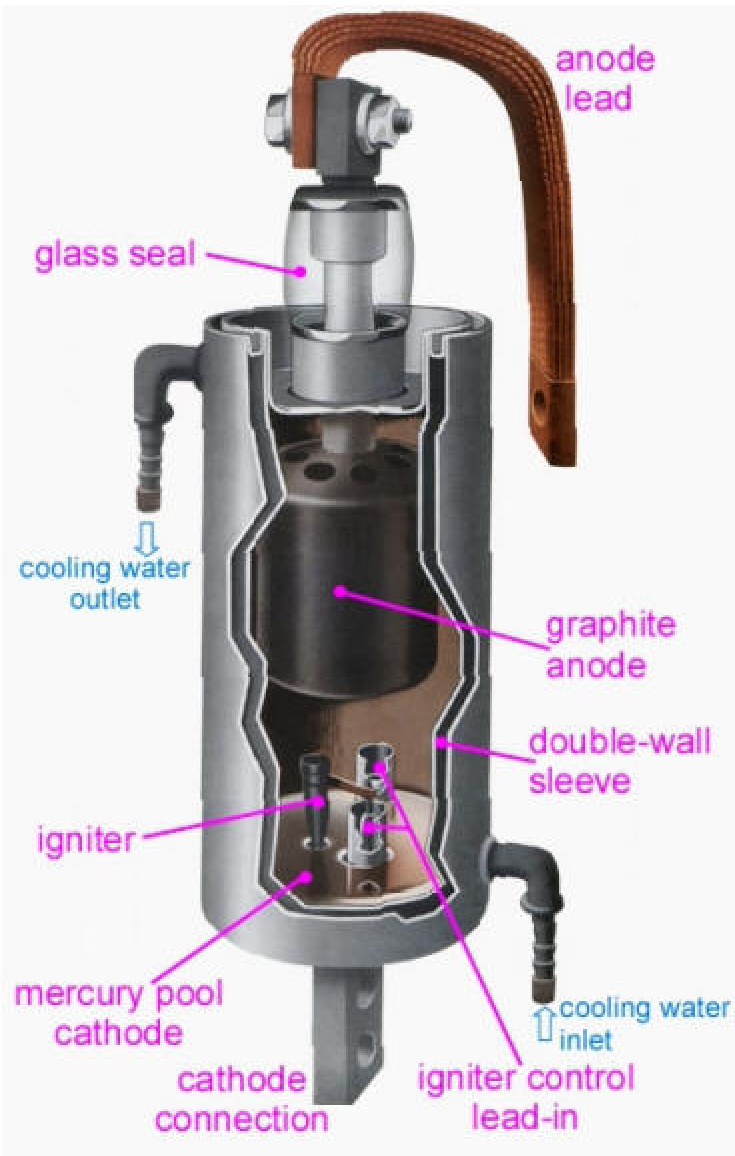
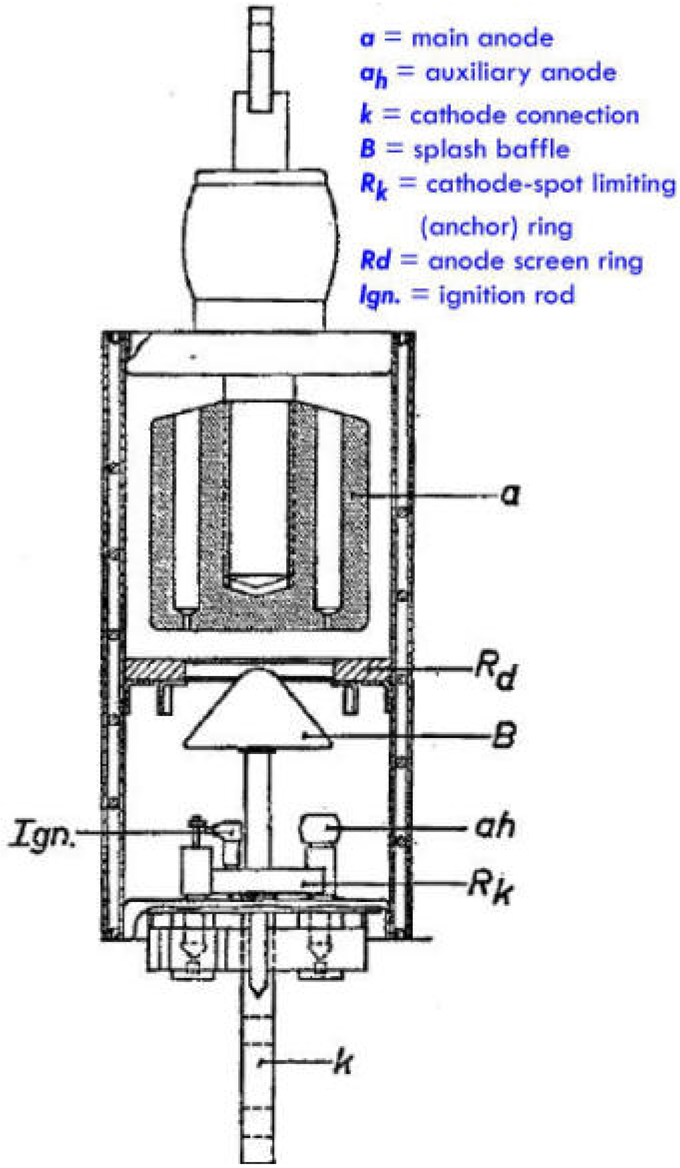
# SOME NOTES ON IGNITRONS AND THYRATONS

The **ignitron** is a special type of Mercury Arc Rectifier (MAR). It was invented in 1932 by Joseph Slepian, while working at Westinghouse Electric Corp. The product was announced in 1933. The ignitron has an ignition electrode made of silicon carbide or boric carbide. Its pointed tip is permanently dipped into the mercury pool.




***Cut-away view of a basic ignitron***
*(without auxiliary anode)*




***Cross-section of a rectifier ignitron - type 5555***
*(source: Fig. 178 in ref. 1)*

Ignitrons for rectification purposes (rather than switching), typically have an excitation anode. The simplest form of controlling the excitation anode is by applying the main anode voltage via a step-down transformer. The figure above shows the cross-section of a typical rectifier ignitron: the common type "5555", made by several manufacturers in the US, the UK, and Europe. In Germany, ignitrons were developed and manufactured by AEG/Telefunken (*Apparate-Werke Treptow*, AT), Siemens, Valvo/Philips, and others.

Basic characteristics of the 1950s "5555" are:

- max anode voltage: 900-1200 Volt (max peak forward & peak inverse)
- max anode current: 150-200 Amps (max average continuous)
- voltage drop: 12.6-19.1 Volts (at 100-1200 peak amps anode current).

It is a fairly compact device: the cylinder has a diameter of about 15 cm (≈6") and a height of 50 cm (≈19.8"). The cylinder is stainless steel and double-walled, for water cooling. The need for such cooling is obvious from the voltage drop, combined with the anode current. Two ignitrons may be connected in an anti-parallel configuration to obtain full-wave rectification. This is not necessary if the DC-motors are designed to handle pulsed power.

Regular ignitrons must be maintained precisely vertical, and are sensitive to movement (jolts, vibration, oscillation,...). Hence, for mobile applications such as locomotives, special construction features were added inside the ignitron, such as a splash screen, mercury retaining baffles, and a cathode-spot limiting/anchor ring.

Instead of MARs or ignitrons, **thyratrons** may be used. These *gas* triodes were first developed around 1926. At first sight, they resemble *vacuum* triodes. However, the arrangement of the electrodes is different: anode and cathode and control-grid are placed inside a cylindrical metal screen. Unlike a vacuum triode, a thyratron can not be used as a linear amplifier. The thyratron's control-grid electrode voltage controls the anode-cathode ignition voltage. Upon ignition, the thyratron acts as a vacuum diode. The grid bias of a *vacuum* triode controls the anode *current*. The thyratron is filled with mercury vapor, or an inert gas or gas mixture: hydrogen, helium, xenon, argon, krypton, neon, ... Therefore, anode currents can be much larger than those of same-size "*hard vacuum*" triodes. Contrary to ignitrons, high-power thyratrons do not require water cooling: convective cooling normally suffices. Thyratrons are basically controlled rectifiers (CR). They were superseded in the early 1960s by solid-state devices: "silicon controlled rectifiers" (SCR), in particular thyristors. The name "thyristor" is actually a contraction of "thyratron transistor".

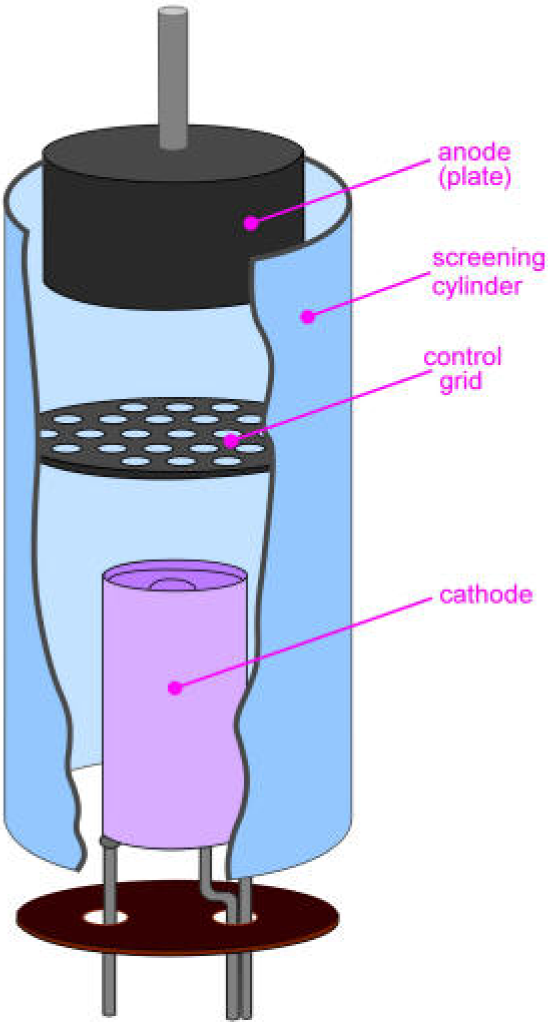
Thyratrons were used in the pulse modulator of several WW2 radar sets, from low power (50 - 100 kW) to high power (100s of kW). However, the high-power radar pulses have a very low duty-cycle of less than 0.5%: pulse duration was 1-3 µsec, and the pulse repetition frequency (PRF) 50 - 3000 Hz. Thyratrons have a ratio of "max peak vs. max average" current rating that, depending on the model, may be as little as 3:1 and as much as 1500:1. For speed control of a DC motor, thyratrons are needed that have an average or continuous current rating that is consistent with the motor's maximum continuous power rating. A thyratron for a 10 kW radar pulse modulator may not be used for controlling the speed of a 10 kW DC-motor. Another application of (small, low power) thyratrons during the 1930s and in WW2 was as switches in bi-stable "memory" cells ("flip-flops"), in shift-registers such as decade ring-counters of calculating machines.

The 30 MHz Berhard system was developed in 1941. Were adequate thyratrons available by then? Yes, for instance the following AEG types:

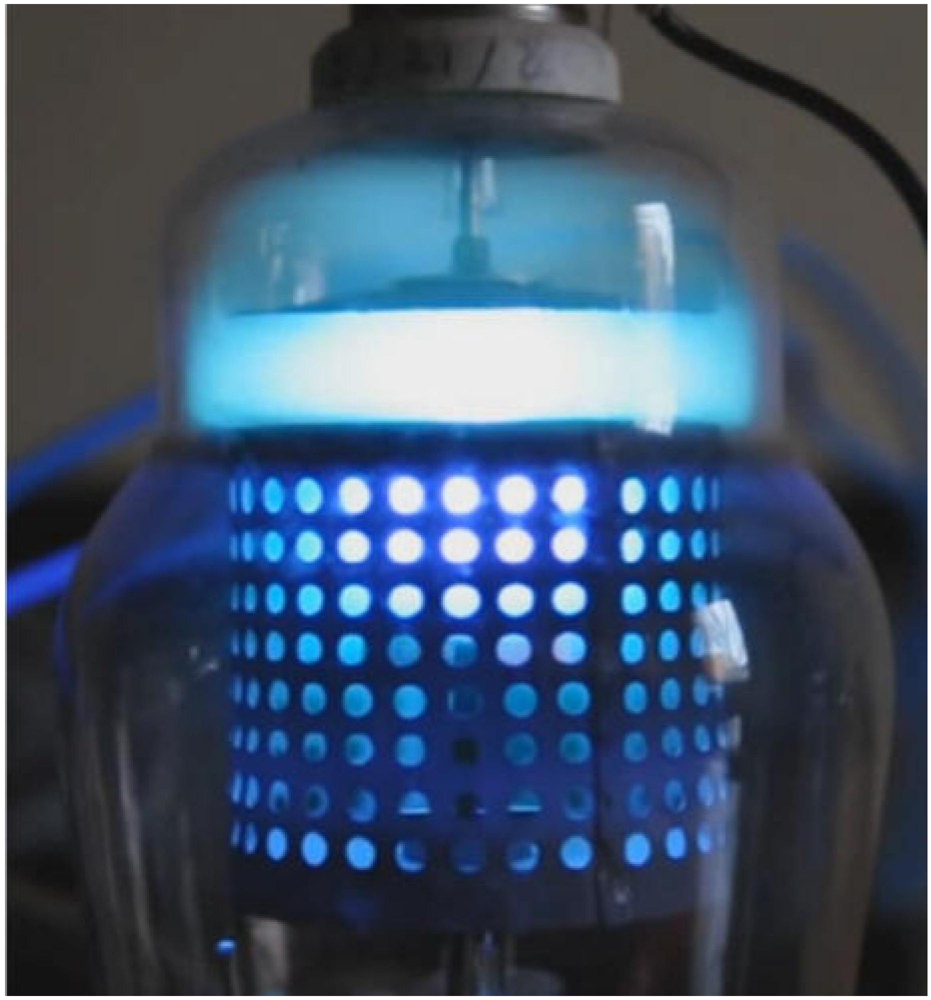
- **S 5/50 i**: 5 kV, 16 A max average rectified current (1939)
- **S 5/100 i**: 5 kV, 35 A max average rectified current.

Standard "radar" thyratrons would not have been suitable for driving the motor of a Bernhard locomotive. For instance, the Siemens LG1001; *L* = "***L**uftfarhtröhre*" (aviation/Luftwaffe tube), *G* = "***G**leichrichterröhre, Spezialröhre zur Impulserzeugung*" (rectifier tube, special tube for pulse generation) was rated for 1000 Vpeak (≈ 670 Vdc out), but only 5 A average current (40 A peak).

Thyratron motor-speed control systems may contain simple circuitry to compensate for the voltage drop across the motor's armature resistance (the load-dependent "IR drop"), and to limit the starting current to, e.g., twice the full load current. Note that without current limiting, the motor's stall current may be as much as 300 - 800% of the motor's nominal max rating.




***Cut-away view of the electrode arrangement of a thyratron***
*(there may be a screen-grid above and below the control-grid)*



***1962 RCA 714/7021 gas-mercury thyratron in action***
*(1250 V max anode foward & reverse voltage, 1 A average current, 3 A peak current, convection-cooled, 15 cm (6.125") tall, 5 cm (2") diameter)*

Ref. 1: "Mercury cathode tubes: Ignitron, Excitron, Sendytron", chapter 6, pp. 210-255, of "Gas-discharge tubes", H.L. van der Horst, Philips Technical Library series, 1964, 318 pp.