for thin covered wire. In view of this fact the lengths of sleeving available were insufficient for carrying out type approval tests.

The following types were observed.

(a) Stranded wire, (42 strands approx. equiv. to 36 s.w.g. copper wire), p.v.c. covered, external diameter 3 mm. wall thickness 1 mm. Very flexible.

(b) Sleeving with internal cotton braid covered by p.v.c. sheath. Internal diameter : 0.75 mm. Wall thickness : 0.75 mm. Smooth surface, probably maintaining good surface insulation.

(c) Covered wire, single core, approx. equiv. to 25 s.w.g. fabric base, varnish impregnated. External diameter : 1.25 mm. Smooth surface.

(d) Same as (c), but approx. equiv. to 19 s.w.g. and external diameter 2 mm.

(e) P.V.C. covered wire, approx. equiv. to 25 s.w.g., internal silk lapping and one marker thread. External diameter 1.5 mm.

(f) Same as (e), but approx. equiv. to 19 s.w.g. and external diameter : 2.5 mm.

(g) Braided cotton sleeving, varnish impregnated, wall thickness 1/2 mm. various diameters.

(h) Stranded wire, (42 strands of 36 s.w.g. copper wire), covered with a thin cellulose acetate film, one lapping of silk and one lapping of cotton which in turn is covered by a thin layer of transparent varnish. It would appear that high insulation resistance and dielectric strength could be achieved by simpler means, and that this type is unlikely to give a satisfactory performance under tropical conditions.

(i) Cableform, consisting of 7 wires of type (h), covered with braided fabric and a layer of p.v.c. 1 mm. thick, with external screen of tinned copper wire (braided). See Plate 10, Item 5.

(j) Same as type (a), but using rubber instead of p.v.c.

(k) Stranded wire, (42 strands of 36 s.w.g. copper wire), covered with thin cellulose acetate film, a layer of rubber and one of p.v.c. reinforced with an internal fabric braiding. Ext. diam. 3.6 mm.

(l) Miniature covered wire, 26 s.w.g., lacquered, covered with one lapping of silk and a thin, translucent layer of p.v.c. Ext. diam. 0.9 mm.

Only types, (a), (c) and (d) were available in sufficient quantities to enable tests to be carried out.

All covered wires have an internal marker thread, which is a manufacturer's designation.

All covered wires except type (a) are used in the form of cableform, held together with waxed string. Almost the entire wiring of the FuG.8 consists of this kind of cableform and it appears that the cable form is made up separately, cut to the desired length and bent to suit the components, before insertion in the set and soldering into position.

In general the wiring occupies very little space, and in the case where cableforms of types (a) and (j) are used the wiring should be fungus and moisture resistant. In some instances 'air wires' are used without insulation. Cableforms are sometimes protected by a form of transparent cellulose film, as shown on Plates 11, Item 22.1. The purpose of this film is not quite clear, however, since it is neither wound tightly nor continuously, but it may be used as a neat form of binding instead of string.

Type (g) is rarely used for the protection of wiring, but it is used as protective cover for small resistors and capacitors.

Type (l) is used on the miniature assembly shown on Plate 12 (Item 2) and Plate 10 (Item 3) and effects a considerable saving of space.

6.2. Experimental Results

The experimental results are given below.

Experimental Results on Sleeving and Covered Wire

The samples were tested to Specn. D.C.D., W.T.820, grade "E".

Initial Dielectric Strength Test

| | | |
|---|---|---|
| Type a | Satisfactory : Breakdown : | 6,000 volts. |
| c | Satisfactory : Breakdown : | 2,000 volts. |
| d | Satisfactory : Breakdown : | 5,000 volts. |

Dielectric Test After Bend Test

| | | |
|---|---|---|
| Type a | Satisfactory | |
| c | Not satisfactory : Breakdown : | 500 volts. |
| d | Satisfactory : Breakdown : | 5,000 volts. |

Dielectric Test After Humidity Conditioning

| | | |
|---|---|---|
| Type a | Not satisfactory : Breakdown : | 500 volts. |
| c | Not satisfactory | |
| d | Not satisfactory | |

Soldering Test    Types a - f satisfactory. (Small external diameters).

"Heat Crack Test" (1 hour at 130°C. covered wire wound on former ½" dia.).

Type a    Unsatisfactory.

It will be seen that these covered wires are all unsatisfactory when tested in accordance with the appropriate British Specifications, even for the lowest electrical grade. Their only advantage appears to be the saving of space achieved by the use of these cable forms.

6.3. Conclusions

The types of covered wires and insulating sleeving available for inspection with the possible exception of type (1), show no outstanding features and those tested are inferior in almost every way to those used in British airborne equipments.

7. RECTIFIERS

7.1. General

Seven types of metal rectifiers were available for investigation, but only three types were undamaged or available in sufficient quantities to justify experimental work.

(a) Selenium rectifier, consisting of 50 selenium discs in series, contained in a bakelised fabric tube. Each disc has a working area of 7 sq. millimetres and is rated at 5 milliamps in half-wave or 10 mA. in a bridge circuit. The complete unit is 4" long and has a diameter of 7/16". These rectifiers seem to be extensively used, occasionally in banks of 10 or more, sometimes in place of a valve rectifier. As the experimental results given below indicate, they are of high quality and do not deteriorate appreciably during climatic conditioning. A leading manufacturer was contacted with a view to examining the possibilities of manufacturing this type of rectifier in this country. It is claimed that rectifiers could be produced which are electrically and mechanically superior to the German types, but it will be several months until the apparatus required for the production of the discs is completed.

(b) Selenium (on aluminium) rectifier, illustrated on Plate 9, Item 7. The unit consists of 23 discs in series. It is 5" long and the diameter of the discs is 1". It is notable for its light weight.

(c) Copper oxide rectifiers, illustrated on Plate 7, Item 6. It consists of a ceramic tube (Item 6.1) containing 6 discs (Item 6.2) (copper oxide on copper) fitted with metal and caps (Item 6.3) and soldering tags (Item 6.4). The unit is hermetically sealed. Length : $1\frac{1}{4}$". Ext. diam. : 5/16"; diameter of discs 2 mm. This rectifier is similar to the British "Westector" type. It is rated at 3 mA. 1/2-wave rectification.

(d) Copper oxide rectifier, illustrated on Plate 12, (Item 2.1). The rectifying discs are similar to those of type C, but they are contained in a plastic tube. Brass end caps are screwed on to this tube which has been previously threaded. This type is not hermetically sealed.

(e) Selenium rectifier for use with instruments illustrated on Plate 9, Item 6. No special features.

(f) Copper oxide rectifier for use with instruments. No special features.

(g) Selenium on iron, heavy current rectifying bridge. Diameter of discs 5". No features of special interest.

7.2. <u>Experimental Results</u>

The types on which measurements were carried out are : a, b and c.

Climatic tests are as specified in W.T. Board Type K.110.

Type a D.C. Current (in microamps) in reverse direction with 600V. applied

| Sample | As Recd. | After Dry Heat Cycle | After 1st Humidity cycle | After 2nd Humidity cycle |
|---|---|---|---|---|
| 1 | 140 | 200 | 240 rapidly decreasing to 140 | 140 |
| 2 | 50 | 120 | 140 | 140 |
| 3 | 400 rapidly decreasing to 180 | 280 rapidly decreasing to 160 | 400 rapidly decreasing to 220 | 80 |
| 4 | 280 rapidly decreasing to 140 | 200 | 160 | 100 |
| 5 | 140 | Not subjected to Climatic Test | | |
| 6 | 260 rapidly decreasing to 160 | | | |
| 7 | 180 rapidly decreasing to 111 | | | |

D.C. Volts drop in forward direction with 5 mA. flowing

| Sample | As Recd. | After dry Heat cylce | After 1st Humidity cycle | After 2nd Humidity cycle |
|---|---|---|---|---|
| 1 | 95 | 95 | 95 | 95 |
| 2 | 82 | 82 | 82 | 82 |
| 3 | 66 | 68 | 68 | 69 |
| 4 | 82 | 82 | 82 | 82 |
| 5 | 80 | Not subjected to climatic test | | |
| 6 | 82 | | | |
| 7 | 120 | | | |

It can be seen that these rectifiers are of good quality and maintain their characteristics during climatic conditioning.

Type b

The results given are compared with the values applying to the corresponding British type, namely S.T. and C. type H25-23-1.

Volts Drop in Forward Direction (with 120 mA. flowing)

| Sample | Volts Drop |
|---|---|
| 1<br>2<br>3 | 23.0<br>19.5<br>21.0 |

S.T. and C. maximum for H.25-23-1 = 27.6 volts with 120 mA. flowing.

Reverse Current with 300V. applied

| Sample | Reverse Current mA. |
|---|---|
| 1<br>2<br>3 | 50.0<br>48.0<br>26.5 |

S.T. and C. maximum for H.25-23-1 with 15V. per disc. (345V) applied = 27 mA.

Load Test

Rectifiers were connected in series and subjected to a load test of 75 mA. in the foward direction for two hours (this being the maximum load permissible for S.T. and C. Selenium-on-Iron rectifiers). After this time the German rectifiers were only slightly warm.

Average weight of German rectifier - 1¾ ozs.
" " " H.25-23-1 " - 5½ ozs.

Apart from their light weight these rectifiers show no interesting properties. The small resistance in the reverse direction may be due to damage to the units before being received for investigation.

Type c

Volts Drop in Forward Direction (with 3 mA. flowing) in volts

| Sample | As Recd. | After dry Heat | After 1st Humidity cycle | After 2nd Humidity cycle |
|---|---|---|---|---|
| 1 | 12.5 | 12.75 | 12.5 | 15.0 |
| 2 | 12.5 | 14.50 | 15.0 | 22.0 |
| 3 | 0.5 | 8.75 | 8.0 | 11.0 |

Reverse Current (in microamps) with 60V. (6V. per disc) applied

| Sample | As Recd. | After dry Heat | After 1st Humidity cycle | After 2nd Humidity cycle |
|---|---|---|---|---|
| 1 | 20 | 15 | 25 | 20 |
| 2 | 10 | 5 | 5 | 5 |
| 3 | 15 | 20 | 20 | 18 |

It can be seen that these rectifiers have a satisfactory performance after exposure to climatic conditions. In this respect they are superior to the corresponding British type ('W' Westector).

7.3. Conclusions

Of the rectifiers examined types 'a' and 'c' are the most interesting. It is thought that similar types with equally efficient seals would find many applications in British equipments and their production should be encouraged.*

8. L.F. TRANSFORMERS AND CHOKES

8.1. General

In the equipments inspected, eight types of transformers and assemblies were found.

An interesting transformer is shown on Plate 15, Item 4. It is completely enclosed in a metal case, lined with impregnated paper. One of the units is filled with chlorinated napthalene wax. The windings are protected by cellulose acetate tape. The leads are brought out through hermetically sealed glass bushes (Plate 15, Item 4.1).

The filling of the metal case with chlorinated napthalene wax and the hermetic sealing of the metal case should result in great resistance to the effects of high humidity, but inferior load characteristics may be expected due to the lack of ventilation, as compared with a similar transformer not sealed in a metal case.

This type of transformer is one of the two units encountered which show any sign of being intentionally "tropical". The other is an audio transformer of the type shown on Plate 15 (Item 5a), mounted in a metal box lined with bakelised paper. The electrical contacts are taken out through the bakelised paper top. The complete assembly is marked "tropical-proof", and is one of the few units so marked. A remarkable feature in German equipments is the existence of "tropical" and evidently "non-tropical" components, in adjacent positions.

This illustrated by Item 2 on the same plate where the windings appear entirely unprotected apart from a thin coating of grey paint, and the soldering tags are mounted on laminated paper boards (non-resistant to water) (2.1).

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* Some British manufacturers are already experimenting with types similar to 'a' and are planning their production.

Item 3 on the same plate is an "audio" transformer and a choke. The two units were originally enclosed in a metal case which was in no way sealed against the penetration of moisture. The insulating materials used are again laminated paper (3.1) and bakelised fabric (3.2) of a type which would not be approved for this purpose in accordance with British Specifications.

The method of mounting seems very simple, but otherwise appears to have little to recommend it. The brackets (Item 3.3) have a tendency to slide off under vibration. The laminations are thus released, with undesirable effects on the electrical stability of the unit.

Item 1, on Plate 15, is a choke taken from a power-supply control unit. Although this unit is for airborne equipment, the materials used to provide protection for the windings and insulation are particularly liable to absorb water. The paper used is very superficially impregnated and the windings are not protected by wax or any other impregnant. The unit has no features of special interest.

Items 5a, 5b and 5c on Plate 15 are "audio" transformers of a different type. They are of no special interest.

8.2. Experimental Results

The test results are shown below. The units which appeared to be in an undamaged condition were subjected to climatic conditioning, consisting of a dry heat cycle at 71°, a humidity cycle at 71° and 100 relative humidity lasting 6 hrs., cold cycle at -40°C. lasting 2 hours, followed by a second humidity cycle. Plate 15.

Tyep 4. Insulation resistance measurements at 500V. D.C.

| Conditions of Measurement | Windings megohms | | |
|---|---|---|---|
| | I - 18 | II - 110 | III - 270 |
| Initially | 2041 | 3450 | 2270 |
| After Dry Heat | 10000 | 10000 | 12500 |
| After 1st humidity cycle | 9 | 62.5 | 43.4 |
| After 2nd humidity cycle | 1 | 2 | 1 |
| 24 hrs. after climatic conditioning | 22 | 5 | 2 |

Plate 15

Type 2 and 3 Insulation resistance measurements at 500V. D.C. between windings 1 and 2

| Conditions of Measurement | Type 2 megohms | Type 4 megohms |
|---|---|---|
| Initially | 6250 | 736 |
| After Dry Heat | 5000 | 5000 |
| After 1st Humidity cycle | 3560 | 31.1 |
| " 2nd " " | 1 | 1 |
| 24 hrs. after climatic conditioning | 4 | 1 |

Plate 15

Type 5 Insulation Resistance Measurements (megohms).

| Conditions of Measurement | 5a | | | 5b | | | 5c | |
|---|---|---|---|---|---|---|---|---|
| | A1A2 | B1B2 | C1C2 | A1A2 | B1B2 | C1C2 | A1A2 | B1B2 |
| Initially | 1110 | 1470 | 2150 | 695 | 2780 | 3170 | 3220 | 4160 |
| After Dry Heat | 7150 | 7150 | 16670 | 7700 | 12500 | 11900 | 6250 | 14300 |
| Aft 1st Hum. cycle | 7 | 9 | 15 | 34.4 | 45.5 | 55.5 | 172 | 152 |
| After 2nd Hum. | 1 | 1 | 1 | 4 | 3 | 2 | 4 | 2 |
| 24 hrs. after climatic conditioning | 1 | 1 | 4 | 7 | 96.2 | 171 | 25 | 8 |

The transformer ratios were measured before and after climatic conditioning and no change was detected.

It is thought that the hermetically sealed type (chlor.naph. filled) should have stood up to the climatic conditioning very much better than the results indicate. Since the lid of the metal can is soldered to the can, the conclusion drawn is that the glass seals must have been slightly damaged when the unit was received. With the means of protection employed much greater resistance to the effects of climatic conditioning could be achieved.

Without exception all the units tested show a very marked deterioration of insulation resistance, amounting to complete breakdown, usually after the second humidity cycle. All units show a slow recovery from the effects of high humidity.

8.3. Conclusions

The only type of special interest is the hermetically sealed unit, fitted with glass insulators. In places where good insulation is essential and the transformer is not carrying a heavy load, a unit of this type should work very satisfactorily under conditions of high humidity. No special processes and techniques requiring further study are in evidence.

9. MOVING COIL INSTRUMENTS

All instruments available had come from crashed aircraft and had sustained considerable damage. A miniature type ($1\frac{1}{4}$" dial) appears to be in frequent use. The instruments are of unknown manufacture and are of no special interest.

One indicating unit (visual indicator) is illustrated on Plate 13, Item 6. It is manufactured by A.E.G. and is very similar to the types used in British aircraft. It contains two 40 micro-amp. movements. The unit is notable for its light weight.

10. INDUCTORS

10.1. Dust Iron Cores

The general use of dust iron cores is very interesting, particularly the very frequent recurrence of coil assemblies, tuning assemblies etc., with extensive use of dust iron cores. Another use of dust iron is seen in the variometer shown in Plate 5, Item 1.3.

In some instances these cores are adjustable in such a manner as to enable tuning to be carried out by a change of reluctance. This type of assembly is shown in Plate 8, Item 3. The assembly in this instance is encased in a plastic frame, probably loaded polystyrene.

Measurements were carried out on one of these units (at 600 kc/s), comparing the inductance of the core with and without the dust iron core. The effective permeability was found to be 5.5 approx. and the introduction of the core into the empty former caused a reduction in 'Q' of 16%.

The assemblies incorporating dust iron cores are extremely neat. A frequent practice (Plate 8, Item 4) is to mount the dust iron cored coil between two ceramic end pieces and mount associated capacitors either on the end pieces along the length of the dust iron core.

10.2. Ceramic Formers

For coils which are used in tuning assemblies the conductor, in general, is wound on a ceramic former or electrolytically deposited on it. These formers are interesting in view of the neat metal inserts found in the ceramic. (Plate 4, Item 4.1). The process appears to take two forms. In most cases the hole to contain the insert is sprayed and silvered and the brass insert soldered in place. Thus the insert is held to the ceramic by a seal of comparatively soft metal. The alternative process is to glaze the ceramic to metal. This process, if it is in common use is worthy of investigation. The ceramic formers have ceramic end pieces on which are generally mounted temperature compensating capacitors used for accurate tuning.

10.3. Plastic Formers

In a few instances, plastic formers are in evidence but the quality of these is inferior and the tropical performance is poor. In all cases the plastic former is inferior to the ceramic type described in 10.2.

10.4. Methods of Assembly

The assembly methods for dust iron cores is mentioned above in 10.1 and as stated there, the whole technique of manufacture and assembly merits attention.

For the ceramic type the following process is fairly common and interesting. Instead of winding a wire round the former, grooves in the ceramic former are sprayed with metal, silvered and subsequently the copper foil is deposited in the grooves by electrolytic action. (Plate 4, Item 4.2.). This process has several advantages: The copper film deposited does not have the same coefficient of thermal expansion as a solid copper strip but assumes the coefficient of the ceramic former on which it is deposited.

It is found that in several cases the ceramic end pieces of a coil former actually form the basis of a variable capacitor with ceramic dielectric. The surface of the end piece is silvered and another ceramic disc mounted on it, the capacitance being adjustable by rotating the disc over the silvered end piece and varying the overlapping area of silvering. This assembly is very compact.

10.5. Conclusions

There are several points of interest relating to inductor units. They are as follows:-

(a) It is thought that a comprehensive investigation of the properties of German dust iron cores, and a knowledge of the process of manufacture would be very useful.

(b) The formers constructed of glazed ceramic material, which have several features about which information may be desired.

(i) The method of inserting the brass fixing nuts into the ceramic material.

(ii) The process of spraying and silvering the grooves in the former.

(iii) The process of depositing the copper coil.

(iv) The general procedure of mounting components on the end pieces of the formers to constitute temperature compensated assemblies.

11. MISCELLANEOUS OTHER COMPONENTS

11.1. Plugs and Sockets

No distinctive plugs and sockets were found. The common type consisted of a bakelised fabric plate with pins and sockets inserted.

This type of plug and socket is used extensively due to the nature of assembly of radio equipments in sections. The various assembled sections are mounted in adjacent positions, lined up by locating pins, and connected electrically by this type of plug and socket (Plate 10, item 3.2). It is perhaps noteworthy that individual components such as relays are, in some instances, mounted in cases, fitted with plugs of this type. Thus the relay is completely wired up and produced with a plug fitting. This is a good method of avoiding danger in the process of wiring up of delicate relays in service and affords a simple method of replacing faulty units.(Plate 13, item 1).

The only other noteworthy feature of plugs was in the German version of the 'W' plug. The neck of the plug contained a hinged flap to facilitate access to the connections to the plug (Plate 12, item 3). It was evident that no precautions had been taken to make this type of plug suitable for use in the tropics. General purpose R.F. plugs and sockets (single and double pole) have been examined on previous occasions. (Ref.16).

11.2 Switches

As in the case of plugs and sockets, no exceptional features were evident on the switches of German origin examined. The normal types of change-over and press-button switches were encountered and the design is similar to that used in this country.

11.3 Terminal Boards

The type of terminal board used consists of bakelised fabric or paper varnished or impregnated with a paxolin backing strip. Neither the materials used nor the design would be approved for this purpose in accordance with British specifications.

11.4 Ceramic Assembly Strips

This type of mounting strip is not in such common use in this country and the type of assembly is shown in Plate 4, item 11.

The connections are usually of one of two types:-

(a) The terminals are inserted in the ceramic base by screw fittings or soldered into holes the edges of which were previously silvered.

(b) The connection between is effected by filling connecting grooves with solder.

The former procedure is the most common and the second method is described in Ref. (5).

11.5 Valve Holders and Retainers

In general valve holders and retainers appear robust and neat. The smaller valves are contained in insulated housings and the retainers are an integral part of the housings. The larger valves are retained by a bayonet type of base mounting. There are several papers published on enemy valves and valve accessories and they are referred to in the appended Bibliography. Ref. 6, 7, 8, 9, 10, 11, 12, 13.

11.6 Low Capacity Switch

An unusual low capacity switch is shown in Plate 4, item 3. The switching is effected by rotating the ebonite rotor (item 3.1) containing grooves in which the wire contacts ride. The base of the switch unit is a solid ceramic strip in which the spring contacts are mounted (item 3.3). The whole construction is clearly indicated in the plate.

11.7 Ceramic Applications

The most unusual application (Ref.15) of ceramic or porcelain is shown in Plate 16, items 1 and 2, Plate 8, item 1, obtained from Enemy Aircraft Section. The whole apparatus in the plates is mounted on a ceramic chassis. The chassis is silvered and copper sprayed to provide screening. The second noteworthy feature is the construction of the tuned circuit. The air dielectric capacitor has silvered ceramic vanes. The inductance of the circuit is provided by an adjustable metal strip which makes contact with the metallised ceramic.

This application of ceramic material is presumably intended to achieve high stability of the circuit. The copper spray on the chassis is interesting due to the rigid nature of its adherence to the silvered ceramic. It was almost impossible to remove the copper film without lifting the silvered surface also.

11.8 R.F. Cables

A low loss concentric R.F. cable of German origin has recently been examined, together with its terminations and a balancing transformer of compact design. For details see Ref.17.

12. GLOSSARY

| | |
|---|---|
| Angemeldet | Registered as a Trade Mark |
| Arbeits-Spannung | Operating Voltage |
| Betriebsspannung | Operating Voltage |
| Betriebstemperatur | Working temperature |
| Bipolar | Bipolar |
| Bis 70°C. Nicht Auslaufend | Hermetically sealed up to 70°C. |
| Dampfungsarm | Low loss |
| Electroyt. Kondensator | Electrolytic condenser |
| Hohenfest | Altitude-proof |
| Induktionsarm | Of low inductance |
| Induktionsfrei | Non-inductive |
| Kondensator | Condenser |
| Negativer Pol am Gehause | Case negative |
| Nennspannung | Nominal voltage |
| Prufspannung | Test voltage |
| Spannung | Voltage |
| Spitzenspannung | Peak voltage |
| Stabil | Stable |
| Strom | Current |
| Tropenfest (abbr. Trop.) | Tropical proof. |

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14. NOTES AND ACKNOWLEDGEMENTS

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Displays of German Components and R.F. Cables have been prepared and are available for inspection at the Components Investigation Section and Cables Section respectively, Radio Department, Royal Aircraft Establishment, (Ambarrow Court).