7. Other Radar specific tubes

This family includes some tubes designed or specified for medium to high power pulsed operation in radar modulators. Most of these tubes are used to generate peak pulses of tens or hundreds of kilowatt and even of megawatts, to drive the magnetron. Basically there are three different types of switches commonly used for the purpose, the spark gaps, the gridded vacuum tubes, triodes or tetrodes, and the high-speed thyratrons.

7.2 - Spark gaps

Spark gaps were used to operate as switches. Applications include the discharge of a charged line through the magnetron, so generating the high-power radio frequency pulses. Spark gaps were also been used as protective devices to prevent excessive voltage build-up in the modulators or even as gas switches in antenna duplexers, just as TR switches. Since no heater is present, efficiency is very high. The major drawback is an appreciable variation of the firing voltage through the life, mainly due to the erosion of electrodes. When used as pulse generators in radar modulators, a jitter in the firing timing can be espected. Spark gaps were made for radar modulators, capable of handling peak currents of hundreds amperes. They were used in series connected circuits, the discharge being triggered shorting the lower gap. When fired, total voltage drop was as low as one hundred volts even with peak currents in the order of some hundreds of amperes. Pulse repetition rate in the order of 2000 pps was obtainable.

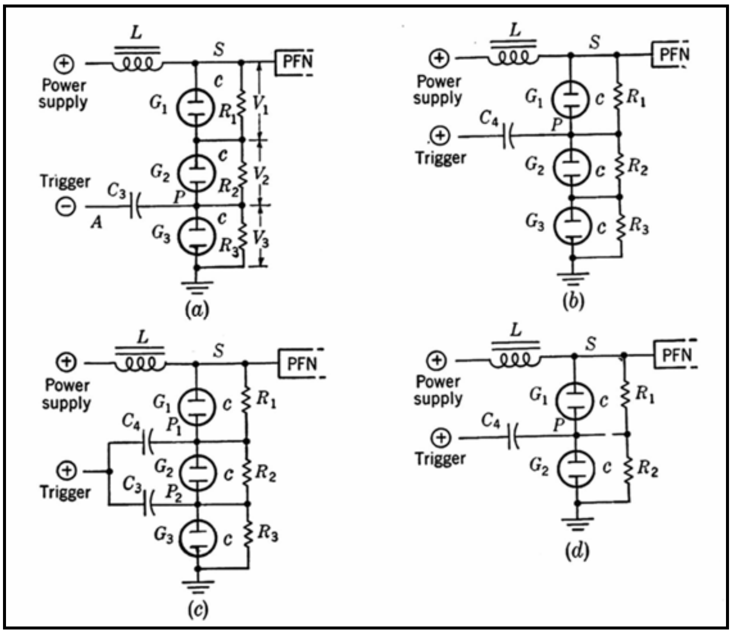

Fig. 7.1 - Typical circuits for series connected spark gaps to discharge the pulse forming network, PFN.

This section includes most of the American two-electrode types described by Glasoe, in his ‘Pulse Generators’, including the mercury-filled iron-sponge 1B42. The development of spark gaps for pulse generators in Western Electric is described in this article from BSTJ.

We also find other examples of T-R switches and protective spark gaps, used to limit excessive voltage build-up across HV circuits in the radar modulators.

Fig. 7.2 – Some two-electrode spark gaps. From left, the popular 1B22 and its smaller variant 1B29, 30 A peak current, the iron-sponge mercury cathode 1B42 and the 1B45, 450 A peak.

The British spark gaps, also known as ‘trigatrons’, were quite different, with a third trigger electrode inside the cathode. Here the firing was more accurate, depending upon the pulse applied to the trigger electrode. Unfortunately their life was quite short. Either British and Canadian trigatrons are in the collection.

Fig. 7.3 – Two trigatron tubes, the second one from Canadian REL, and detailed view of the internal spark gap, with the trigger electrode tip just visible in the middle of the cathode dome, its stem being covered by a glass tubing, protruding from the bottom press.

Fig. 7.4 – Protective spark gaps, used to prevent excessive high-voltage build-up in radar modulators. Sealed construction and some radiactive activators are used to grant predictable trigger voltage, regardless of the environmental conditions, temperature, pressure or moisture.

7.3 - Hard switch tubes, triodes and tetrodes

Power triodes or tetrodes have been used as switches in radar pulsers, when flexibility, speed and precision as per pulse width, duty and pulse repetition rate were required. The major drawback was the low efficiency, due to the relevant heater power needed to grant the proper emission and to the quite high driving power required. Early tubes were directly derived from transmitting types. Some were just specified and tested to different pulsed operating conditions. In other cases some redesigns were needed to better handle higher voltages and peak currents of the application.

Fig. 7.5 – Some tubes used as switches in radar pulsers and derived from transmitting types.
From left, the VT-129 (304TL) was designed, assemblying four electrode packs of the 75TL transmitting triode. The 6C21 in the middle actually is a 1000T, specified for higher filament voltage, in order to grant the required emission. The 3E29 dual tetrode was derived from the transmitting 829, replacing ceramic spacers for the previous mica ones, to prevent arcing at high voltages.

Fig. 7.6 – Tubes specifically designed for pulse modulators are characterized for their high cathode surface, their excellent insulation and often guard rings to prevent corona discharge. Here from left a 5D21, with four in-line cathodes, a 701A, with four electrode sets of 350A, and a 4PR60B. Probably the PL-185/527A, even if used in the VHF ring oscillator of the radar AN-TPS-18, was also one of the largest tube used as hard pulser, being capable of handling pulses of 60 amps at 30 kvolts.

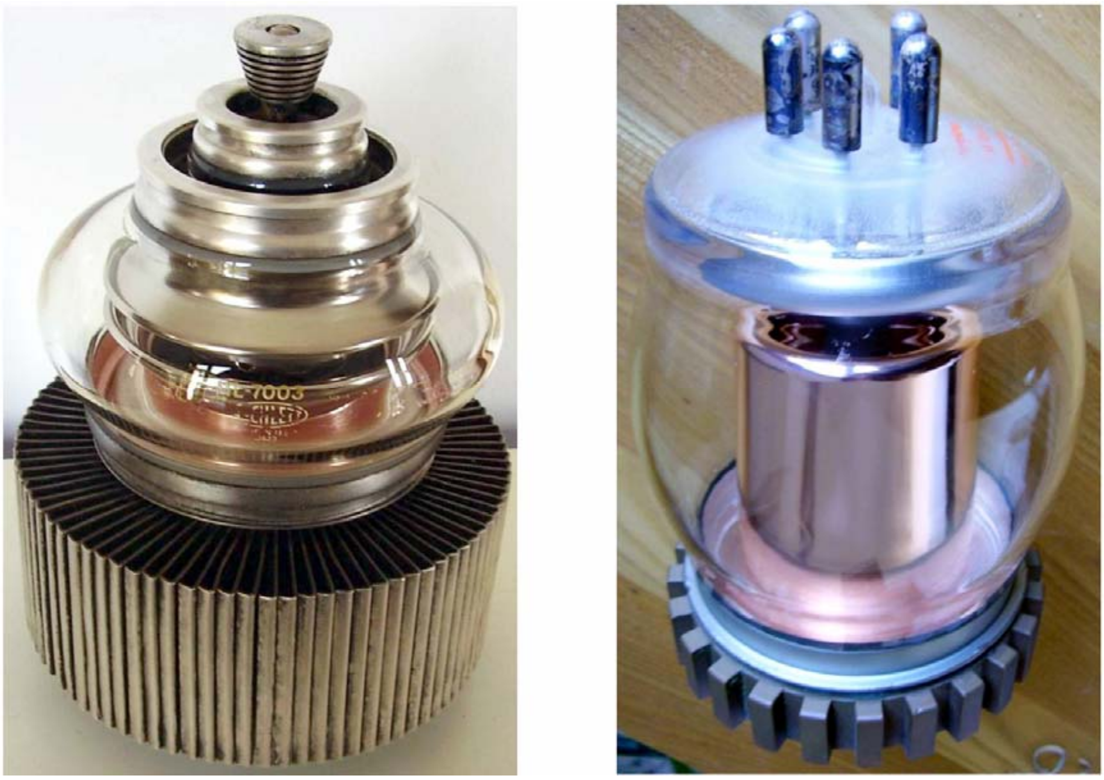

Fig. 7.7 - Two high-power tubes designed for pulse switching applications. The ML-7003 is a shielded grid triode capable of operating at 40 kV, 80 A peak. The AX-10318 is a tetrode capable of operating at 100 kV.

7.4 - Thyratrons for radar pulsers

Thyratrons offer some advantages over hard tubes, since require much less driving power, just a short trigger pulse to start the conduction which ceases when current from the PFN drops to zero. Unfortunately deionization in mercury thyratrons is quite slow and, due to the mass of mercury ions, the cathode oxide layer can easily be destroyed at relatively low voltage drop. Mercury types were just used in early low p.r.r. radar sets. Hydrogen types are fast enough and, due to the low mass of hydrogen ions, suffer remarkable oxide destruction only at voltages exceeding some 600 V. Their major drawback is the gas cleanup during operation, which could require hydrogen addition through their life, usually from titanium-hydride reservoirs in larger units. Thyratron is used with a pulse forming network, a delay line, which stores the energy to be transferred to the load and ensures the tube cutoff once the stored enegy is fully dissipated at the end of the pulse.

Fig. 7.8 – Thyratrons for radar pulsers. The first one is a British mercury type CV22. Other are hydrogen thyratrons, the third and the fourth with titanium-hydride reservoirs. The latest one is a small thyratron in a miniature glass envelope, yet capable of switching 20 amps at 1.2 kvolts.

7.5 - Tubes for radar duplexers, TRs and ATRs

Here we find a variety of British and American TR and ATR switches for balanced or coaxial lines and for waveguides. Quite interesting are some very early types, as the RCA 1B25, for balanced lines, and the British type CV8, a micropup hot cathode diode designed to be mounted inside a coaxial line.

The very early gas switches, as the CV43 and CV1297 below, directly derived from the 'Sutton tube', built filling a NR89 klystron resonating structure with low pressure water vapour. These gas switches were the forerunners of successive British and American types, where we find improvements in sensitivity and life by the addition of ionizing materials.

Fig. 7.9 – Some samples of British and American TR switches.

In the RF plumbing often we find a reference cavity, with unloaded Q in the order of 2000, used to stabilize the frequency of the local oscillator.

Fig. 7.10 – X-Band waveguide flanged cavities.