The History of the Receiving Valve

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As early as 1884, research was being carried out in England, Germany and America on phenomena which, when eventually understood, proved to be the basic principle of the **Thermionic Valve.** Briefly these effects described:

(i) the conductivity of the air in the neigbourhood of a metal heated to incandescence,

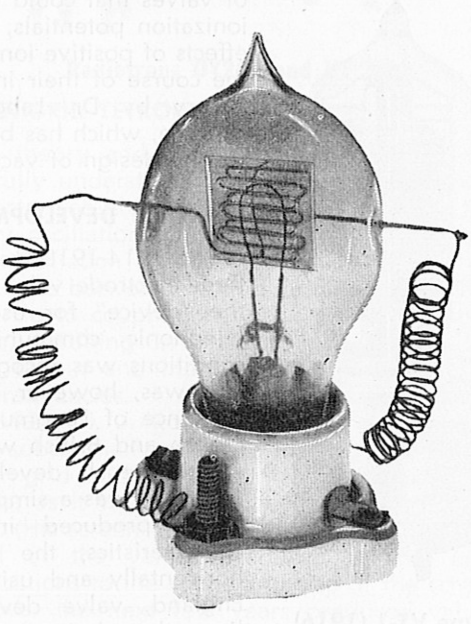
(ii) the negative charge acquired by a metal plate when placed in the vicinity of an incandescent filament,

(iii) the increased value of this negative charge when the metal plate and the incandescent filament were placed in an evacuated enclosure.

So far as is known, no practical application of these findings were suggested in that era. The first commercial application of any of these effects occurred on the 16th November, 1904, when Professor J. A. Fleming filed British Patent Specification No. 24850. It described a two electrode valve for the rectification of high frequency alternating currents.

As with many other important inventions, the **Fleming Diode** was the result of the application of a known phenomenon to a new field.

Fleming, as a scientist, had been greatly interested in an electronic voltage regulating device, shown to him by Edison when he visited America in 1884. Back in England, he carried out further research to prove to himself that the "Edison Effect" was unidirectional.



De Forrest Triode (1906)

When the rectification problems confronted him years later, he applied his findings to the solution of this problem, and so was born the thermionic valve.

THE DE FORREST TRIODE

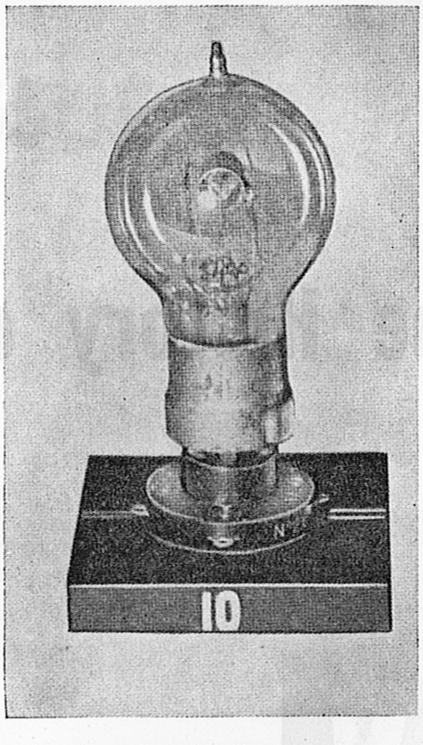
The triode was invented by Dr. De Forrest in 1906. He added a third electrode, a grid, between the cathode and the plate which controlled the current passing through the valve. In his patent application he described his invention as a "Device for amplifying feeble electric currents". Although De Forrest demonstrated the use of the "Audion" (the name he applied to his three electrode valves), as a detector and amplifier of radio signals, little interest was shown, mainly due to its limited application. The output of the early Audions did not exceed six milliwatts.

The Fleming Diode and the De Forrest Triode were both "soft" valves. As such they had to be operated with small plate voltages, to prevent excessive ionisation. This limitation stemmed from an understandable lack of knowledge of the techniques necessary to de-gas the elements of the valve and to obtain the required degree of vacuum.

EXHAUST TECHNIQUE

Improvements in exhaust techniques were retarded by a theory prevalent at that time. It was considered that the conduction of current through the valve depended upon gas ionization, and that a small gas content was therefore essential for successful valve operation.

A major contribution of the advancement of the radio valve following De Forrest's Audion



French R-Triode (1915)

was made by Dr. Irving Langmuir, W. C. White and Dr. Saul. This group recognised the need for "hard" valves and was responsible for establishing improved vacuum techniques. They discovered the advantages that could be gained by pre-baking tube parts in vacuum prior to assembly, and the useful effects that were obtained by electron bombardment of the electrodes.

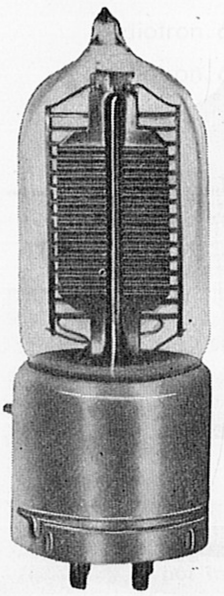
The result of their research was the introduction of valves that could be operated above gaseous ionization potentials, substantially free from the effects of positive ions. Experiments made during the course of their investigations led to the discovery by Dr. Langmuir of the 3/2 power formula, which has become the fundamental law for the design of vacuum valves.

WARTIME DEVELOPMENT

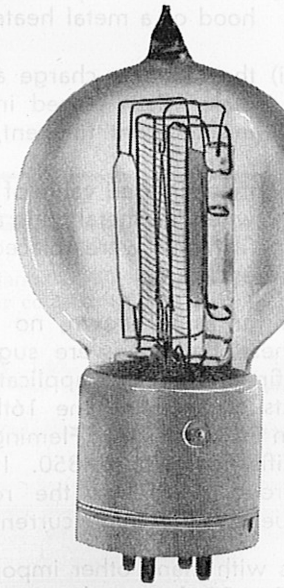
The 1914-1918 war period was one of intense three-electrode valve development. The value of the "device" for use in both telegraphic and telephonic communications under front line conditions was recognised.

It was, however, remarkable that the major influence of Langmuir's work was first seen in French and British war time developments.

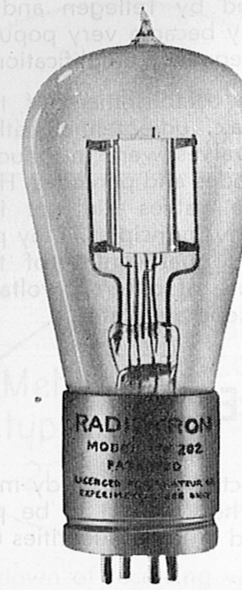
The French developed the famous type R-Triode. It was a simple rugged valve capable of being produced in quantity with uniform characteristics, the electrodes being mounted horizontally and using a tungsten filament. In England, valve development followed similar lines, there being in all cases an attempt to free the valve and the electrodes of all traces of gas.



Type VT-1 (1916)



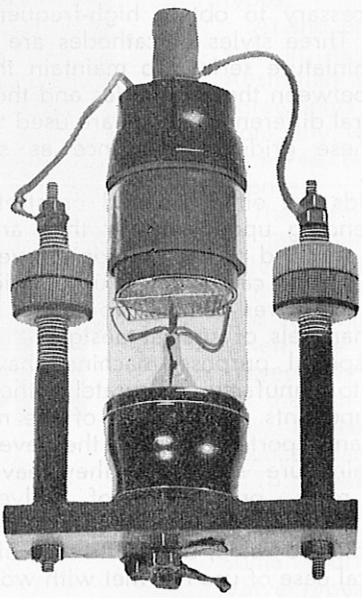
Type 102-D (1921)



Radiotron UV202 (1922)

With the entry of America into the war in 1917, urgent development of valves suitable for mass production was initiated in U.S.A. Western Electric had been making small quantities of valves for telephone service and was therefore, best equipped to meet this demand. They developed the **VT-1 Triode.** It was a hard valve and made history by being the first mass produced valve to use a platinum filament coated with barium oxide.

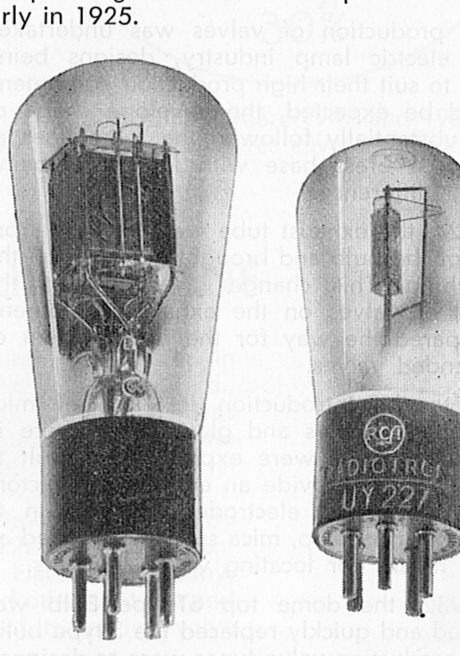
Although the barium oxide coated platinum filament gave higher emission levels, it was not generally accepted by the industry, the trend being toward the use of a thoriated tungsten wire. This type of filament, when properly activated and used in a gas-free valve, gave superior performance with half the filament power required for tungsten filament.



Tetrode DES625 (1926)

The UV-201A introduced in 1922, was the first valve to use such a filament. In 1926, a suitable oxide coated filament was perfected and gradually replaced the thoriated tungsten filament, as it in turn required less filament power. It is now almost exclusively used in receiving valves. (The thoriated tungsten filament is still used in many current power valves.)

The introduction of the indirectly heated oxide-coated cathode was the next major development. As early as 1921, H. M. Freeman, of the Westinghouse Company, suggested an a.c. unipotential cathode construction substantially like the indirectly-heated cathode now in use. Valves incorporating this cathode were put on the market early in 1925.



Radiotrons UY247 and UY 227

SCREEN-GRID TETRODE

The theory and operation of the triode was now fully understood. It was in general use as a detector, amplifier and generator of high frequency oscillations. However, the triode has a major limitation in its inherent high internal capacitance between the grid and the anode. This gives rise to coupling between grid and anode circuits, resulting in uncontrolled reaction between output and input circuits, particularly at high frequencies.

In 1926, H. J. Round, added a screen grid which substantially screened the anode from the control grid and so a four element tube, the Tetrode, as it was commonly known, was introduced. (His screen grid tetrode type DES625 was typical of the valves produced in this era.) Modifications to the shape and size of the screen grid over the next few years produced valves having anode to grid capacitance some thousand times lower than that of the triode.

The limitation of the tetrode was soon found to be secondary emission. The secondary electrons emitted from the anode by bombardment, instead of returning to the anode, were collected by the often more positive screen grid. This was undesirable as it disturbed the relationship between anode current and anode voltage.

The substantial suppression of secondary emission in tetrodes was not an easy matter. By far the most common method was to include a suppressor grid at filament potential between grid screen and anode, as was the case in the Pentode invented by Tellegen and Holst. The pentode naturally became very popular for both high and low frequency amplification.

Following the establishment of the pentode valve and the a.c. unipotential cathode, many multi-electrode valves were introduced, such as double-diode triodes and pentodes. However, the design of these valves did not involve any fundamentally new principles. They provided for the simultaneous dual control of the electron stream by the use of different voltages applied to two or three separate plates.

STRUCTURAL CHANGES

Initial production of valves was undertaken by the electric lamp industry, designs being adopted to suit their high production equipment. As could be expected, the envelope shape of valves substantially followed the same lines as the lamp, a brass base with long pins being the major difference.

In 1924, the exhaust tube was removed from the top of the bulb and brought out through the stem tubing. This change greatly eased the handling of valves on the exhaust equipment, and prepared the way for the development of double-ended valves.

Prior to the introduction in 1926 of mica spacers, lava spacers and glass beads were in general use. These were expensive, difficult to use and did not provide an entirely satisfactory method of locating electrodes. In addition to being light and cheap, mica spacers provided an accurate means for locating valve elements.

IN 1932, the dome top ST-type Bulb was introduced and quickly replaced the S-type bulb, all high production valve types were re-designed for adoption to this bulb. This step was a major development, as it provided not only an efficient means of supporting valve electrodes, but also permitted the use of a cheaper and less complex mount structure. Large quantities of valves using the ST-type bulb are still being produced (e.g. 6G8G, 6A8G).

The next major change was the introduction of the **Metal Valve Series.** These were initially produced in Europe and England, the metal envelope constituting the anode and therefore at high potential. A second shield surrounding the valve was necessary to safeguard against shocks and shorts. This type of valve was not popular, and was replaced in 1934 by a range of metal valves that used the envelope as a shield, the envelope being at earth potential. This series was to undergo many structural changes over the next few years, as improvements and simplification of mount design were effected.

The **GT Bulb** was the next development. The experience gained in the production of metal valves was reflected in the sturdy mount design of this series. They proved to be popular and are still produced in large quantities (e.g. 5Y3GT, 6AX4GT).

MINIATURIZATION

The introduction of the Miniature Series was perhaps the most important of all structural changes. These small, compact, single-ended valves, requiring no base or top cap, greatly simplified radio set layout and wiring, as input and output circuits are on opposite sides of the valve.

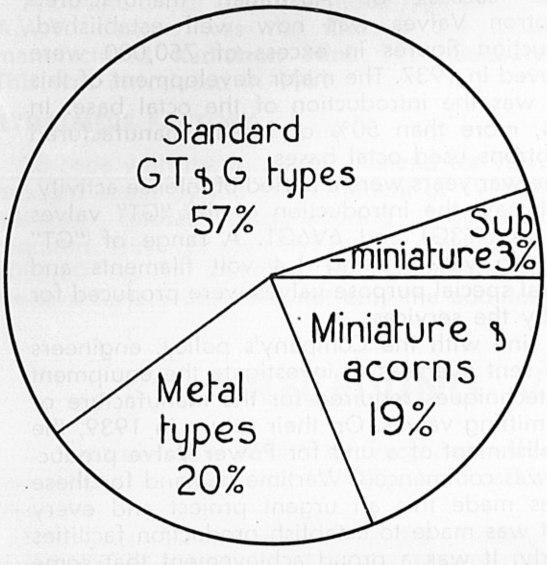
The individual component parts of miniature valves are small. When assembled they produce a light mount, which exerts relatively small forces on supporting members under conditions of mechanical shock. The short supporting leads and the support provided by the bulb contacting micas result in a very rigid unit.

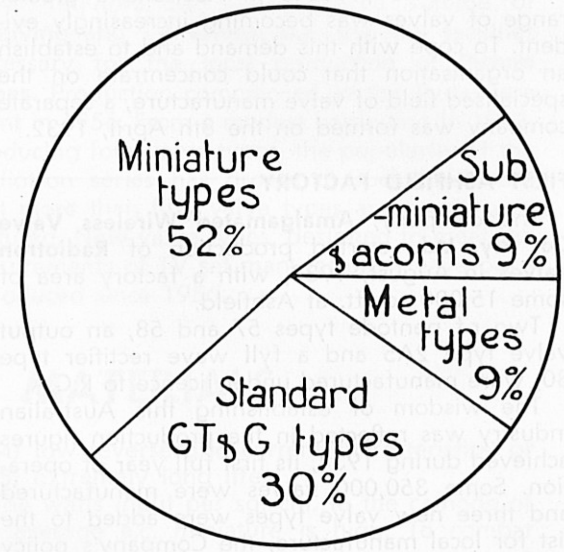
A most important structural feature in many a.c. miniatures is the spacing required to be maintained between cathode and control grid. Spacing as low as .002" is common, this being partly necessary to obtain high-frequency performance. Three styles of cathodes are used in the a.c. miniature series. To maintain the small spacings between these cathodes and the control grid, several different methods are used to manufacture these grids to tolerance as small as ± .0005".

The grids are either formed or stretched to size, depending upon whether they are to be used with a round or flat cathode sleeve. Where oval cross-section cathodes are used, grids using robust lateral wires can be wound to size employing mandrels of special design.

Many special purpose machines have been designed to manufacture accurately other critical valve components. The success of the machines has been an important factor in the development of the miniature series, as they have made possible mass production of valves with substantially uniform characteristics.

The miniature valve, due to its size, efficiency, and general ease of use has met with world-wide acceptance.





A breakdown of receiving valve types manufactured in U.S.A. for the years 1947 and 1955, shows the rapid increase in the popularity of the miniature series. The 1955 figures cover the production of some 480,000,000 valves.

THE AUSTRALIAN SCENE

Radiotron type 33 (1927)

Receiving valve manufacture was initiated in Australia by Amalgamated Wireless (A'sia.) Ltd., in 1920. Production of a "soft" Triode known as the **Expanse B** was started in a section of the Company's manufacturing unit, then situated at Knox Street, Sydney.

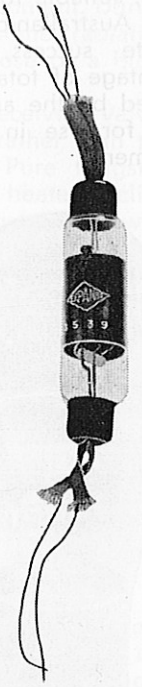
The Radio Corporation of America had already been formed in October 1919, acquiring patent rights from the General Electric Company, Westinghouse Electric Co., and others. At the end of 1920, it began production of its first two valve types.

At the end of 1924, while broadcasting was still in its infancy, there being only 38,000 Australian broadcast receiver licences in force, agreements were negotiated by our parent Company with R.C.A. to enable selected valve types to be manufactured in Australia under licence.

These agreements, still in existence, have been an important factor in keeping the Australian valve industry abreast of world progress.

By the end of 1927, broadcasting in Australia was making rapid progress. History was made when the A.W.A. short wave station, 2ME, successfully beamed the first Empire Broadcast on the 5th September, 1927. Broadcasting was now an established industry: the number of licences had increased to 258,000.

To meet the rapidly increasing demand, Amalgamated Wireless (A'sia.) Ltd., was then manufacturing four valve types and distributing some fourteen Marconi and eighteen R.C.A. Valve Types.



Expanse B (1920)

The need to produce in Australia a greater range of valves was becoming increasingly evident. To cope with this demand and to establish an organisation that could concentrate on the specialised field of valve manufacture, a separate company was formed on the 8th April, 1932.

FIRST ASHFIELD FACTORY

The company, **Amalgamated Wireless Valve Co. Pty. Ltd.**, started production of **Radiotron valves** in August, 1933, with a factory area of some 15,000 sq. ft. at Ashfield.

Two r-f pentode types 57 and 58, an output valve type 2A5 and a fyll wave rectifier type 80, were manufactured under licence to R.C.A.

The wisdom of establishing this Australian industry was reflected in the production figures achieved during 1934, its first full year of operation. Some 350,000 valves were manufactured and three new valve types were added to the list for local manufacture, the Company's policy being to supply the best possible range of valves for use under local conditions. The year 1935 was outstanding in its rapid expansion. Manufacture of multi-purpose valves such as the double-diode-triode, the double-diode-pentode and the pentagrid converter was undertaken. The establishment of a complete range of indirectly heated valves using 6.3V. heaters climaxed a year of great achievement.

During 1935, it was made possible to introduce a range of low-drain, high-performance valves, suitable for use in battery operated sets. These Australian-designed valves were an immediate success, and represented a high percentage of total production. They were later adopted by the armed services during the war years for use in a variety of communication equipment.

The success of Australian manufactured Radiotron Valves was now well established. Production figures in excess of 750,000 were achieved in 1937. The major development of this year was the introduction of the octal base. In 1938, more than 50% of locally manufactured Radiotrons used octal bases.

The war years were a period of intense activity, which saw the introduction of the "GT" valves such as 5Y3GT and 6V6GT. A range of "GT" receiving valves using 1.4 volt filaments and several special purpose valves were produced for use by the services.

In line with the Company's policy, engineers were sent overseas to investigate the equipment and techniques required for the manufacture of transmitting valves. On their return in 1939, the establishment of a unit for **Power Valve** production was commenced. Wartime demand for these valves made this an urgent project and every effort was made to establish production facilities quickly. It was a proud achievement that some 35,000 power valves were produced during 1941, comprising seventeen valve types.

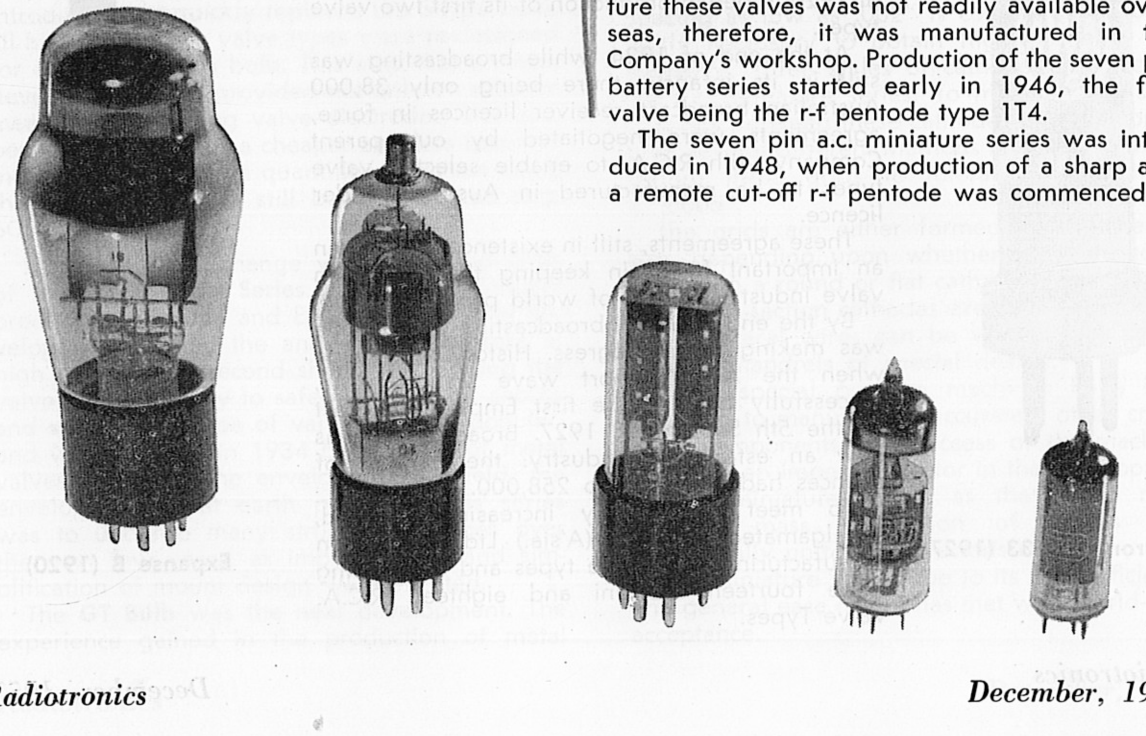
SECOND ASHFIELD FACTORY

To provide more production space to meet the ever increasing demand for Radiotron Valves, a three storey building of some 60,000 sq. ft. was erected at Ashfield. Production in this factory started in March, 1942.

The introduction of **Seven Pin Miniature Valves** was the next major local development. Overseas the miniature valve and the specialised equipment required for their manufacture were being developed. They were mass produced during the war years and, in general, proved themselves in a wide field of applications.

The complex equipment required to manufacture these valves was not readily available overseas, therefore, it was manufactured in the Company's workshop. Production of the seven pin battery series started early in 1946, the first valve being the r-f pentode type 1T4.

The seven pin a.c. miniature series was introduced in 1948, when production of a sharp and a remote cut-off r-f pentode was commenced.



A double diode output pentode type 6BV7, of A.W.V. design, was the first of the locally manufactured **Radiotron Nine Pin Miniatures**. This was introduced in 1951.

RYDALMERE FACTORY

To cope with the increased demand for valves brought about by the establishment of TV transmission, further manufacturing space was required. This was obtained by the erection of a 100,000 sq. ft. building at Rydalmere. This modern factory provided not only the additional space required for the increased volume of receiving and TV valves, but also the facilities necessary for the local production of **Picture Tubes.** Production commenced at the Rydalmere plant in 1956. From a modest beginning in 1933, producing four valve types, the popularity of the Radiotron series has grown to such an extent that more than fifty valve types are now manufactured. New valve types, designed to meet the requirements of TV set manufacturers have been introduced since 1956.

RECEIVING VALVE MATERIALS

In the early days of the art, receiving valves had only one application, namely, in broadcast receivers.

Following the introduction of the Miniature series, and as a result of an ever widening field of electronic applications, the demands on the receiving valves were greatly increased. They were used in Computers, in communication equipment, and often in equipment in which they were subjected to abnormal mechanical shocks and vibration. For this reason, since 1945, the valve manufacturers of all countries have been engaged on research to make their product as reliable as possible for general use.

The greatest advances in this field have been in the new materials tested and proven suitable for better valve quality, constant research providing many new materials.

Molybdenum and tungsten are now commonly used for grid lateral wires, where high cathode temperatures would cause the softer manganese nickel wire to distort. To prevent reverse grid current, grid wires are often coated with gold or silver.

Nickel plated iron has generally replaced nickel as grid support rod wire because of its marked rigidity at high temperatures. Where rapid conduction of heat from a grid is required, a copper alloy containing a small percentage of Chromium is used. The added chromium makes the side-rod rigid and capable of withstanding reasonable shock treatment. The advances in cathode base metal materials have been marked, and a wide range of nickel-alloys are available. The normal cathode sleeve metal is 98.00% nickel, 1.00% cobalt, the remaining 1.00% being made up of seven to nine other elements, the percentage of each element remaining in the final melt being accurately controlled. Selected alloys are used to produce valves having predetermined characteristics that can have either:

(1) high efficiency at low temperature,

(2) low leakage characteristics over a range of temperature,

(3) low interface development,

(4) low reverse grid current characteristics, or

(5) extremely long life.

The watts input per sq. cm. to the cathode of the average a.c. miniature is high. To combat leakage paths formed by metal evaporation at high temperatures during life, several types of efficient mica sprays have been developed. Where voltage breakdown between electrodes is a problem, aluminium oxide is used as a mica spray.

To dissipate heat, several excellent rigid electrode materials having high radiation properties are available. In addition to several varities of carbonised material, one worthy of mention is a multi-layer material, aluminium-clad iron. This bright material is becoming increasingly popular as it has a low initial gas content. During r-f treatment, it turns black and assumes radiation properties closely approaching those of a black body.

The heaters of most Radiotron receiving valves are now made of pure tungsten rather than the tungsten alloy previously used. Pure tungsten is capable of standing repetitive heater cycling over a long period. When this tungsten base-wire is coated with a high grade alundum, closely controlled for grain size and impurities, the use of higher heater cathode voltages becomes possible.

The materials mentioned represent only a few of the advances made in this field. New materials and techniques are under constant surveillance by the A.W.V. engineering group. Each is completely investigated and incorporated into the production of Radiotron Valves where any improvement in performance as general purpose valves can be obtained.

CONCLUSION

The thermionic valve was created to solve a problem in communication. In its infancy it became the primary tool of radio. It is now produced in the hundreds of millions per year. Due to its astonishing and versatile properties, the valve has been adopted in almost all fields of human endeavour, fields remote from those that gave it birth.