

THE VACUUM TUBE

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The Nuvistar Story

In 1955 George Rose and his Receiving Tube Advanced R&D Staff at RCA were asked to develop a vacuum tube that would compete with the then-blossoming transistor. As a result of this decision, the thimble-size Nuvistor (The New Look) was introduced in 1960. The Nuvistor revolutionized the art of tube making by introducing new construction techniques and eliminating or minimizing the defects that had plagued the tube industry from the beginning. It combined dramatic improvements in performance, efficiency and reliability with drastic reductions in size, weight, mass and power consumption. It became 'state of the art.' Before the Nuvistor passes into history, it is fitting that its role be properly documented.

Research started in 1956 and many avenues of approach were investigated. Planar structures, cylindrical structures, ceramic-spaced stacked structures, metal-to-glass seals, metal-to-ceramic seals and many other types of construction were carefully explored. The cylindrical concentric open-ended cantilever configuration was selected because it was found to provide a mechanically sound design which allowed for ease and simplicity of construction and readily lent itself to miniaturization.

When a tube structure is proportionally scaled down in size, some characteristics remain constant, others improve, and still others degenerate. For example, cathode efficiency and high frequency performance both improve. General operating characteristics such as mutual conductance and plate resistance remain substantially the same. Cathode current density, however, increases

and the grid and plate operate at much higher temperatures. These latter effects tend to act adversely on tube life and reliability. It was discovered that these effects could be offset if the electrode spacings were spaced down by a greater factor than the other dimensions and if more efficient thermal paths were provided for removal of excess heat.

This differential scaling made possible the use of much lower electrode voltages thereby providing several advantages in addition to the corresponding lowering of the necessary power input. One of the major advantages of voltage reduction was a substantial improvement in cathode life because less energy was imparted to any residual gases which might damage the cathode through ion bombardment. Another advantage was the reduced high-voltage insulation required in the tube, the socket, and associated circuit elements.

In the design of the Nuvistor, specific requirements were established for the elimination of glass and mica, which have temperature and strength limitations that interfere with high temperature processing. Spot-welding during assembly was



From left to right: half-size double-ended triode; 7586 single-ended triode; 8058 double-ended triode; 7587 double-ended tetrode. These are shown approximately 150% of actual size.

also eliminated because it required a high degree of skill and could be a source of residual strains.

For ruggedness, a strong ceramic base-wafer (forsterite) was used as a platform on which was erected an array of tube electrodes, each solidly held in place by brazing. With this type of construction, the Nuvistor electrodes could be made into small, light cylinders which, because of their form and light mass, made for a rugged tube.

The simplicity and cylindrical symmetry of the tube parts and jigs permitted maximum mechanization of the tube assembly. Individual matching of parts, which may have been required in a close-spaced planar design, was not required for Nuvistors. The accuracy of the tube assembly permitted close spacing of the tube elements and, at the same time, provided increased protection against interelectrode shorting.

The materials chosen to form the basic framework of the tube structure, ceramics and strong metals, could be processed at high temperatures in brazing and vacuum exhaust furnaces which eliminated the need for a getter. The combination of a strong brazed structural assembly, all ceramic-metal construction and high-temperature processing, resulted in a tube that operated efficiently under difficult environmental conditions such as thermal or mechanical shock and continuous vibrations.

Nuvistors that were operated for fifty hours at 350 degrees centigrade and subjected to severe shock tests came through unscathed. When immersed in liquid nitrogen the Nuvistors continued to function. It was also discovered that the tubes could be exposed to high doses of radiation without damage.

As Figures 1, 2 and 3 show, the cylindrical electrodes of the Nuvistor were supported on short, tripod-like structures which, in turn, were fastened firmly to a ceramic base-wafer. The wafer served as both a mount support and part of the tube envelope. The forsterite base-wafer



Skewer-like rods held approximately 300 Nuvistors for mass evacuation and induction heating.

(a magnesia-alumina-silicate compound) was metallized prior to use by 'dunking' in a specially developed solution of molybdenum and lithium salts.

The black-coated wafer was then fired in hydrogen to reduce the molybdenum salt to strongly adherent metal. A light grinding operation removed the metal from the top and bottom surfaces (to prevent shorting between the lead-wires), leaving a metal layer on the edge of the wafer and lining the lead-wire holes. These metallized surfaces joined readily to the metal parts during subsequent brazing operations.

The open-ended construction permitted the loading of all but two of the tube parts on a simple assembly jig. The parts were placed in the jig, base up. As a final assembly step, a special jig was used to aid with the placement of the lead-wires, which doubled as pins. At a later date, it became standard practice to place a copper filigree around the base of the pins to insure a better wafer-to-pin seal during the brazing process.

After the basic mount structure was assembled, the tube, while still in the assembly jig, was brazed in a hydrogen atmosphere at a temperature of 1130 degrees centigrade. This brazing operation provided strain-free joints, dimensional stability, uniformity in the finished tube and removed oxide coatings from the metal parts of the structure.

In this process, the hot hydrogen also tended to replace other gases occluded in the various tube parts, thereby simplifying the final exhaust process. To eliminate lint and other impurities that may have gotten into the assembly, it became the practice to give the mounts a high pressure air-blast just prior to exhausting.

The two remaining parts, the active cathode surface and the metal shell, were added just prior to exhausting. The coated cathode cup was placed over the cylindrical cathode support sleeve and bonded to it metallurgically during exhaust and aging. The metal shell was then joined to the ceramic base-wafer at the end of the

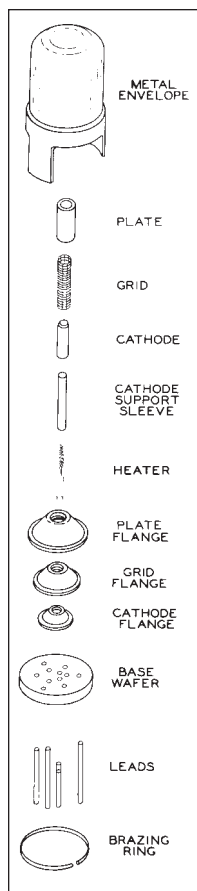


Fig. 1. Exploded view of a Nuvistor triode.

exhaust cycle by a brazing ring which melted and bonded the shell to the outer edge of the wafer, thus completing the vacuum-tight seal. This final vacuum-seal braze was made with a brazing alloy which had a melting point sufficiently below that of copper to prevent the remelting of the copper-brazed electrode junctions.

The tubes, before being exhausted and receiving the final vacuum-seal braze, were removed from their assembly jigs and the cathodes, metal shells and brazing rings added. These were then mounted, base up, in small circular racks which were stacked, shish-kebab style, along a one meter, skewer-like, rod. Each rack held eight to ten tubes and the rod could support thirty to thirty-five racks, accounting

for about 300 Nuvistors per rod. The rods were then inserted into special tubes for mass evacuation and processing by induction heating.

The Nuvistor double-ended triode and tetrode are look-alikes. They can be distinguished, however, because the distance between the bottom of the external ceramic insulator ring and the top of the wafer bulge in the metal shell of the triode is approximately half the corresponding distance in the tetrode.

By July, 1961, RCA had manufactured its one millionth Nuvistor. Later in 1961, after many of the manufacturing processes had been mechanized, the production rate was greatly increased.

The Nuvistor was manufactured for over twenty years, first by RCA until its plant closed in 1976 and then by Sylvania until the early 1980s. Nuvistors were also manufactured by the Japanese.

A full family of Nuvistors was released during this period, including single and double-ended

triodes, half-size, double-ended diodes and triodes, tetrodes, at least one five-watt pentode and long lead-wire versions of many of these tubes, manufactured without indexing lugs, for circuit-board mounting.

A jumbo-sized beam-power Nuvistor was also developed but it is not known if this was ever released. A large variety of "A"-numbered tubes were special purpose Nuvistors or modified ver-

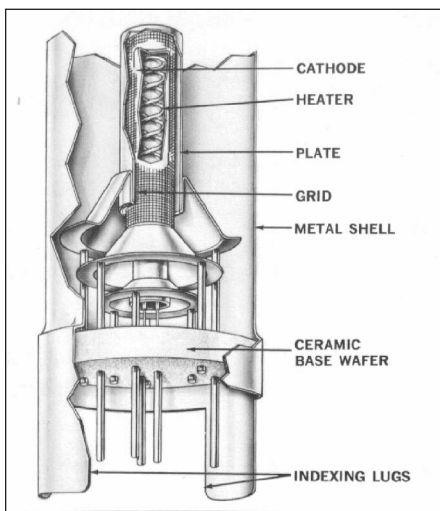


Fig. 2. Cross section of a Nuvistor triode.

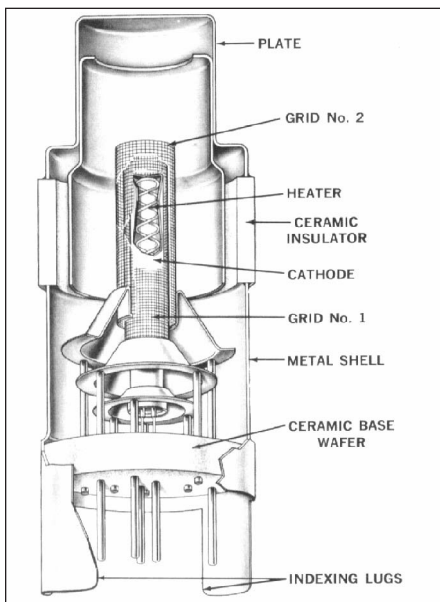


Fig. 3. Cross section of a Nuvistor tetrode.

sions of previously released tubes, manufactured to specification, in limited quantities, for industrial, military and scientific uses. Commercial numbers were never assigned to these tubes.

Because of its longtime success and its many contributions to vacuum tube technology, the Nuvistor deserves a special place in the history of the vacuum tube. The transistor, which it was developed to compete with, eventually caused its demise, but this took many years to accomplish. The Nuvistor was mainly responsible for the success of the RCA TV color sets in the early sixties. ZENITH, RCA's number-one competitor at the time, also used Nuvistors in the front end of their color TV sets.

The success of the Nuvistor Program at RCA was made possible through the cooperation and persistence of many departments: The Advanced Development Group, the Chemical and Physical Laboratory Group, the Receiving Tube Development Group, the Engineering Processes Group and the Equipment Design and Development Group.

Acknowledgements: George M. Rose, father of the Nuvistor, for numerous interviews, many original samples and his copious notes; Joseph C. Poyner, Nuvistor Production Manager, for his tours of the Nuvistor Plant and numerous Nuvistor parts; and John J. Thompson, Nuvistor Design Group Leader, for many Nuvistor tube samples and for proofreading the original draft of this article.

Some of the early uses of the Nuvistor: *Communications Equipment*: oscillators, FM i-f stages; *Telemetry Equipment*: ultrastable oscillators, preamps; *Airborne Weather Radar*: cascode pre-



George Rose with various Nuvistor samples. The large one is the beam-power Nuvistor.

amp, i-f chassis amplifier; *Satellite Mass Spectrometer*: control oscillator; *Surveillance and Closed-Circuit TV*: preamp, video amplifiers; *Nimbus Satellite*: camera preamp; *Weather-sonde*: blocking oscillator; *Sonar*: preamps; *Sonobuoys*: preamp, oscillator and transmitting stages; *VHF Tuners*: TV and FM; *UHF Tuners*: oscilla-

tors; *Integral-Cavity TRF Amplifiers*; *Test Equipment*: VTVM, electrometer devices, vibration analyzers and jet-engine analyzers.

A list of the commercially released Nuvistors with their registration dates follows:

Entertainment Types

2CW4	11/21/60
6CW4	07/04/60
13CW4	11/26/62
2DS4	08/06/62
6DS4	08/21/61
2DV4	09/10/62
6DV4	09/10/62
2EG4	01/03/67

Industrial Types

7586	02/15/60	8393	05/04/64
7587	03/20/61	8441	10/14/63
7895	06/29/60	8456	10/14/63
8056	02/19/62	8627	04/26/65
8058	01/08/62	8628	04/26/65
8203	05/04/64	8677A	02/08/70
8380	10/14/63	8808	06/23/69
8382	10/14/63		



the improvised support line attached to the end of the lens, slung around some hardware at the top of the camera, and weighted down with a tangle of cables.

COVER PHOTO

Chicago's WGN-TV first hit the airwaves in 1948 with a two-hour gala broadcast from its new main studio theater. But from the beginning, the station has had a strong emphasis on news and sports. In this photo, probably taken sometime in the late 1950s, cameraman Charlie Seatsma focuses his RCA TK-10 on the action at a remote broadcast, possibly a Cubs or Sox game. Charlie's long lens seems to have needed a little extra stabilization to stop the wobbles! Note