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INSPECTION TEAM

This report brings together information which has been obtained by various interrogations of Telefunken staff in Hamburg and Berlin by W/Cdr. G.L. Hunt, S/Ldr. E.C. Greaves, F/Lt. Holt, S.D.O. F.H. Powell and S.D.O. E.J. Hubbard, all of M.A.P.

1. Introduction. This report on the manufacture of metal-ceramic valves is based on information obtained from the interrogation of Dr. Kleen, Telefunken, at Hamburg on 25th August, 1945, supplemented by information obtained at the Osram valve factory in Berlin, Sickingenstrasse, 71, where Dr. Weth and Dr. E. Wiegand were interrogated. At the latter target it was hoped that Dr. Pulfrisch could be interrogated but he was not available although reports which he had prepared on the manufacture of the ceramic were found and removed.

2. General Construction of the Valves

A range of metal/ceramic valves has been developed by Telefunken for use at decimetre wavelengths. The valves bear some resemblance to the American "Lighthouse" valves and are designed for use in concentric line circuits. No glass is used in their construction; instead a special ceramic has been developed which is claimed to be vacuum tight provided the wall thickness exceeds 3 mm.

The appearance of the valves is illustrated in Fig. 1. The anode cooling block is of aluminium and is screwed on to a stud projecting from the copper anode.

The seals between the ceramic and metal portions of the valve are soldered.

Details of the construction of the valves are given in the following sections of this report.

3. Manufacture of the Ceramic

3.1 Constituents

- 10.20 kg. Speckstein (Talcum or magnesium silicate)
- 1.44 kg. Zettlitzer Kaolin (China clay obtained from Zettlitzer in Czecho-Slovakia)
- 0.48 kg. Zirconium dioxide
- 0.24 kg. Kali-Feldspat (Potassium feldspar)

3.2 Preparation of Powder. The above constituents are mixed with 25 litres of distilled water in a hard unglazed porcelain mill of 60 litres capacity together with 35 kg. of hard unglazed porcelain balls, 25 mm. in diameter. The mill is driven at 48 r.p.m. for 18 hours after which 15 cc. of acetic acid are added by means of a centrifuge and the milled material then separated from the liquid by centrifuge or suction. The material is then dried at 120 - 150°C.

A further milling is then given in a hard unglazed porcelain mill of 50 litres capacity which is loaded with 3 kg. of the material from the first mill and 3 kg. of hard unglazed porcelain balls of 25 mm. diameter. This mill is driven at 75 r.p.m. for 1 hour.

3.3 Preparation of ceramic material paste. 3 kg. of the powder prepared as in 3.2 is put into an aluminium pot of about 10 litres capacity with 300 gms. of solid paraffin (melting point 52° - 56°C.). The mixture is heated to 100°C. for 15 mins. approx. with constant stirring until the paraffin is uniformly distributed, and, while still hot, the mixture is twice put through a sieve of 200 mesh.

3.4 Granulation of Ceramic mass. The pasty ceramic mass is pressed in a hydraulic press into cylindrical form, about 50-60 mm. dia. and 60-70 mm. long, the pressure used being 300 kg./cm.². These cylindrical blocks are afterwards granulated to a consistency of fine powder (it should feel greasy when rubbed between the fingers).

The protracted milling processes described above are necessary to get the finest possible powder to prevent the inclusion of air.

3.5 Pressing of ceramic valve parts. This is done by means of a lever press at a pressure of 300-500 kg./cm.², the powder being piled to 2 or 3 times the final dimension.

3.6 Firing of ceramic parts. Firing is done in a gas or electric oven, the parts being placed on quartz sand in clay capsules. The firing temperature is 1350° - 1400°C. according to the purity of the talcum. The oven is brought up to its maximum temperature over a period of 6 hours and is then maintained at the maximum for a further 3 hours.

(According to Dr. Kleen this firing is done in an atmosphere of nitrogen (30 mm. pressure) but there is no mention of this in the notes prepared by Dr. Pulfrish.)

At this stage of production the tolerances on the ceramic are not critical. It was stated by Dr. Kleen that the minimum thickness of material for no leakage in the finished valve was 3 or 4 mm.

3.7 Grinding of ceramic parts. That part of the ceramic which is to form the seal is next ground to size. Grinding and polishing is done to tolerances of 0.1 mm. or less.

3.8 Testing for Porosity and Cracks. The ceramic parts are dipped in dilute red ink and quickly rinsed with water and then dried at 100°C. in a dry heat oven. After drying they are examined for cracks and pores which can be recognised readily by any red-ink marks which remain.

3.9 Physical properties of the ceramic.

Dielectric constant	5.5
Dielectric loss (at $\lambda = 5 \text{ m.}$)	6.8×10^{-4}
Resistance to fracture by bending	1800-2000kg/cm ² .
Temperature coefficient	$65 - 70 \times 10^{-7}$
Contraction during firing in direction of pressure	12-20%
Contraction during firing in direction perpendicular to pressure	8-10%
Porosity	0

4. Metallising the Ceramic Parts

Where the ceramic forms a seal with the metal portion of the valve, it is metallised to simplify the subsequent soldering process. The metal coating is molybdenum with iron and nickel added.

4.1 Preparation of molybdenum powder. 200 gms. of molybdenum powder are mixed with 1000 cc. of alcohol and left to stand 3 minutes. The coarse particles of the powder are deposited and the fine particle powder is decanted off with the liquid. After standing a further 3 hours the fine powder is deposited and the liquid poured off. The fine powder is then dried at 150°C.

4.2 Preparation of Iron Powder. 100 gms. of iron powder are mixed with 500 cc. of alcohol and left to stand 1 minute when the fine powder is decanted with the liquid. This fine powder is recovered after allowing it 2 hours to settle and pouring off the liquid. It is dried at 150°C.

4.3 Preparation of Molybdenum-Iron Paste. 40 gms. of fine grain molybdenum powder and 0.8 gm. of fine grain iron powder are stirred into 200 cc. of 10% collodium solution in "Polysolvan".

(According to Dr. Kleen, although a mixture of molybdenum and iron as described above can be used, the iron is not necessary and the paste can be made with molybdenum powder only.)

4.4 Application and firing of paste. The paste is applied to the ceramic surfaces which have previously been ground (see 3.7) using a camel hair brush. The applied layer should be 0.03 - 0.04 mm. thick and should be a continuous and well covering surface.

The ceramic parts thus prepared are placed on a molybdenum sheet thinly covered with sand and moved in a molybdenum carrier through an oven for firing. The firing temperature is 1330° - 1340°C. and the parts travel through at a speed of 2 metres per hour giving a baking time of about 30 minutes. Firing is done in an inert atmosphere for which the gas supply is 500 litres per hour nitrogen and 200 litres per hour hydrogen (these figures are for an oven of about 80 mm. clearance).

Dr. Kleen, during his interrogation stated that difficulty had been experienced with this process of firing the molybdenum paste. He said the prime requirement was to burn in the metal at the highest possible temperature to get better adhesion, but too high a temperature would give deformation of the ceramic. Accordingly the temperature was brought as near to the ceramic firing temperature as possible but due to the limited accuracy of temperature measurement a difference of 50°C. between the ceramic firing temperature and the molybdenum firing temperature was desirable.

4.5 Nickel layer. Although the molybdenum layer produced as described above is capable of being soldered to metal, better wetting of hard solder can be obtained if an additional nickel layer is applied. This nickel layer is prepared as follows:-

40 gms. of nickel powder is stirred in 20 cc. of 10% collodium solution in "Polysolven" and the mixture is painted over the molybdenum layer. The layer of nickel should be about 0.05 mm. thick after the evaporation of the solvent.

It is possible to solder without further processing but the latest experiments show that better results are obtained if the nickel layer is fired in a hydrogen oven at 980°C. The speed of movement through the oven is 1 metre per hour with a gas supply of 500 litres/hour.

4.6 Other methods for coating the ceramic. Dr. Kleen referred to other experiments which had been made. In one of these the coating applied to the ceramic was molybdenum with 1% nickel added. The metal powder mixture was dissolved in amyl acetate and applied with a brush and subsequently fired. He also referred to a finishing layer of silver which was baked on at 850°C. in a nitrogen (?) atmosphere to make it compact but stated that this process had been found unnecessary. It seems certain that this metallising of the ceramic was the most troublesome part of the valve development and that it was difficult to get a process which produced valves free from leakage troubles.

5. Preparation of Metal Parts for Metal/Ceramic Bonding.

5.1 Composition of metal parts. For vacuum tight metal/ceramic hard soldered joints, pressure is wanted between the metal and the ceramic. Therefore two types of nickel-iron alloy are used according to whether the metal is inside or outside the ceramic. For soldering the metal inside a ceramic ring or cylinder, "Feri 46" is used and, when the metal comes outside the ceramic, "Feri 42". The composition of these alloys is indicated by the numerical part of their title which gives the percentage of nickel.

Thus Feri 46 is 54% Fe and 46% Ni.
and Feri 42 is 58% Fe and 42% Ni.

The requisite pressure is obtained by taking advantage of the different coefficient of thermal expansion of these alloys between one another and with relation to the ceramic.

5.2 Forming of metal parts. The material was obtained by Telefunken in strip form about 0.3 mm. thick and all metal parts were pressed from this strip. In the case of tubular parts the strip is first pressed into the form of a cylinder with one end closed and the unwanted closed end then cut off. At those places where the metal is to form the seal it is turned down (or rolled) to a thickness of 0.1 - 0.14 mm.

The nickel iron was obtained from Krupps or Hereus, Hanau, but some of the material obtained from the latter source was unsuitable for metal/ceramic seals. This was because the marks of rolling were still left on the surface of the metal. In the subsequent silvering process which is the last before the actual bond with the ceramic is made, these rolling marks cause the silver to form "islands" and this imperfect silvering produces poor joints giving rise to leaks.

5.3 Silvering of metal parts. For a satisfactory surface the nickel-iron is first nickel plated to a thickness of 7 - 10 μ , and then silver plated to a thickness of 5 μ . It is then baked in hydrogen at a temperature of 1050°C. when the silver melts and forms a uniform layer. It is during this baking stage that bad surface nickel-iron causes the silver to break up into small islands and the material used was carefully selected by Telefunken.

6. Vacuum tight hard soldered joints - metal/ceramic.

6.1 Process of Soldering. Soldering is done with pure silver which is used in the form of a wire of about 0.8 mm. dia. for the largest seals. It is necessary to ensure that the gap between metal and ceramic which is to be sealed does not exceed 0.1 mm. The metal and ceramic parts are assembled in ceramic soldering pots which are made from STG material of Steatite Magnesia A.G., Berlin, Pankow, and the silver is melted in an electrically heated hydrogen oven at a temperature of 1050°C. The process takes 7 - 12 minutes and the seals are tested under water with hydrogen at 4 or 5 atmospheres pressure before the completed parts are built into valves. Fig. 3 shows the method of assembly and the construction of the ceramic soldering pot for making an inner and outer seal to a ceramic ring, both seals being made simultaneously.

7. Valve Assembly

7.1 Sub-assemblies. The valves are assembled in two halves as shown in Fig. 2. The particular arrangement shown here is not necessarily found in all types of valve in the range

/ but

but is typical. In the valve illustrated the grid and anode are built into one sub-assembly and the heater and cathode in another. In other variations the grid has been put into the cathode sub-assembly before final assembly.

7.2 Anode. A solid copper anode 1 is used turned as shown in Fig. 4A. It rests on the shoulder at the bottom of the nickel iron cylinder 2, to which it is soldered by eutectic solder at a temperature of 810 - 850°C. This is some 200°C. lower than the temperature used when making the seal between ceramic and nickel-iron so that the process does not disturb this previously made seal. Apart from the eutectic soldered joint an air space is carefully preserved between the copper anode and the nickel iron cylinder so that the copper is free to expand without putting any strain on the seal between metal and ceramic.

Another variation of anode construction is shown in Fig. 4B. This construction is used in valves used under high voltage pulse conditions where a long discharge path is wanted over the ceramic.

7.3 Grid. The grid disc, 3, is made from molybdenum and is dished. In some valves this disc is fixed to the outer nickel iron cylinder by small welded brackets as shown in Fig. 2A, but, according to Dr. Kleen in those valves in which the grid is associated with the heater cathode sub-assembly, the grid disc is soldered to the outer nickel iron cylinder using eutectic solder. The grid itself is of molybdenum mesh which is nickel plated. In the smallest valve in the range the mesh is made of wires 0.02 mm. dia. spaced 0.3 or 0.5 mm. apart. The mesh grid is soldered to the molybdenum disc for which purpose silver is used. The disc is prepared for soldering by being nickel plated.

7.4 Cathode and Heater. The essential features of the cathode-heater assembly are shown in Fig. 4C. A double tube assembly is used so that adjustment of grid-cathode clearance can be obtained after the valve is pumped and sealed off. This process is described later. The inner nickel-iron tube 1, is a tight sliding fit or push fit in the outer nickel iron tube, 2, and the two are soldered together at the bottom ends. The exhaust tube, 3, is of nickel-iron and is about 3.0 mm. diameter. The ceramic discs, 4, 5, are soldered to the nickel iron tubes. In the finished valve the space within the inner cathode tube, 1, below the inside ceramic disc, 5, is at atmospheric pressure. The cathode coating is sprayed on the spherical end, 6, of the inner cathode tube. Normal spraying methods are used and triple carbonates (Barium, strontium and calcium) used when a smooth coating is essential.

The heater is of tungsten joined at one end to the cathode and at the other to the exhaust tube.

7.5 Final Assembly. The two sub-assemblies are put together as shown in Fig. 2C. To ensure that the two halves are assembled with correct axial alignment, a steel ring which fits inside the outside nickel-iron cylinder on the cathode sub-assembly, projects beyond the flange which can only butt properly against the flange on the grid-anode sub-assembly when the iron ring has been properly slipped inside the outer nickel-iron cylinder of the grid-anode sub-assembly. In the particular type of valve described by Dr. Kleen, in which the grid disc was soldered to the outside nickel-iron tube of the cathode sub-assembly, only the bottom end of the grid disc skirt was inserted into the cathode sub-assembly before soldering. The grid disc therefore projected beyond the flange of the cathode sub-assembly and the projecting portion of the skirt therefore served the same locating purpose as the iron ring does in the type of valve illustrated in this report.

The two halves of the valve are joined by silver solder. In the process used by Telefunken welding plant was used. A silver ring was placed between the two flanges and ring electrodes were used to pass current through the joint and melt the silver thereby forming a satisfactory seal.

8. Exhaust

8.1 Preliminary Bake. Before pumping the valves are baked at 450°C. for one hour. Electrically heated ovens are preferable to gas heated ones to avoid sulphur contamination.

8.2 Pumping. Glass-valve machinery was used for this purpose by Telefunken and for this reason a glass extension was added to the nickel-iron exhaust tube. This glass extension was not joined directly to the nickel-iron tube. An intermediate iron-nickel cobalt tube was used to give a graded joint. The pumping process was normal with short time activation of cathode and at the end the valve was sealed off at the glass tube. Later the metal tube was sealed by welding and the glass discarded.

8.3 Ageing. During ageing the valves are fitted with anode cooling block and forced air cooling used.

9. Finishing Processes. After ageing the valves are tested and the grid-cathode clearance adjusted. This process is explained with the aid of Fig. 4C. Adjustment is made by inserting a suitable mandrel tool inside the cathode tube, 1. Adjustment of this tool produces lateral pressure on the inside of the groove, 7, which is distorted and produces an axial movement of the cathode towards the grid. The adjustment is made while the valve is on the test board and the correct grid-cathode clearance obtained by observing the mutual conductance. The final clearance is about 0.1 mm. In the early experiments the adjustment was checked by observing anode current but this method was discarded because valves were found in which the cathode and grid were not truly coaxial and in these cases although the anode current was satisfactory the mutual conductance was low. Non-axial movement of the cathode is prevented as far as possible by the fact that tube 1 is a tight fit inside tube 2 but faulty sealing of tube 2 into the ceramic disc 4 would result in the displacement of the cathode relative to the grid. Adjustment of grid-cathode clearance was not made in all types in the range but only in the LD.6 and LD.12.

When test and adjustment are complete, the end of the cathode tube is closed with a ceramic disc and the heater connector fitted. The cathode tube is simply spun over the ceramic disc since a proper seal is not required. After this all external metal surfaces are silver plated.

10. Getter

Ceto getter, which is made from a sintered mixture of Thorium and an alloy of aluminium and cerium, is used by Telefunken. This getter is not evaporated but is placed in an appropriate part of the valve where it is heated to a temperature of about 200°C. when the valve is operating. Appendix I gives a description of the processes involved in the manufacture, storage and use of Ceto. It does not act as a getter until its temperature exceeds 150°C. and it gives off its absorbed gas at temperatures in excess of 300°C. Since it is not evaporated in the valve there is no danger of any metallic deposit being formed on insulating parts and the high frequency performance of the valve impaired in consequence.

APPENDIX I

The preparation of "Ceto" getter

1. Composition

80% by weight powdered thorium metal
(obtained from Auer Gesellschaft, Berlin)

20% by weight of an alloy of aluminium and
cerium mixture metal.

2. Manufacture

2.1 Alloying aluminium and cerium mixture metal.

Composition: 72%, by weight, cerium mixture metal.
28%, by weight, aluminium.

The cerium mixture which is stored in paraffin oil is degreased with Xylol or Petrol and cleaned with a steel wire brush. The cerium mixture and aluminium are then put into a hard porcelain (or iron) beaker. This beaker rests in an iron protective vessel which must be at least 50 mm. longer than the beaker. The mixture is melted in vacuum with arrangements made for observing the melting process. After evacuation the oven is heated until the material reacts normally at a temperature of 750°C. The reaction can be recognised by a strong agitation of the material accompanied by a sudden temperature rise to 1500°C. with intermittent evolution of gas. When the reaction is complete the heater is switched off immediately and the pump after a further 10 minutes. The resulting material of glass hardness is cooled under vacuum and is then pulverised in a porcelain or iron mortar to the size of "semolina grain".

2.2 Ceto Pressing. 200 gms. of the above powder and 2400 gms. of Thorium powder are mixed for 30 minutes in a mixing machine and the mixture is then pressed in a hydraulic press at 2000 kg./sq.cm. into rods of 12 mm. x 12 mm. cross section and of suitable length for the heating section of the sintering oven.

2.3 Ceto-Sintering. The sintering of Ceto pressings is done in either vertical or horizontal ovens. The melting pots or carriers and the glowing tubes can be of hard porcelain or "Bergkristall" (quartz?). The use of such crystal tubes must however, be watched carefully, particularly in horizontal ovens, since the glowing tube is destroyed if it comes in direct contact with a melting Ceto mass. The actual melting

of the Ceto must be avoided by means of accurate temperature control because melted Ceto is ductile and difficult to powder and shows poorer gettering qualities than the sintered product.

Before heating, the pressure in the plant must not exceed 0.001 mm. The temperature is raised gradually until it reaches 1000°C. after 3 hours and it is maintained at this level for a further 2 hours when the heaters are switched off. Pumping is continuous during the heating and the pumps are switched off 15 minutes after the switching off of the heaters. The material is left to cool 4 or 5 hours or more, if possible overnight.

2.4 Ceto Powder. The rods, which in the course of sintering have more or less caked together, are carefully separated and cleaned with a steel wire brush, and are then broken up in a porcelain mortar and a ball mill. A maximum of 50 gms. of sintered material is dealt with at a time. It is broken up in a mortar by hand and put through a silk sieve No. 25 (mesh width 0.02 mm.). The powder which passes through the sieve is useable. The remainder is put into a hard porcelain ball mill, wetted with methanol and ground for 8 hours in a nitrogen atmosphere. Because of its high inflammability the ground mass is removed while moist and then dried and sieved.

3. Storage.

Since Ceto powder is inflammable and sensitive to friction and shock and under some circumstances (e.g. if the nitride content is high and the humidity of the air is high) tends to spontaneous combustion, it must be stored in tightly closed containers free from fire danger and kept cool and dry. It must be protected from friction and shock (e.g. bottles with ground stoppers should not be used). The amount of Ceto material in each bottle should not exceed 3 kg.

Operators should wear protective glasses when working with Ceto and sand should be available to extinguish fires.

Ceto should only be transported in the form of the sintered material and scraps should not be put in any general rubbish dump but destroyed independently.

4. Use.

Ceto is used in the form of a paste which is made by mixing 5 parts of powder in 1 part of 2.5% collodion solution. The paste is applied by means of a camel hair brush by hand and after application is sintered under vacuum at a temperature of 1000°C. if applied to Nickel-iron or 800°C. if applied to silver.

APPENDIX II

The Rating and Application of Valves in the
Metal/Ceramic Range

The types on which data is available in the metal/ceramic range are the LD.6, LD.7, LD.8, LD.9, LD.11, LD.12 and LG.11.

The valves are intended for use under pulse or continuous operating conditions and, generally speaking, with grounded grid circuits. They have been used with concentric lines and with cavity resonators.

The LD.12 has been used successfully down to 20 cms. as an amplifier and a mixer in grounded grid circuits and it is claimed that, compared with a pentode, it has the advantage of a considerably better signal to noise ratio owing to the reduced shot effect. When the LD.12 is used as a driven R.F. amplifier its low cathode-anode capacity of less than 30×10^{-9} pF. makes neutralisation unnecessary.

The LD.14 was in the last stages of development but was not used in any equipment. Its construction was similar to that of the LD.6, LD.7, LD.9, and at 20 cms. it had been tested under pulse conditions with measured outputs of 100 kW.

When these valves are used without the anode cooling block they are given a new number formed by adding a "0" to the normal type number. Thus a range LD.60, LD.70, LD.80, LD.90, LD.110, LD.120 is formed.

In the following pages the data on these valves as given in published Telefunken data sheets are given but claims have been made which suggest that they can be operated at wavelengths considerably less than those quoted. Thus it is claimed that the LD.7 has been operated under pulse conditions at 9 cms. with $V_a = 9$ kV., $I_a = 10A.$, $W_a = 300w.$ giving power outputs of 10-15 kW., that the LD.9 has been used with continuous operation to give an output of 20 watts at 9 cms. with $V_a = 1.5$ kV. and $I_a = 200$ mA. and that the LD.11 or LD.12 can operate down to 8 cms. with an output at 9 cms. of 10 watts obtained with $V_a = 100$ V. and $I_a = 80mA.$

/ Valves

Valves were planned with built-in resonators and limited frequency range and Telefunken believe such valves could be made to operate down to 5 cms.

I. D. 6

Decimetre triode oscillator (for anode modulation)

Tentative Data.

<u>Heater voltage</u>	12.6 $\pm 3\%$
<u>Heater current</u>	approx. 1.9A.

For pulse use it is important to observe the $\pm 3\%$ tolerance but for continuous operation the heater voltage may drop to 12.6 v. - 10% provided the consequent power loss is tolerated. Even on continuous operation the tolerance of 3% on overrunning should not be exceeded if heater-cathode short circuits are to be avoided.

<u>Heating-up time</u>	approx. 2 mins.
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Capacities.

Measured hot and including stray capacities of connecting leads

(a) Grid-cathode	approx. 13 pF.
(b) Grid-anode	approx. 5.7 pF.
(c) Cathode-anode	approx. 0.2 pF.

Maximum operating conditions.

Anode voltage (continuous operation)	3000 v.
Anode voltage (pulse use)	9000 v.
Cathode current	
(a) Continuous operation, $V_f = 12.6$ v.	0.4 A.
(b) Continuous operation, $V_f = 12.6$ v. - 10%	0.3 A.
(c) Pulse operation. Pulse length ≤ 10 μ secs.	12 A.
Anode dissipation	300 W.
Grid dissipation	6 W.
Common cooling of anode and grid with 150 litres/min. air flow	
Instantaneous grid voltage	+300 v. -500 v.

Characteristics At $V_a = 1000$, $I_a = 150$ mA.

Mutual conductance

Durchgriff

Amplification Factor

Grid voltage

20mA/v.

1.3%

77

-5 v.

At $V_a = 1000$, $I_a = 2$ mA.

Grid voltage

▷ -22 v.

Conditions for use as oscillator

Pulse operation, anode modulated.

Pulse length ▷ 10 μ secs. Duty ratio 1 : 300.

Wavelength (cms.)	Output (kW.)	V_a (kV.)	I_a (A)	Eff. (%)
20	25	9	7.5	40
30	30	9	7.5	46

With suitable precautions against sparkover, e.g. a protective gas atmosphere or similar device, the rating can be increased and at 20 cms. with $V_a = 11$ kV., $I_a = 8$ mA., an output of 40 kW. obtained. Grid bias is obtained with a cathode resistor and is about 100 v.

Continuous operation

Wavelength (cms.)	Output (watts)	V_a (v.)	I_a (mA.)	W_a (w.)	Eff. (%)
25	72	800	350	210	25
30	120	1050	350	240	33
35	170	1200	350	250	40
50	300	1700	350	300	50

Grid bias is obtained by cathode resistor and is 15-25 volts. The grid current is about 50 mA.

L D . 7

Decimetre Triode Oscillator

Preliminary Data.

The valve is intended for use as an oscillator or a driven stage in grounded grid circuits. For C.W. use it operates down to a wavelength of 20 cms. and as an anode modulated pulse oscillator it will operate down to 11 cms. For C.W. oscillation below 25 cms. the LD.9 is superior.

Heater voltage 12.6 v.

Heater current approx. 2.1A.

Capacities

Measured hot and including stray capacities of connecting leads.

(a) Grid-anode	5.6 pF.
(b) Grid-cathode	11.3pF.
(c) Cathode-anode	0.075pF.

Characteristics

Durchgriff $V_a = 1300/1500$ v. $I_a = 150$ mA.	1.7%
Amplification Factor	59
Mutual conductance $V_a = 1300$ v. $I_a = 150/170$ mA.	18-28mA/v.

Maximum operating conditions

Anode voltage for continuous operation	
Class B use	2500 v.
Anode voltage for anode modulation	1500 v.
Anode voltage for pulse use (Pulse ≥ 10 usecs.)	9000 v.
Peak voltage for anode modulation	18,000 v.
Grid voltage for continuous operation	+ 60 v.
	- 300 v.
Peak grid voltage with anode pulsing	+ 500 v.
	- 800 v.

Cathode and anode currents

	Cathode Curr.	Anode Curr.
Continuous operation - Class B	400 mA.	300 mA.
For anode modulation	330 mA.	250 mA.
Frequency doubling (60° conduction angle)	330 mA.	250 mA.
Anode pulsing (mean during pulse)	10 A.	7.5 A.
(Pulse length ≥ 10 usecs. Duty ratio 1 : 700)		
Effective mean current	600 mA.	(300mA/cm ²)

Anode dissipation and cooling

The permissible anode dissipation depends upon the cooling. The following table gives typical values.

Dissipation	100	200	300 watts
Air flow (Entry temp. 50°C.)	50	240	600 litres/min.
Air flow (Entry temp. 20°C.)	40	160	425 litres/min.
Anode block temp.	215	192	166 °C.

An air flow of 200 litres/min. requires a pressure corresponding to 5 mm. of water and 500 litres/min. a pressure of 30 mm. of water.

Grid dissipation and cooling

Max. dissipation

3 watts

When operating under conditions of maximum grid dissipation the thermal grid current may be as much as 5 mA.

The temperature of the outer valve body opposite the grid must not exceed 100°C. and radial air cooling can be used at a flow of 60 litres/min. with an air entry temperature of 20°C. or 140 litres/min. with an air entry temperature of 50°C.

/ Operating

Operating Conditions as Oscillator - Class B

For 300 w. anode dissipation, $I_a = 300$ mA., grid bias obtained from cathode resistance and I_g dependent upon the external resistance but lying between 40-80mA.

Wavelength (cms.)	Output (watts)	V_a (v)	Effcy. (%)
90	300	2000	50
60	255	1800	46
40	165	1550	35
30	105	1300	26
20	35	1100	10.5

Operating Conditions for Pulse Use - Anode Modulated

Anode voltage 9 kV.
 Pulse length ≈ 10 usecs., duty ratio 1 : 700.
 Grid bias obtained from cathode resistance giving
 $V_g = -130$ to -180 v.

Wavelength (cms.)	Output (kw.)	I_a (A)	I_g (A)	Effcy. (%)
50	32	7.5	2.5	48
40	32	7.5	2.0	47
30	29	7.5	1.5	43
20	24	7.5	1.0	35
12	12	7.5	0.5	20

L D. 8

Decimetre Triode Oscillator

Tentative Data

Heater voltage 12.6 v.

Heater current approx. 1.2 A.

The heater voltage should not be permitted to fall below 12.6 v. -10% nor rise above 12.6 v. +5%. If the latter figure is exceeded there is danger of heater-cathode short circuit.

Heating-up time approx. 50secs.

Capacities

Measured hot and including stray capacity of connecting leads.

- (a) Grid-cathode approx. 10pF.
- (b) Grid-anode approx. 5 pF.
- (c) Cathode-anode approx. 0.09pF.

Maximum operating conditions

- Anode voltage (continuous operation) 3000 v.
- Anode voltage (pulse use at ground level) 9000 v.
- Cathode current (continuous operation)
 - Class B use with normal heating 0.25 A.
 - with $V_f = 12.6 - 10\%$ 0.18 A.
- Cathode current (pulse use) Pulse \triangleright 10usecs. 5 A.
- Anode dissipation 200 W.
- Grid dissipation 4 W.
- Common cooling anode and grid with 75 litres/min. air flow.
- Instantaneous grid voltage +200 v.
- 500 v.

Characteristics At $V_a = 1300$ v., $I_a = 120$ mA.

- Mutual conductance 20mA/V.
- Durchgriff 0.9%
- Amplification factor 111
- Grid voltage -4 v.
- At $V_a = 1000$ v., $I_a = 2$ mA.
- Grid voltage \triangleright -15 v.

Conditions for use as oscillator

Continuous operation

Wavelength (cms.)	Output (watts)	V _a (v.)	I _a (mA.)	Eff. (%)
16	50	1300	200	19
20	90	1500	200	30
30	140	1800	200	39
50	200	2300	170	51

Grid bias is obtained by cathode resistor and is 15-30 volts. The grid current is about 30 mA.

L D . 9

Decimetre triode for driven stage of frequency doubler

Tentative Data.

<u>Heater voltage</u>	12.6 v.
<u>Heater current</u>	approx. 1.2A.

For pulse use it is important to see that V_f is maintained within limits of 12.6 v. $+3\%$, but for continuous operation V_f may drop to 12.6 v. -10% provided the consequent power loss is tolerated. Even on continuous operation, the tolerance of 12.6 v. $+3\%$ should not be exceeded if heater-cathode short circuits are to be avoided.

<u>Heating-up time</u>	approx. 50secs.
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Capacities

Measured hot and including stray capacities of connecting leads.

(a) Grid-cathode	approx. 10 pF.
(b) Grid-anode	approx. 5 pF.
(c) Cathode-anode	approx. 0.025pF.

Maximum operating conditions

Anode voltage (continuous operation)		3000 v.
Anode voltage (pulse use)		9000 v.
Cathode current (continuous operation)		
	Class B	Doubler
Normal heating	0.25 A.	0.22 A.
$V_f = 12.6$ v. -10%	0.18A	0.16A.
Cathode current (pulse use)	Pulse $\dagger 10$ μ secs.	5A.
Anode dissipation		250 W.
Grid dissipation		4 W.
Common cooling of grid and anode with 120 litres/min. air flow.		
Instantaneous grid voltage		+300 v. -500 v.

Characteristics At $V_a = 1300$ v., $I_a = 120$ mA.

Mutual conductance

Durchgriff

Amplification factor

Grid voltage

20mA/v.

0.9%

111

- 4v.

At $V_a = 1000$, $I_a = 2$ mA.

Grid voltage

-15v.

Conditions for use as a frequency doubler (continuous operation)

Wavelength (cms.)	Output (w.)	I_a (mA.)	V_a (v.)	V_g (v.)	W_a (w.)	$\frac{\text{Power in}}{\text{Power out}}$
100/50	85	175	1500	65	180	1 : 5
70/35	75	175	1700	65	220	1 : 3.5
36/18	45	175	1500	57	220	1 : 2.5
28/14	25	175	1500	55	230	1 : 1

As a self-excited oscillator below 15 cms. wavelength anode modulation may be used. Reaction must be provided by external circuit coupling.

L D . 1 1

Decimetre triode oscillator

Tentative data

<u>Heater voltage</u>	12.6 v.
<u>Heater current</u>	approx. 0.8 A.

Overrunning up to $V_f = 14.5$ v. is permissible but the heater voltage should not drop below 12.6 v. -3%. Heater voltage variations are to be avoided if frequency stability is required.

Capacities

Measured hot and including stray capacities of connecting leads.

(a) Grid-cathode	approx. 11 pF.
(b) Grid-anode	approx. 4 pF.
(c) Cathode-anode	approx. 0.15 pF.

Maximum operating conditions

Anode voltage (continuous operation)		800 v.
Anode voltage (continuous operation) valve cold		1000 v.
Anode voltage (pulse use). Pulse ≈ 3 μ secs.		2000 v.
Cathode current (continuous operation)		100 mA.
Cathode current (pulse use) Pulse ≈ 3 μ secs.		1.5 A.
Instantaneous grid voltage		+50 v. -150 v.
Anode dissipation	60 25	10 watts
Grid dissipation	2 1	0.5 watts
Cooling air	100 50	0 litres/min.
Grid circuit resistance	10,000	ohms

Characteristics At $V_a = 400$ v., $I_a = 15$ mA.

Mutual conductance	9 mA/v.
Durchgriff	1%
Amplification Factor	100
Grid voltage	- 2.5 v.

At $V_a = 800$ v., $I_a = 2$ mA.

Grid voltage	\approx -16 v.
--------------	------------------

/ Grid

Grid leakage is 2 mA. maximum under the maximum conditions of dissipation for any given degree of cooling.

Conditions for use as oscillator

For $V_a = 500$ v., $I_k = 100$ mA. and $V_f = 12.6-14.5$ v.

Wavelength (cms.)	Output (w.)	Efficiency (%)
15	1 - 2	4
25	8	20
30	12	30
40	16	40

Under these conditions $I_a = 70-75$ mA., $I_g = 25-30$ mA.
and the optimum value of $V_g = 0$.

L D . 1 2

Decimetre triode for driven stage or frequency doubler

Tentative Data

<u>Heater voltage</u>		12.6 v.
<u>Heater current</u>	approx.	0.8 A.

Overheating of the heater up to 14.5 v. should always be used for pulse operation but under-running below $V_f = 12.6$ v. -3% gives instability and loss of power.

Capacities

Measured hot and including stray capacities of connecting leads.

(a) Grid-cathode	approx.	10 pF.
(b) Grid-anode	approx.	4 pF.
(c) Cathode-anode	approx.	0.03pF.

For operation in the decimetre waveband the valve should always be used with the grid grounded. The output circuit between anode and grid when looking into the valve is equivalent to a capacity of 3.3 pF. in series with an inductance of 3×10^{-9} H.

Maximum operating conditions

Cathode current (continuous operation)		100mA.		
Cathode current (pulse operation) Pulse $\times 3$ μ secs.		1.5A.		
Anode voltage		800 v.		
Anode supply voltage		1000v.		
Anode voltage (pulse operation) Pulse $\times 3$ μ secs.		2000v.		
Instantaneous grid voltage		+ 50v. -150v.		
Grid circuit resistance		10,000 ohms.		
Anode dissipation	60	25	10	watts
Grid dissipation	2	1	0.5	watts
Cooling air	100	50	0	litres/min.

To work under the conditions quoted above it is necessary to see that connections to the electrodes are cooled as well as the electrodes. The temperature of the anode cooling block should not exceed 150°C.

Characteristics At $V_A = 400$ v., $I_A = 15$ mA.

Mutual conductance	9mA/v.
Durchgriff	1%
Amplification Factor	100
Grid voltage	-2.5 v.

At $V_A = 800$ v., $I_A = 2$ mA.

Grid voltage	-16 v.
Grid leakage is 2 mA. maximum under the maximum conditions of dissipation for any given degree of cooling.	

Conditions for use as frequency doubler

	100 cm./50 cm.	50cm/25cm.
Anode voltage (volts)	500	500
Grid voltage (approx.)	-100	-70
Cathode current (mA.)	100	100
Anode current (mA.)	70	70
Grid current (mA.)	30	30
Output power (watts)	18	6-9
Driving power (watts)	12	10
Anode efficiency (%)	50	20

For a wavelength of 20 cms. and with the use of good resonance circuits, e.g. line or cavity, the output resistance of the valve is about 13,000 ohms.

L G . 1 1

Receiving Diode for Decimetre Use

<u>Heater voltage</u>	12.6 - 14.5 v.
<u>Heater current</u>	approx. 1A.
<u>Capacities</u>	
(a) Cathode-anode	approx. 3.4 pF.

Maximum operating conditions

• Voltage in anode circuit	+200 v.
Momentary value of H.F. voltage between anode and cathode	-200 v. + 20 v.
Pulse voltage between anode and cathode in non conducting direction (Pulse \uparrow 3 μ secs.)	1000 v.
Effective anode current	80 mA.
Peak anode current during pulse (Pulse \uparrow 3 μ secs.)	1 A.
Heater-cathode voltage	50 v.
External resistance between heater and cathode	10,000ohms.
Anode current with $V_f = 12.6$ v., $V_a = 3.0$ v.	30-70 mA.
Anode voltage with $V_f = 12.6$ v., $I_a = 3 \times 10^{-7}$ A.	-1.5 - 0v.

The valve is normally used so that it forms the end of a concentric line. It is suitable for use as a mixer.

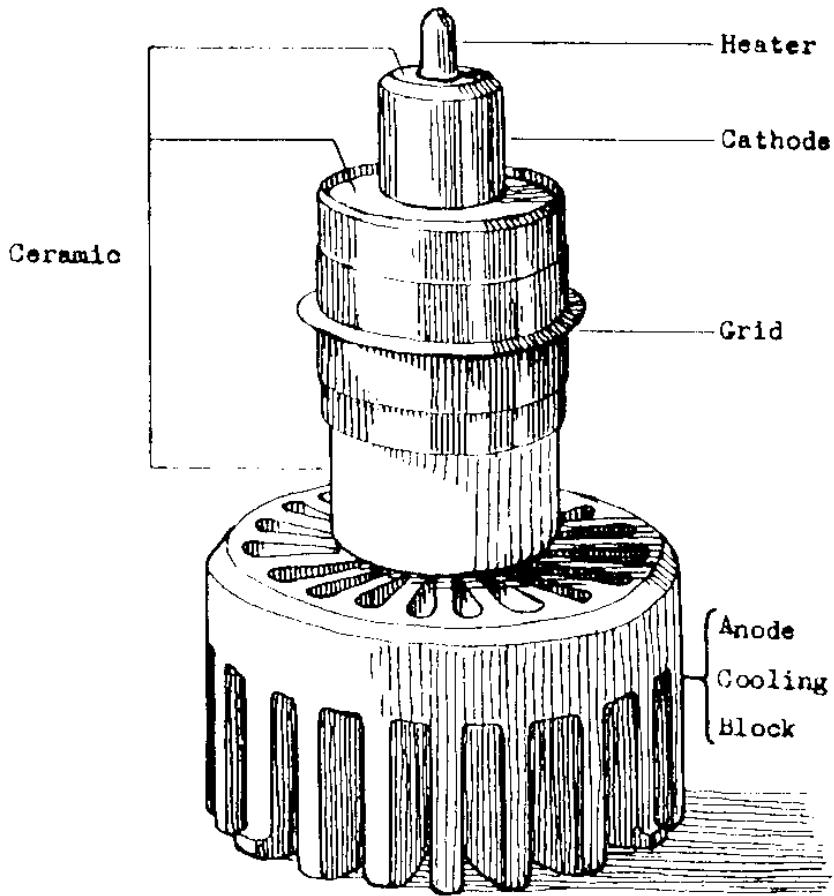
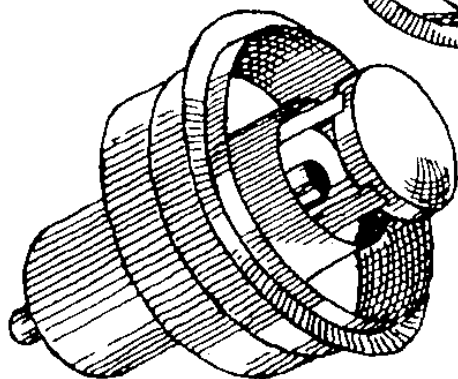
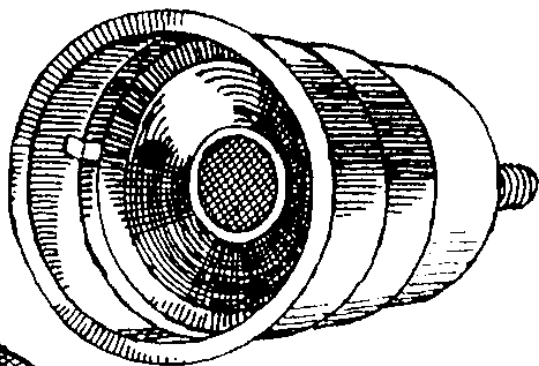


Fig.1. External view of typical metal/ceramic valve.

A. Grid and Anode
half of valve.



B. Heater and
Cathode half,
of valve.

C. (Below). Valve
construction in
diagrammatic form.

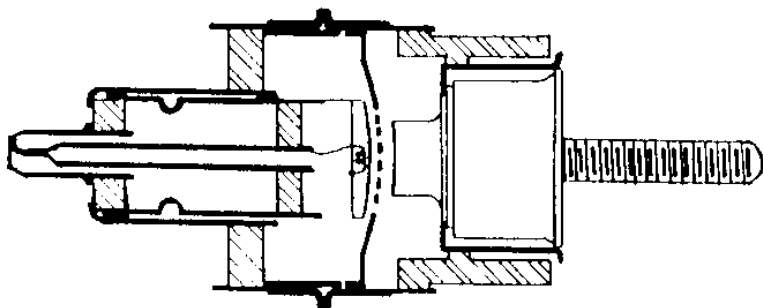
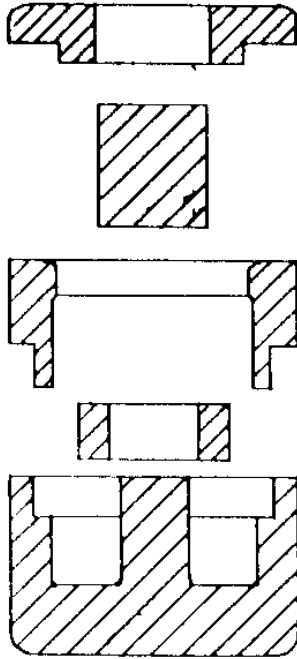


Fig.2. Main constructional details.



Above: Component parts of soldering pot.

Below: Assembly of pot and valve parts prior to soldering.

Silver Rings

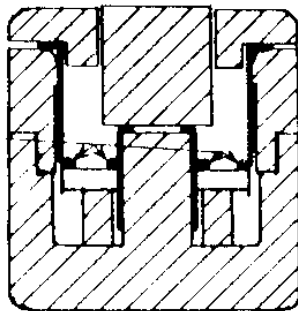
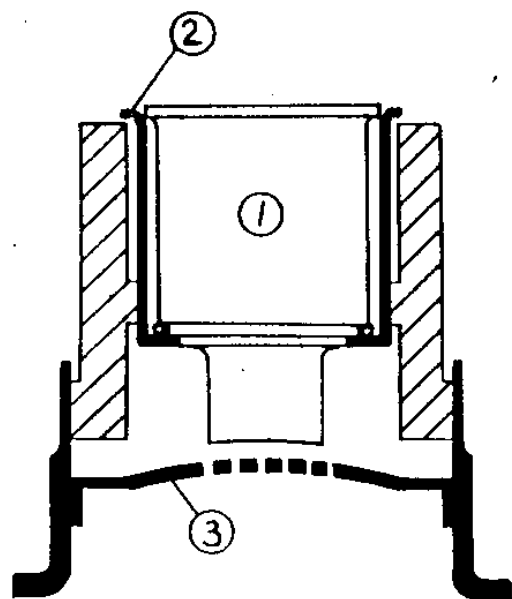
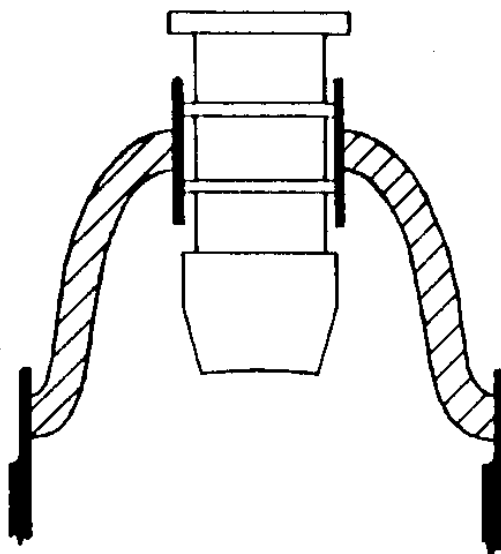


Fig. 3: Use of silver soldering pot for making metal/ceramic seals.



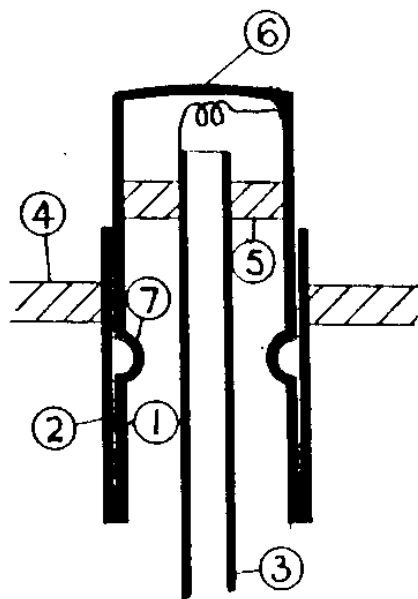
A.

Anode-grid sub assembly



B.

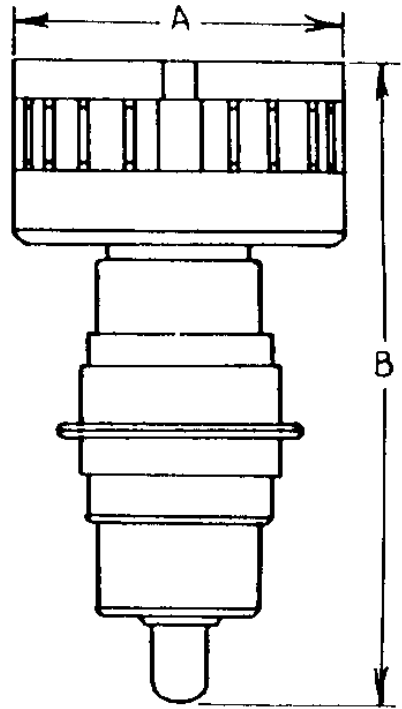
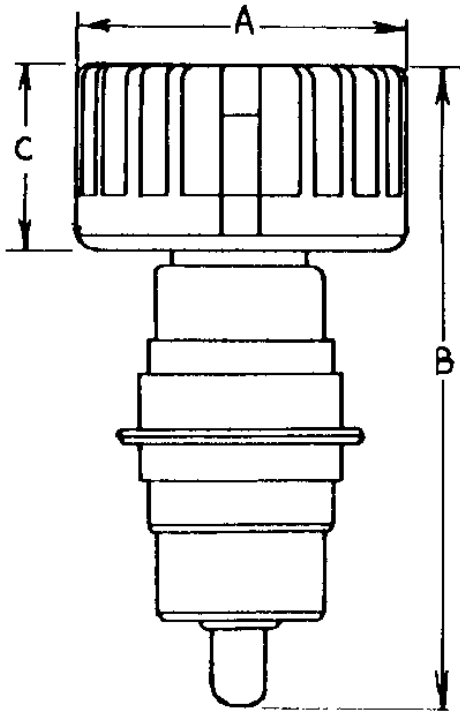
Another form of anode assembly



C.

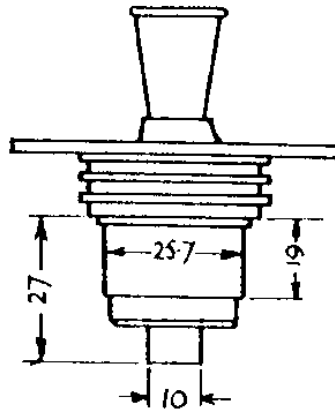
Heater-cathode sub assembly

Figure 4: Sub assembly details.



	LD7	LD9	
A	65	65	mm
B	107.5	110.5	"
C	35	35	"

	LD6	LD8	LD11	LD12	
A	65	65	45	45	mm
B	110.5	110.5	88.5	88.5	"



LD11 Dimensions in mm.

Fig. 5: Main Dimensions of Metal/Ceramic Valves.