

## The "Crystal Gayle effect" or How a Song can Shut off a Radio Broadcast Transmission

There have been several Eimac tubes that went to market only to discover later they had latent defects in their design. The 3CX3000A7 was one of them.

In the late 1960's the 3X2500A3 and later the 3CX3000A7 triodes were designed by Eimac's tube engineer Jack Kendall (now KC5GBF).

With its high-Mu grid, the 3CX3000A7 made an excellent switch tube and was designed into the pulse duration modulator stage of high efficiency AM transmitters in the mid 1970's.

Bob Sutherland (ex-W6PO) once recalled to me some of the issues associated with this product. Around 1977 some AM stations began to report tube problems to Eimac. While broadcasting a specific recording, their transmitter would fault and go off the air. The station engineers were told by the DJ's that the fault always occurred when a certain vocal note was hit in Crystal Gayle's recording "*Don't it make my brown eyes bluuuuue*"<sup>1</sup>. The tube would work again if the overload detector was reset or until that recording was played again! The PDM and final tubes were sent back to Eimac for testing and possibly failure analysis

At Eimac a bench "cold test" was set up with a variable sine wave oscillator amplified to a high rms voltage and a stroboscope sync'ed to the oscillator to freeze the motion of the grids. The AC voltage was applied to the elements of a tube while under a glass bell-jar so a vacuum could be provided. At a particular frequency it was observed that a grid would begin vibrating with movement sufficient to allow it to contact the filament. When this occurred in an operating transmitter the grid bias was shorted and a triode momentarily become a diode and conducted extremely high plate current thereby tripping the transmitter's overload circuit.

Physically, the grids in a 3CX3000A7 consists of many fine tungsten wires arranged side-by-side in a cylinder with gaps between the wires for electrons to pass. This structure had circumferential tie-wires welded around the diameter at a few points to keep the wires parallel. By adding additional tie-wires the mechanical resonance was eliminated.

This phenomenon became known as the "Crystal Gayle" effect at Eimac, associated with her song that excited the grid resonance.

As they say, history repeats itself and over two decades later a similar problem would arise when Eimac was developing a new high power tetrode. This was a tube intended to second-source the French TH-558, a 500 kW tetrode designed by Thales. Eimac designated their version as 4CM500,000G. My responsibility was writing a data sheet

for this tube as well as the 4CM300,000G which Eimac developed as an equivalent to Thales TH-537.

Both of these new tetrodes utilized pyrolytic graphite (PG) grids that were cut using a laser. PG is the only material thin enough and able to withstand extreme temperatures and not melt when subject to intense electron bombardment in an operating tube. A large PG grid is very costly to make, for example a single PG grid for Eimac's 2500 kW tetrode cost around \$1500 each to build in the mid 90's.

Eimac's first 500 kW tubes tested good for dc characteristics so they were sent to a shortwave transmitter OEM for evaluation where they performed well until, at a specific modulation frequency the tube shorted internally. The failures were repeatable and occurred at an audio frequency around 400 Hz. It was the Crystal Gayle effect all over again!

To solve this problem the PC software that positioned the laser during its cutting process had to be written to cut a different pattern in the PG grids, one that hopefully would be free of similar mechanical resonances.

To accomplish this change, grid patterns were cut that were somewhat like a snowflake, they were very unlike the normal vertical and horizontal rectangular openings employed with wire grids. It took nearly 6 months to develop new grids and eventually another prototype tube was available for evaluation. RIZ, a transmitter company in Zagreb, was evaluating these tubes and the time required to send a tube there and have it evaluated added up to months of delay. Eventually it took nearly 15 years for this tube to be revised to the point it was functionally equivalent to the TH-558 but by then the market for the tube had nearly vanished, many of the transmitters using the TH-558 had been replaced or modified to use a different, newer Thales tetrode.

While Eimac's 4CM300,000G never exhibited any design problems the 4CM500,000G became a bad dream to Eimac's management.

Just as the final revisions to the 4CM500,000G were being evaluated the market for that tube as used in shortwave transmitters had diminished significantly after Thales had converted most of the SW stations using that tube to their TH561, an "improved" tetrode. During these years several large scientific accelerators have designed the TH-537 and TH-558 into high power pulsed applications and they continue to operate successfully with the Thales tetrodes.

In 2006 CPI sold the property where the Eimac San Carlos plant had been operating since it was built in 1958 and the PG furnaces were moved to CPI's Mountain View machine shop (now closed) and stored outside in the rear parking lot. The largest of Eimac's PG furnaces stood approx. 20 feet high (pic below). These were never incorporated into the Palo Alto facility where Eimac was integrated into the ex-Varian Microwave Power Products facility and after several of sitting outside exposed to the

elements the furnaces were sold for pennies on the dollar after CPI's management decided to use a smaller PG furnace "because it looked better".

Then, in 2016, the only PG furnace at CPI that was capable of making the large grid cups was destroyed as the result of a steam explosion when a defective part was installed during maintenance. Due to the excessive cost associated with a custom-designed PG furnace, CPI elected not to replace it (effective June, 2020) and is seeking an outside supplier for PG grids. This ended Eimac's decades-long effort to second-source Thales PG tetrodes and the associated development costs were never recovered due to limited sales.



Pyrolytic graphite furnaces being disassembled for shipment (San Carlos, 2006).

1. Thanks to J. Fred Riley, ex-CEC, for details on the song where faults occurred.
2. For data sheet see <http://www.tubecollectors.org/eimac/archives/4cm500,000g.pdf>

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