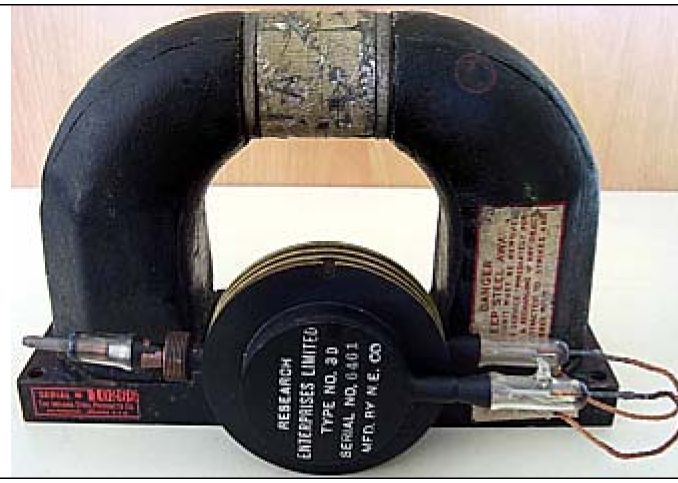
Magnetron Tubes



- Click on images to enlarge.

Tyne gives examples of early experiments on tubes where magnetic fields generated by solenoids control the flow of electrons. De Forest and Von Lieben patented some kinds of such electron devices and Moorhead sold the A-P solenoid tube for a while.

- Cyclotron type magnetrons

In 1921 A. W. Hull described for the first time static characteristics of a device called magnetron (1). Actually the tube was a diode, with a filament in a coaxial cylindrical plate. The plate cylinder was surrounded by a winding, used to generate a magnetic field. The radial electric field and the superimposed magnetic field forced electrons to follow circular orbits before reaching anode. When the magnetic field was increased, radius of the orbits became smaller and smaller until electrons could no longer reach the plate, so causing the cut-off of the anode current. Hull also noted that the tube could sustain self-oscillations in a resonant circuit, when biased near to the border between conduction and cut-off,.

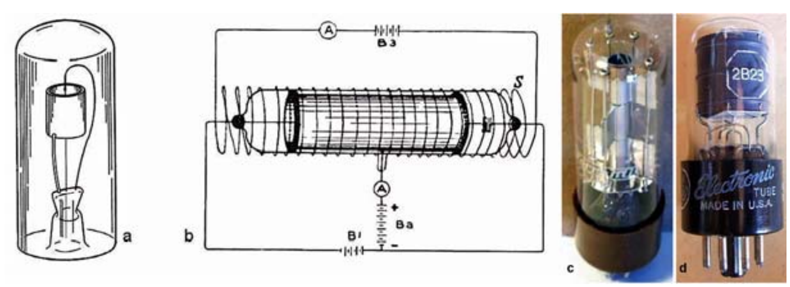


Fig. 1 – a) Draft of the Hull original diode. b) Diagram of the experimental circuit. c) Ferranti GRD7 was a didactic tube used to demonstrate the operation of Hull diode. d) 2B23 is a magnetically actuated switch. Click to enlarge.

The cylindrical anode magnetron oscillates in the so-called cyclotron mode, as the result of a sinusoidal voltage built up between cathode and anode. It was found that oscillation occurred following the relation λB = constant, where B was the intensity of the magnetic field. It was also noted that the period of oscillations was equal to electron transit time from cathode to anode and back. Since 1924 E. Habann proposed a split anode magnetron design, in order to have more stable oscillations at higher frequencies. In 1936, Cleeton and Williams reached frequency as high as 47 GHz with such a structure.

- Negative resistance types

The split anode magnetron may also operate in a different mode, not depending upon the transit time, as far as it is small when compared with the period of oscillation. Under the effect of a strong magnetic field, electrons follow spiral trajectories, describing several complete loops and being preferably attracted by the segment having the lower potential. In 1936 G. R. Kilgore succeeded in observing trajectories, made luminous by the introduction in the bulb of some gas to permit ionization. Kilgore obtained efficiency as high as 25% at 600 MHz with 100W input power. General Electric built some split anode fluid-cooled magnetrons, capable of delivering about 150W at frequencies between 15 and 1200 MHz. The four registered types used in radar jammers, 5J29, 5J30, 5J32, 5J33 and ZP-599 were introduced during WWII. They are described in 'Very High-Frequency Techniques', Vol. II, Radio Research Laboratory, Harvard University.

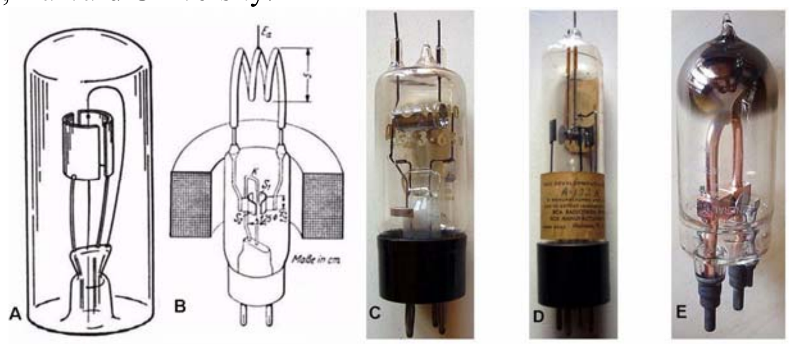


Fig. 2 – A) Early split anode magnetron. B) Complete oscillator, also showing the magnetic field generating coil, surrounding the glass bulb. C) CW10 is a split anode magnetron used in the mid thirties for UHF experiments of radio-localization. D) To operate at higher frequencies, resonating circuit was moved into the glass bulb in this RCA A-103A, operating at 3 GHz. E) 5J29 was a split anode magnetron manufactured by General Electric capable of generating 150W at 400 to 700 MHz. The tube was fluid-cooled through the hollow anode legs. (Click to enlarge.)

The structure shown in figure 2B may also contain more than two anode plates, as in figure 3A.

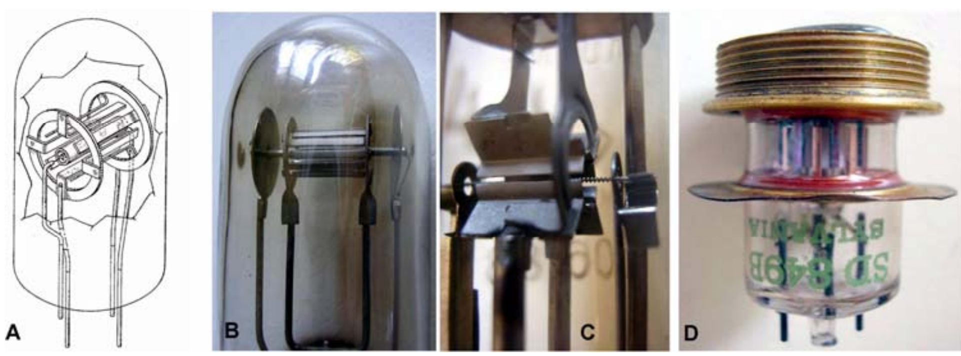


Fig. 3 - A) The draft of an eight-anode interdigital magnetron. Plate tabs all around the cathode sleeve are alternately welded to the two side rings. In the above samples two rods connect the two opposite anode rings to the external resonating circuit. B) A 12-segment British GEC experimental magnetron. GEC made several similar devices, as this 8-segment prototype and CV79. D) The German RD4Ma uses filamentary tungsten cathode. E) In the 3J22 anodes are connected to ring seals to operate within an external cavity. Click on the image to enlarge.

Interdigital or squirrel-cage magnetrons are split-anode types with as many rotating spokes as the fingers connected to one of the two side rings. The higher the number of finger pairs, the smoother their operation at low magnetic field. As we will see later in the section dedicated to voltage tunable magnetrons, interdigital structures can also operate without resonating circuit, their output frequency depending only upon the applied anode voltage.

- The ‘Turbator’: a split anode design with integral resonator

In the forties Brown Boveri was a supplier of high-frequency communication systems based upon available German triodes. The need of operating at higher frequencies, in order to transmit several channels on the same carrier, forced them to move to a split-anode magnetron with integral resonator, in order to obtain the required high spectral purity. A similar solution can be found in the coaxial magnetron, where a vane structure is surrounded by the resonating cavity. Here images of the BBC MD 10/2000 **‘Turbator’** and of a coaxial type, the Litton L-5035.

- Microwave multi-cavity magnetrons (Traveling-wave type)

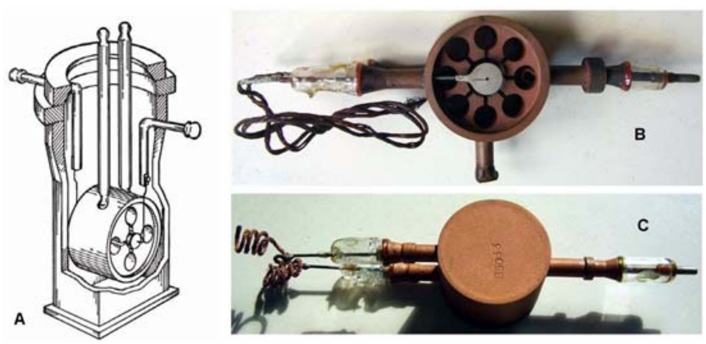


Fig. 4 – A) Laboratory multi-cavity magnetron by Alekseroff and Malearoff. B) The first 8-cavity E.1189 prototype made at GEC. B) Sample of early strapped magnetron by the Sayers group at Birmingham. Click to enlarge.

In 1934 Samuel at Bell Telephone had proposed multi-cavity structures, forerunners of the high power devices in use since WWII. The multi-cavity magnetron was subsequently investigated in Russia by Alekseroff and Malearoff. Between 1934 and 1935 K. Posthumus at Philips developed a four segment magnetron. Posthumus also left a theoretical treatment of the rotating electron clouds, which gave the relations between the tube geometry, as the number of anode segments, and the intensity of electrical and magnetic fields. In 1937 Herriger and Hülster recognized the phase-focusing by which electrons were synchronized. Nevertheless, until WWII magnetron was just a physic laboratory oddness. Around the late ‘930s, when the war was rapidly approaching, military pushed the search for high power sources at considerably high frequencies to make possible the airborne installation of radar sets. Power obtainable at the time with triodes dropped sharply above a few hundreds megahertz. Much higher frequencies were required both for easier installation of antennas in airplanes and for higher resolution, to detect small targets. Multi-cavity magnetron structures were then investigated in Great Britain as RF power generators at microwave frequencies.

- The early high-power multi-cavity magnetron

Multi-cavity structures were not new when the first high-power microwave magnetron was assembled by J.T. Randall and H.A.H. Boot at Birmingham University. The relevant departure from the early experimental devices was the use of an external anode block which greatly simplified heat dissipation. The six hole-and-slot prototype, sealed by wax and water-cooled, operated while continuously pumped from 21 February 1940. RF bursts of about 500W were generated at about 3 GHz. GEC was asked to assemble industrialized prototypes, known as E-1188. Six units were built, all with filamentary tungsten cathode and water cooling. Six-cavity anode blocks were machined at Birmingham using a revolver chamber as drilling template. Soon later they were followed by a six-cavity E-1189 design, modified for air-cooled pulsed operation. An annular eight-fin radiator was brazed to the anode to improve cooling. The anode block length and the end spaces were reduced to fit the unit into a standard permanent magnet. The center hole diameter of anode was increased, hosting a thoriated-tungsten spiral wire. Taking advantage of the parallel experience of Gutton at SFR, Paris, a second sample with more efficient indirect-heated oxide-coated cathode was also successfully tried. The No. 2 sample operated very satisfactorily in pulsed operation, giving about 1 kW at 1000 gauss and 12 kW peak output pulses at about 1400 gauss. The design E-1189 was modified again with eight-cavity anode block, to operate efficiently at 1000 gauss in the pole pieces of a standard 6-lbs magnet. The 8-slot design had a larger center hole to accommodate a 10 mm diameter oxide-coated cathode cylinder. Four units were built, presumably from 18 July 1940. Two of them were used to run performance and life tests on the modified design, while the other two units were sealed and serialized as E.1189 No.12 and No 13. Test results are given in this report by Megaw, dated 11 October 1940. A sample believed to be the first one of the four eight-slot prototypes is on display in the collection. See E-1189 prototype for more information. The sample No. 12 was picked up by Bowen on 11 August 1940 and brought to U.S. and Canada by the Tizard Mission. This sample gave origin to the countless magnetron types designed in America and used in radar application through the war and after. The sample No. 13 was used by Megaw to fully characterize the new variant, as reported in his 1946 paper.

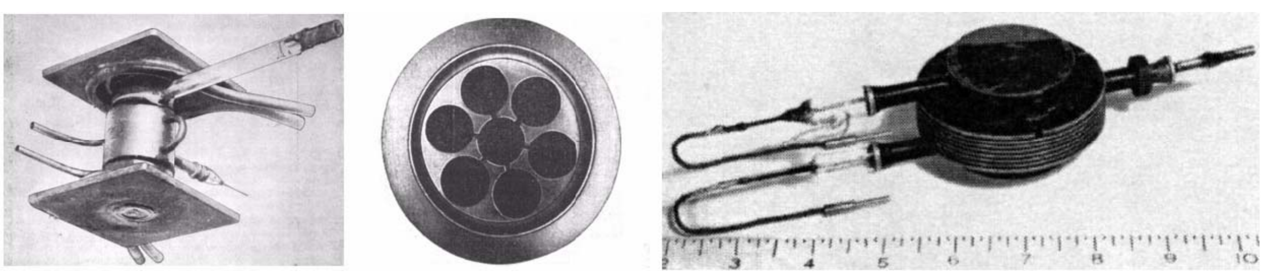


Fig. 5 – From left: the prototype of the multi-cavity magnetron by Randall and Boot, the six-cavity anode block of early prototypes, and the sample of E1189 S.N. 12, brought to America by the Tizard Mission and now on display at the National Museum of Science and Technology in Ottawa. Click to enlarge.

Once in America the sample No.12 was operated at the Bell laboratory in a 1050 gauss magnetic field, giving an astonishing output power estimated in 15 kW at 9.8 cm (*10). This figure was 750 to 1000 times higher than the power the best Western Electric high-frequency triodes could give at the time (*11). It was therefore decided to retain the eight-cavity anode design for future productions. Design details were transferred by the British to Western Electric, Raytheon and to MIT Radiation Laboratories which coordinated the microwave research in US. Both Western Electric and Raytheon received orders for small qualification lots of their copies. Western Electric built some 60 units of its copy with the developmental code D-160052, their delivery to MIT Radiation Lab. and presumably to other interested people beginning since December 1940. Sample S/N 56 still survived in the collection of the late Jerry Vanicek, TCA.

Fig. 6 - Western Electric built few copies of the British E1189. This sample, S/N 56, survived today in the collection of the late TCA member Jerry Vanicek.

According to Otto J. Scott (*11), even Raytheon was asked to submit its own qualification samples to British, but quantities are not known. Other industries, as GE, RCA and Westinghouse were involved. American magnetrons began to differentiate from the British types. In 1941 Western Electric designed its first magnetron, the L-band 6-cavity 700A, whose design departed considerably from the one of the British prototype. In order to facilitate volume productions, in close collaboration with MIT Radiation Labs, Raytheon introduced several improvements to the original design, eliminating the expensive gold solder of the copper covers. The machined copper anode block was replaced by a silver brazed stack of punched copper discs. Soon later the same firm introduced the strapping rings to simplify the wire strapping devised by Sayers at Birmingham, figure 4C. Thanks to these improvements, Raytheon alone was able to produce 2600 units per day. While British magnetrons retained the same basic shape of the early prototype through the war, American types significantly departed from original design, usually fitted with integral mounting flanges or brackets and a protective glass boot on the heater supporting stems. Also packaged magnetrons, with factory assembled magnets, were soon introduced to simplify their in field replacement. Another improvement was the introduction of tunable types to replace complete families of fixed-tuned ones, with considerable savings in the handling of spares.

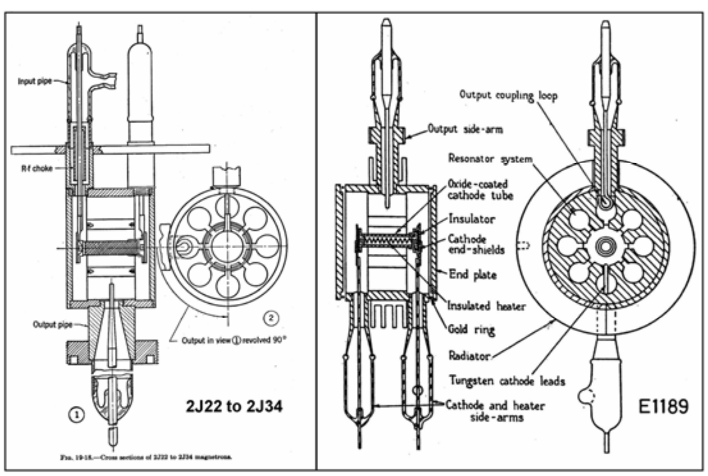


Fig. 7 - The internal structure of a typical Raytheon S-band magnetron, left, compared with the draft of the E1189 approved as NT98 or Admiralty Pattern W2510.

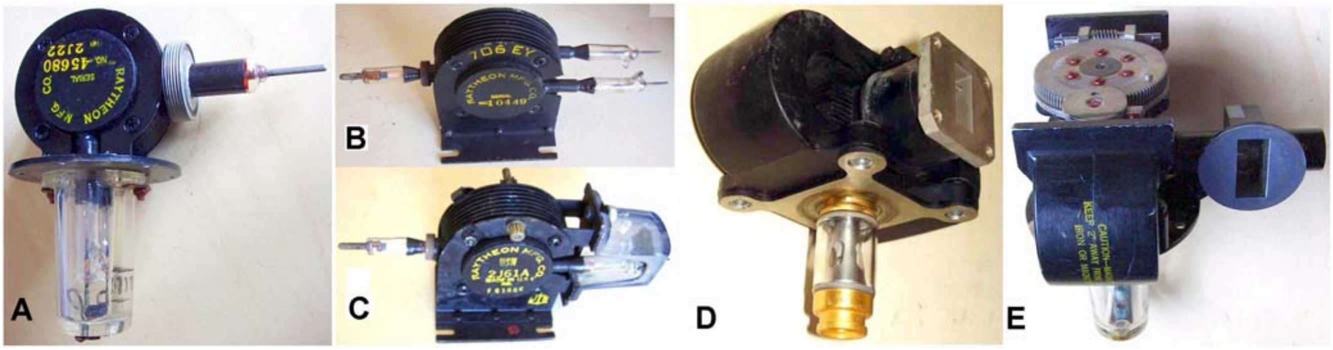


Fig. 8 - Typical shapes of American magnetrons introduced during WWII. In A we see the 2J22 a Raytheon fixed frequency S-band magnetron, with glass boot over the heater stems and round mounting flange just below. This shape was designed for airborne applications, cathode connections and associated high-voltage circuits being fitted inside an oil-filled hermetic enclosure. In B we see a 706, the first S-band magnetron introduced by Western Electric, still recalling British types even if with added mounting brackets. In C the Raytheon tunable S-band magnetron 2J61A which replaced the entire family of the above type, 706AY to DY. In this case heater pins are protected by a sturdy glass boot. In D we see a packaged X-band magnetron, the fixed-frequency type 4J52. The packaged magnetron in E, a sample of WE 2J51A, was also tunable over the entire X-band.

The E-1189 prototype brought in America by Tizard Mission was eventually left in Canada at R.E.L. which was the radar-manufacturing arm of the Canadian National Research Council through the war. Due to the limited production capabilities, saturated during the war by manufacturing radar sets, CRTs and optical devices, production of magnetrons and of other tubes was outsourced. In the collection we find what can be considered the volume production of the early Western Electric D-160052 prototypes. Types 3C and 3D, equivalent respectively to E-1198 and to E-1189, were manufactured for REL by Northern Electric, the Canadian subsidiary of Bell Laboratories and sister of Western Electric. The story of the early magnetron development in Canada is summarized in this article by Paul Redhead.

In England E-1189 was redesigned with a four-fin brass radiator and approved in 1941 as NT98 or AP W2510. It was used in the Naval radar Type 271, in service since the end of March and capable of detecting the periscope of a submarine at about 6 miles. E-1198, later CV38, and the Canadian equivalent 3C were frequency variants operating at 9.1 cm, used in the airborne set AI Mark II since March 1941. Early production of NT98 and even of its successor CV56 were characterized to operate at the single wavelength of 9.5 cm. Starting from 1942 four frequency selections were introduced, identified by the suffix A to D. NT98 had been standardized as CV1255. Other titles, CV1491 to CV1494, were assigned to NT98 A, B, C and D. Even the strapped CV56 was followed by its frequency selections, identified by suffixes A, B, C and D.

Early multi-cavity magnetrons showed erratic operations because of their tendency to jump from the fundamental pi-mode to other spurious modes. The strapping technique, devised in July 1941 at the Birmingham University, see figure 4C, overcame the problem and pulse power was limited by the modulator power capability. Unstrapped E-1198 gave under 10 kW peak output power, with efficiency around 10%. The strapped variant was capable of generating about 100 kW in output, with some 200 kW in input. CV56 was the very early strapped magnetron to enter in production in the late 1941.

The variant for airborne application CV38/E-1198/REL 3C was replaced by CV64 early in 1942. CV64 gave about 40 kW peak power, about four times the power of the unstrapped type. Echelon strapping technique was soon followed by improved schemes, as double ring strapping, or by intrinsically stable multi-cavity anode structures, as the ‘rising sun’ below.

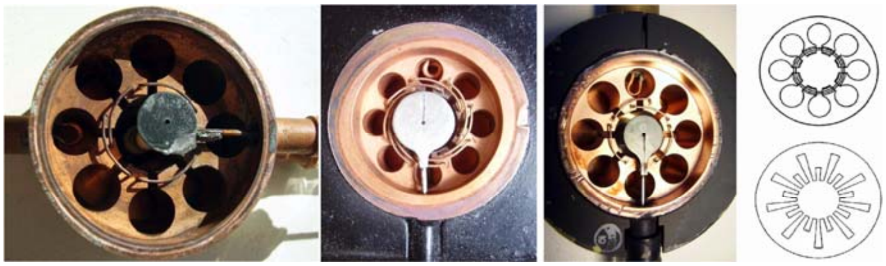


Fig. 9 – Strapping arrangements. Asymmetrical strapping is used in this Q85033 sample likely from the Sayers group. The echelon strapping, in the case in a CV160, was one early scheme to be used. A simplified scheme looks to be used in CV1479. Right, drafts of double-ring strapping and of rising-sun anode. Click on image to enlarge.

Very soon several types of multi-cavity pulsed magnetrons were available in US and in Great Britain for frequencies up to 10 GHz and over, with output power ranging from some tens to several hundreds kilowatt or even megawatts. To have an idea of the unprecedented growth of the magnetron market we must consider that during the war about 270.000 units of just the X-band 725A were built and over than 92.000 units were shipped to Britain and Commonwealth under the Lend and Lease Act.

German Radar magnetrons

Germany learned of the British multi-cavity magnetrons quite late from sets found on crashed or captured planes. CV64 was copied as Telefunken LMS 10, originating a line of Berlin microwave radar sets. Anyway its production remained very low until the end of the war, with some five units per month made by Telefunken and few lots made by Sanitas. Germany also developed other magnetrons of its own design, never come out of experimental stages before the end of the war.

Fig. 10 - German magnetrons. A) A sample of the 12-segment X-band LMS 12, used in the quasi-experimental Berlin D radar set. B) LMS 13 was a scaled-down version operating at 18 GHz. Both were designed with 12 cavities to operate at low magnetic field. C) RM 4025. a split-anode X-band Siemens experimental device. Click to enlarge.

- How does a multi-cavity magnetron operate?

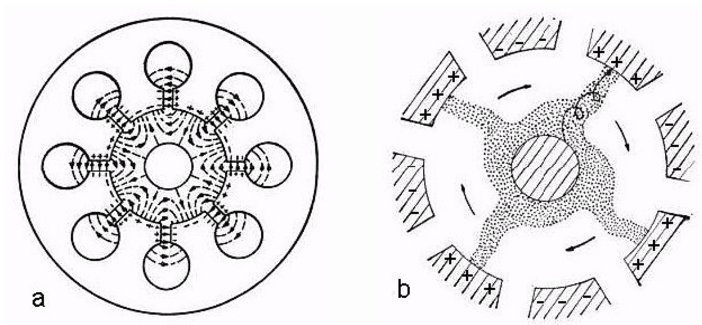


Fig. 11 – Bunching of electrons in 8-cavity magnetron. a) Draft shows the distribution of electric field inside the anode block in the π mode, so called because the phase difference between adjacent resonators is π. In the shown eight-cavity structure alternatively four segments are positive and four segments are negative. b) Draft shows the cloud of electrons inside the tube. When operating, the charges on the internal surface of anode segments follow the oscillations in the cavities behind, creating a clockwise rotating electric field. The magnetic flux lines are parallel to the cathode. Under the combined effect of electric and magnetic fields, electrons are bunched in four spokes directed time after time to the nearest positive anode segment, each electron following spiral trajectories. The operation resembles that of a synchronous motor. Strapping forces the synchronization of polar ends of each other resonator

The figure 10 above shows how electrons interact with electric and magnetic fields inside a multi-cavity magnetron. Each cavity is equivalent to the inductor and the slot to the capacitor of a resonating circuit.

- CW and Pulse magnetrons

Many multi-cavity magnetrons were designed for pulsed operation in radar applications. Multi-cavity magnetron is a complete self-contained source of RF energy, usually not requiring external resonating circuits. Tuning of the simplest types is fixed, depending upon the geometry of the internal resonators and factory adjusted to the wanted frequency. Some types are mechanically tunable, with plungers entering in the cavities, driven from the outside through a bellow.

What is needed to generate RF is just a DC supply, if CW, or a pulser to build the anode supply pulses. Actually anode resonator system is connected to chassis and negative pulses are applied to cathode. Average RF power can be in the order of tens or hundreds watts. In pulsed operation, peak RF pulses of hundreds kilowatts or even megawatts are generated with fairly high efficiency, around 50%. As general rule pulsed magnetrons use oxide-coated unipotential cathodes. Special porous coatings have been devised to increase instantaneous emission level and to protect emitting surface from ion bombardment. Nonetheless pulse magnetrons must be driven at low duty cycle and pulse duration not exceeding few microseconds, otherwise the oxide layer could be quickly destroyed. Even electron back-bombardment of the cathode surface could impair the cathode life. In many cases heater voltage must be considerably reduced or even switched-off when magnetron oscillates.

CW magnetrons are available in a variety of types intended for ECM, RF heating and diathermy. With the exception of special types for ECM, they usually operate at fixed assigned frequencies with output power ranging from hundreds watts to some kilowatts. Common microwave ovens use CW magnetrons as source of heating radiation. Major differences against pulsed magnetrons are in the anode geometry and in the lower magnetic field, to operate at relatively low anode voltage.

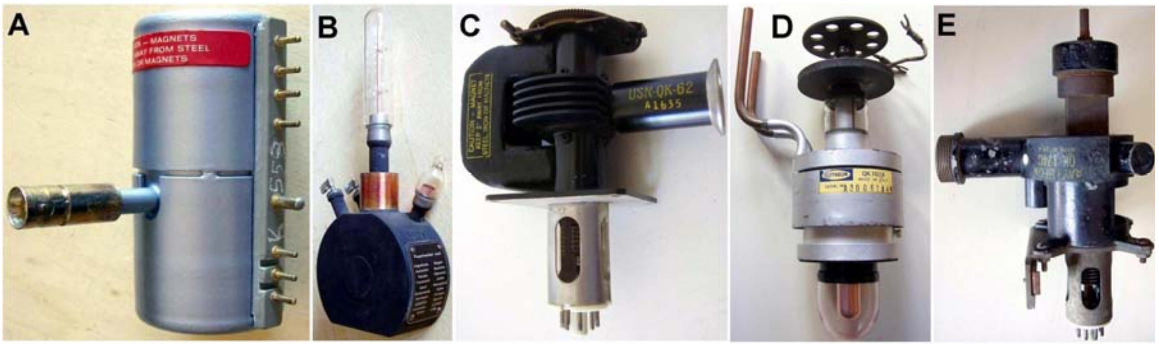


Fig. 12 - A) The Raytheon 6177A is a CW FM-modulated magnetron, intended for doppler altimeters. Modulation is electro-mechanical, with a vibrating reed tuner. B) The Telefunken MG-8 is a CW medium power magnetron used in diathermy equipment. C) The Raytheon QK-62 was a tunable type for ECM equipment. It was CW rated, since it was intended for operation at variable pulse width and repetition rate. The same basic design originated the fixed frequency 5609, used in diathermy. D) A Raytheon-ELSI QK707A, used in the Raytheon-licensed Microlambda 'Radarange' cooking ovens. E) The Raytheon QK174C is a FM magnetron, mechanically tunable from 1900 to 2200 MHz. It is a quite unique device, using six auxiliary electron guns looking into six out of the twelve cavities in order to obtain the FM modulation by electronic tuning. Click to enlarge

Pulse magnetrons are intended to generate short RF pulses at high peak power levels. To obtain the wanted power, their design is optimized to operate at very high voltage and current during the pulse. Frequency may vary from less than 1 GHz to over than 20 GHz. Depending upon the application, output pulse power ranges from about one hundred watts to some megawatts.

The variety of types and solutions was closely related to the diffusion of radar in many fields and applications. We already saw how multi-cavity magnetrons have a common origin in the E.1189 prototypes made at GEC and how rapidly in America appeared types diversified from the prototype. Here a quick survey of other British and American magnetrons.

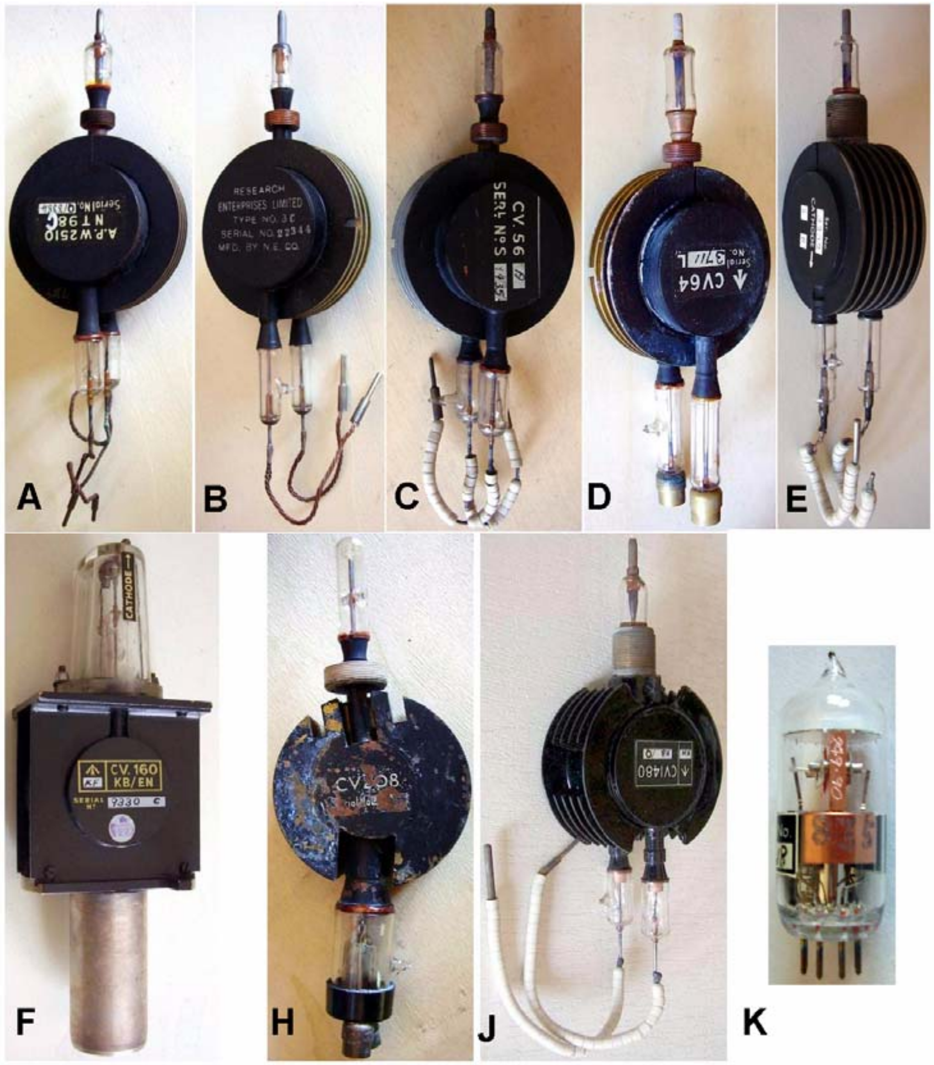


Fig. 12 - British magnetrons. A) GEC E.1189 was standardized as NT98, the first magnetron to go in volume production in 1941. B) 3C was the Canadian equivalent of CV38, used in airborne S-band applications. CV56 was the first strapped magnetron, derived from NT98 and capable of delivering about 80 kW. D) CV64, the strapped variant of 3C and CV38, was used in the H2S airborne radar. CV76 was a high-power variant of CV56, used in the Type 277 surface search marine radar. F) CV160 was a British magnetron characterized by a quite unique square shape of the finned radiator in addition to a glass boot on the heater connections. H) The shape of the X-band CV208 did not deviated significantly from the one of S-band types, but for the special heater connector. J) CV1480 shows an improved radiator to generate 500 kW pulses. K) CV2380 was a low-power magnetron in miniature glass envelope. Click to enlarge.

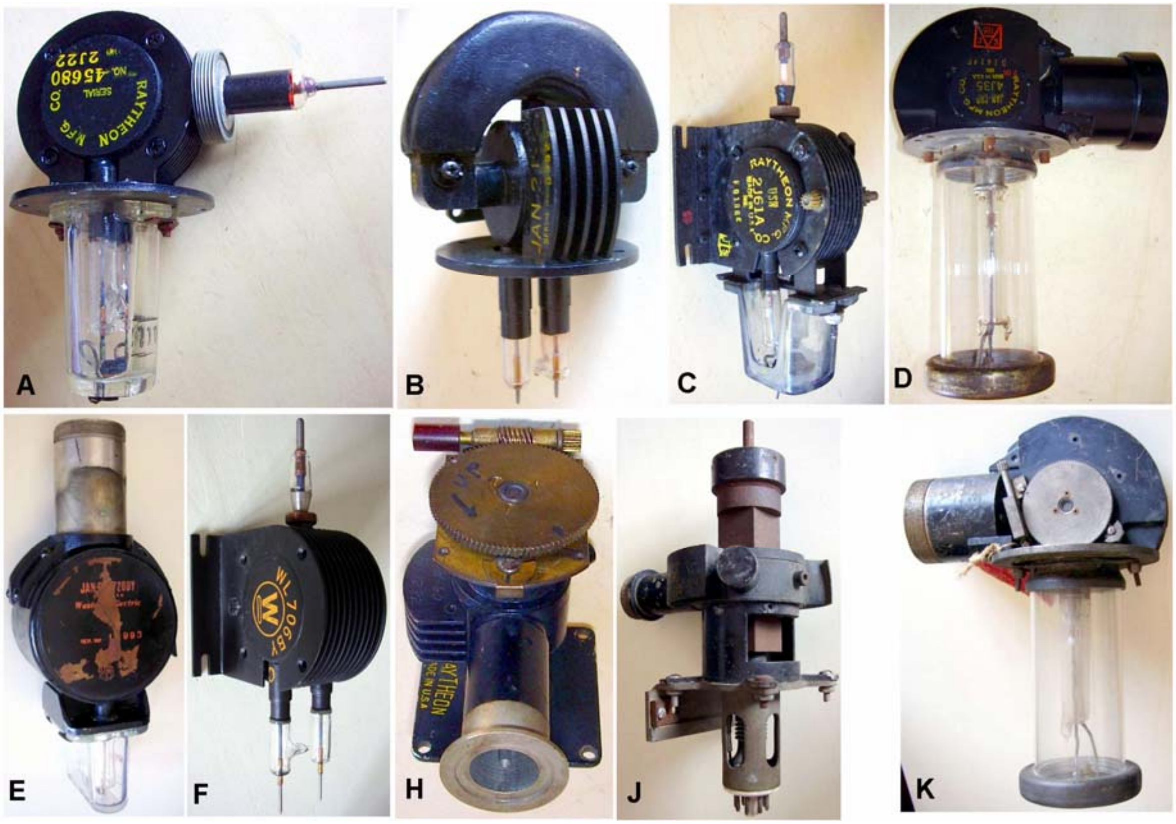


Fig. 13 - Shapes of relatively low frequency American magnetrons from WWII. A) 2J22 is one of the early strapped types from Raytheon. B) 2J39 is a small packaged magnetron capable of delivering up to 10 kW pulses at 3.3 GHz. C) 2J61 is a tunable magnetron, 35 kW output pulses from 2.95 to 3.15 GHz. D) Raytheon 4J35 is capable of delivering 750 kW pulses at 2.7 GHz. E) Western Electric 728AY to JY was a family of L-band fixed frequency magnetrons, delivering up to 400 kW pulses at 900 to 970 MHz. F) 706 was the early Western Electric S-band family, directly derived from E1189 British prototype. Later strapped variants, AY to GY suffix, delivered 200 kW pulses in output. H) Rytheon QK60, registered as 4J61, was a low-power magnetron, mechanically tunable in the S-band used in radar jammers. J) QK174C was a CW magnetron mechanically tunable from 1900 to 2200 MHz with six auxiliary electron guns for frequency modulation. K) The tunable 5586 replaced the family of fixed-frequency magnetrons 4J31 to 4J35. Click to enlarge.

A similar variety of types can be found in X-band magnetrons, as shown in the picture 12 below. The most successful design, the one of the fixed-frequency 725A, led to a modular structure. Its anode was a machined or punched block with twelve hole-and-slot resonators and double ring straps. Then this block was brazed inside an external radiator. Many variants soon appeared, using the same anode block with different tuning frequency or simply a different radiator or even a rotation of the heater leads with respect to the output probe, as in the 730A. Even anode blocks with vane-type resonators were manufactured. The standard cathode was an oxide-impregnated nickel mesh, but special cathodes were devised for types intended to operate at high-power levels and higher duty, as the 2J53.

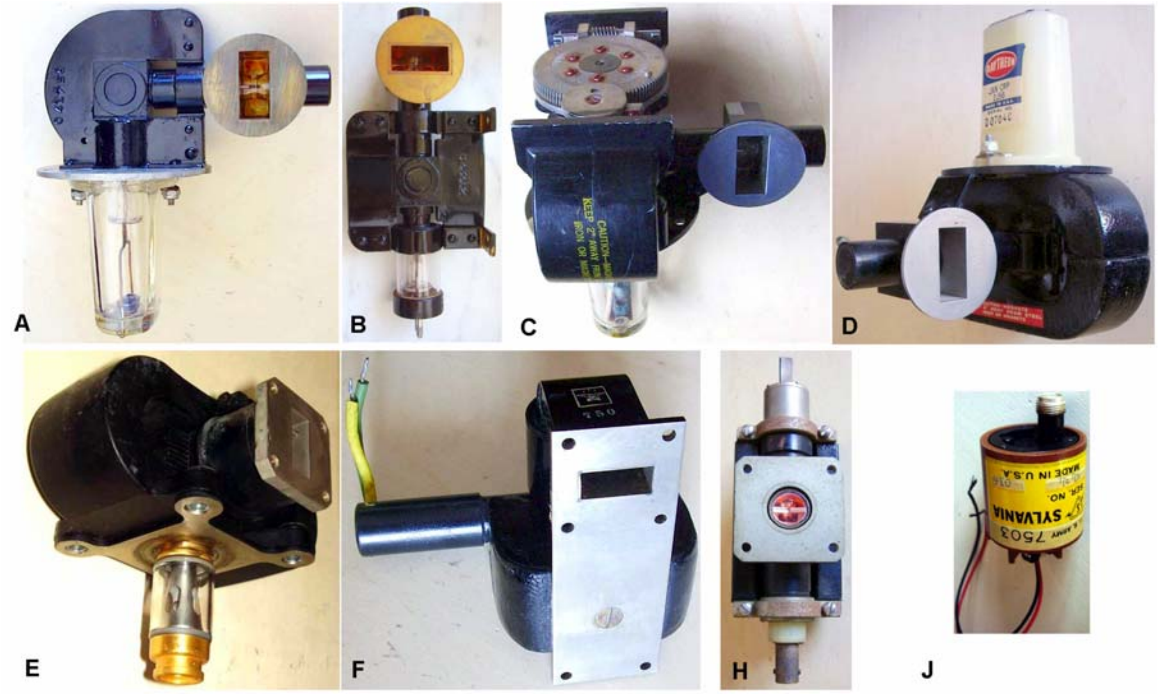


Fig. 14 – Samples of American X-band pulse magnetrons. A) The popular X-band magnetron 725A was designed by Western Electric. Originally its anode was a machined separable 12 hole-and-slot resonators which was brazed to the radiator. It originated many variants, as 730A, 2J49, 2J50 or 2J53. B) the 730A is similar to 725A, with heater terminals rotated 90 degrees. C) 2J51A was the mechanically tunable variant of 725A, with factory-installed magnet. D) The 2J56 and other types appeared as simplified fixed-tuning variants of the 2J51A. E) 4J52 was a high-power type, capable of generating pulses up to about 300 kW. F) The low-voltage 2J42 became another industry standard with countless copies and variants, specially for small marine radar sets. H) The 6229, a small packaged magnetron with mechanical tuning and coaxial connector output, appeared only later for the guidance system of the Nike-Ajax missile. J) 7503 is a baby X-band magnetron for beacon applications, 200W peak.

Voltage tunable magnetrons

Another magnetron family includes the so-called VTMs, voltage tuned magnetrons. Here the anode has an interdigital vane structure. Bunching effect does not depend upon the Q of resonating cavities and it is difficult to obtain in the presence of a normal space charge. The problem was solved by the use of a virtual cathode, a deflector that launches in the interanode space a limited number of electrons injected from a conventional cathode placed elsewhere in the tube.

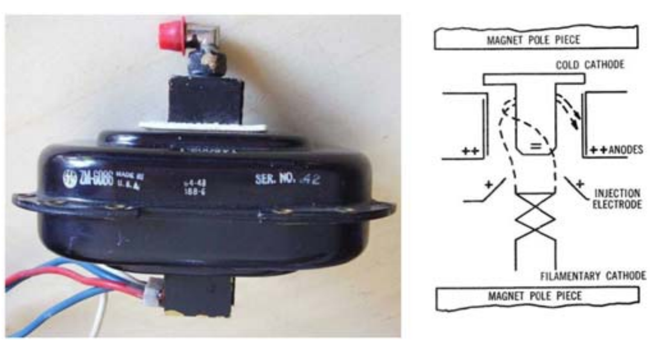


Fig. 15 – ZM-6086, CW voltage tunable magnetron, and draft of the virtual cathode used to facilitate electron bunching.

The Platinotron or Amplitron

Platinotron, also called Amplitron, is a microwave high-power amplifier introduced by Raytheon around 1957. It was originally proposed to build add-on equipment for existing radar sets, to increase their search range: more or less as a linear amplifier does when added to a 200W transceiver. The platinotron looks like a multi-cavity magnetron and like a magnetron it requires a transverse magnetic field. But in its operation it also recalls a TWT because of the interactions between electron spokes and a wave moving along the internal transmission line.

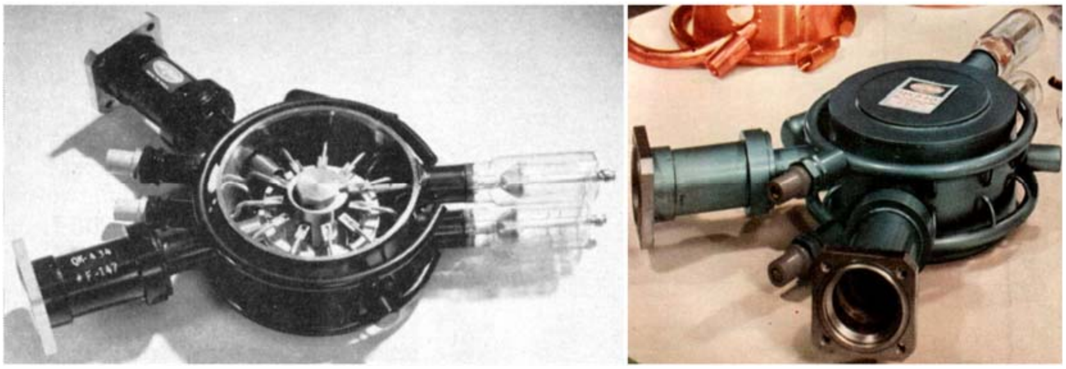


Fig. 16 – Two views of the QK520 platinotron. The first one with cover removed shows the unit inside. Coolant flows through the two pipe fittings between input and output connectors. Small copper ducts connect anode vanes to the outer cooling rings.

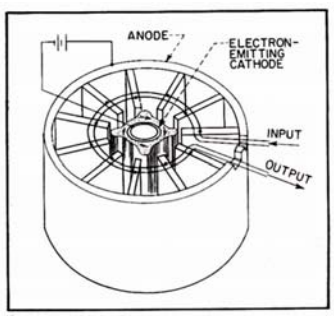


Fig. 17 – Internal schematic of the QK520 platinotron. It is very similar to any vane anode magnetron. The only difference is the bifilar ring line from the input to the output port: odd vanes are all connected to one ring, even vanes to the other. A rotating four-spoke cloud of electrons is also represented around the cathode. Not visible in this figure the external magnetic field with flux lines parallel to cathode.

When RF is applied to the input port, it propagates through the bifilar line to the connected vanes that form the anode structure up to the output. Now a voltage pulse with a controlled ramp-up is applied between cathode and anode. Under the combined effect of electric and magnetic fields electrons start to rotate. Their angular velocity increases with the ramp-up of the voltage pulse, until peripheral electrons rotate synchronously with the propagating signal wave. At this point electrons are bunched in rotating spokes, as in any other cavity magnetron. Rotation speed is locked on the propagation speed of the input signal regardless of any further voltage increase between cathode and anode, which only causes a subsequent increase in the current flow. Energy is then transferred from electrons to the signal.

As amplifier the platinotron shows peculiar behaviors. It is a saturated amplifier rather than a linear type. As evidenced by the following figure 18(a), it does not operate until the input signal rises over a given threshold: clearly if the electric field between anode vanes is too low no bunching occurs. Once locked on the input signal, the magnitude of the RF output depends almost exclusively on applied DC power. Input signal has just some influence on the efficiency, which increases at high drive levels. Input power is almost entirely transferred at the output port, added to the output of the platinotron amplifier. Other important features are the wide bandwidth and the efficiency of this amplifier. Platinotron locks on input signals over a typical 10% bandwidth, with efficiency from 50 to 70%.

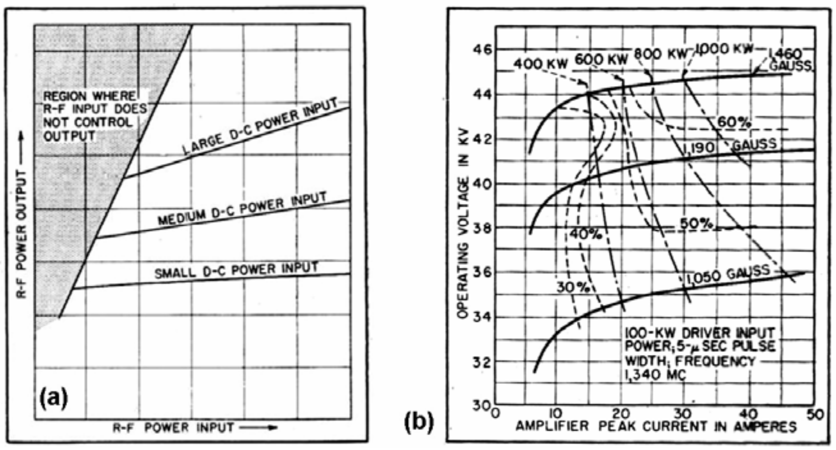


Fig. 18 – (a) Plot of typical output versus input power at different supply levels. (b) Typical performance chart at different magnetic field levels.

In typical operation as radar amplifier QK520 can be pulsed to 40 kV at 35 A. Driven by 40 kW input pulses it gives 800 kW in output. Efficiency is over 55% from 1225 to 1350 MHz.

Of course platinotron can also be operated as oscillator, as in the backward wave oscillator, with a reference cavity to stabilize frequency.

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