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ALL ABOUT GETTERS

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Have you ever wondered why some early vacuum tubes had clear glass envelopes, so that the electrodes inside were visible, while other tubes were almost completely coated on the inside with a silvery metallic substance, and still others had a multi- colored appearance? These differences arose from the type of getter used. A getter is a substance placed inside the tube to aid in the removal of residual gases--to "get" or trap the gas molecules that the evacuation process failed to remove during manufacture.

Those not familiar with tube technology may assume that because "vacuum tube" is an often-used synonym for radio tube, all radio tubes were evacuated. This was never the case. The famous "Tungar" rectifier bulbs and the '00 and '00A detector tubes popular during the 1920s contained gas. (The UV-200 and UX-200 used argon gas, but the later UX-200A used cesium vapor.) Gas-filled rectifier tubes such as the 0Z4 and voltage regulator tubes such as the 0B2 are examples of later tubes intentionally containing gas. Nevertheless, the majority of radio tubes required a high degree of evacuation to operate properly, and when such a tube became gassy due to leakage around the seals or gradual release of gases initially trapped inside, it was usually necessary to replace the tube.

The History of Getters

The precise origin of the vacuum tube getter is difficult to establish. Since gettering techniques were closely associated with proprietary tube manufacturing technology, relatively little was published about getters. My radio history books do not completely solve the mystery of the first use of a vacuum tube getter. The earliest tubes clearly did not use getters, but by the early 1920s, getters were commonplace. Evidence exists (see below) that getters were used as early as 1917.

In placing the development of vacuum tube getters into perspective, it is helpful to recall the primitive state of the art during the early years of tube development. Both evacuated and gas-filled tubes contributed to the development of radio, but pioneers often did not fully appreciate the different but useful roles of each nor did they always understand why each behaved as it did.

The first useful radio tube was the diode (two-element) wireless detector tube invented in 1904 in England by John Ambrose Fleming; it utilized an evacuated bulb. In fact, Fleming specified in his patents that the envelope be evacuated to the highest degree achievable in order to get best performance.[1] He further recommended that the bulb be heated by some external means during the evacuation process to help drive off occluded gases. (This high-temperature "bake-out" process is still an essential part of vacuum device manufacturing.) Fleming apparently did not use any type of getter in his detector tube, or "oscillation valve" as he called it.

By the turn of the century, Lee de Forest in the U.S. was striving to develop a complete, practical system of wireless. He recognized, as did many of his contemporaries, that the detector (generally a coherer in those days) was the weakest link in the then-popular systems. De Forest experimented with a number of detectors, including modified coherers, electrolytic detectors, and flame detectors, but concluded that some radically new and improved detector was needed. His 1906 invention of the triode (three-element) tube, or "audion" as he called it, stands as one of the great discoveries in the history of radio technology.

Debate continues today as to whether de Forest invented the audion solely as an outgrowth of his work on flame detectors or whether he was merely trying to find a way to circumvent the Fleming patent. De Forest always claimed the former and denied that he even knew of Fleming's valve prior to his invention of the audion, which he said had little in common with the Fleming valve other than superficial appearance. Both Gerald Tyne and Hugh Aitken state that there is evidence that de Forest was well aware of Fleming's invention.[2] In any case, de Forest's audion was not a highly evacuated tube. Indeed, he argued that the presence of gas in the bulb was an essential part of the invention. Accordingly, there were no getters in audion tubes. Tyne explains the operation of the audion as follows: "A tube containing a small amount of gas, such as the early audions, has sensitive spots (kinks) on its characteristic curves, particularly when operated at low anode voltages. These result from the ionization of small traces of gas, too small to make the tube break over into blue glow. This ionization causes a reduction in space charge and results in greatly increased anode current. When operated on one of these kinks the tube has phenomenal sensitivity as a detector."[3]

During the first two decades of the twentieth century, understanding of the physics of electronic conduction in vacuum and ionized gases was sketchy, and arguments raged on in the technical press about whether radio tubes should be highly evacuated or have gas purposely introduced. The terms "hard tube" (referring to a highly evacuated tube) and "soft tube" (referring to a tube containing gas) were adopted, and each had its champions.

It is easy to understand why confusion developed during this period as to which type of tube was best. The available facts at first seemed inconsistent. The Fleming diode was highly evacuated and worked fairly well as a detector. The de Forest audion was gas-filled and worked even better. H. W. McCandless, who manufactured audions for de Forest, warned his customers that a high vacuum decreased rather than increased sensitivity.[4] The type '00 (UV-200) detector, introduced in 1920, was gas-filled and was a very sensitive detector. In light of this string of successes for gas-filled tubes, many non-experts concluded that gas-filled tubes were the design of choice for detectors, and there was probably a tendency to assume that the same was true for tubes intended as amplifiers. But evidence was steadily accumulating from work at General Electric and Western Electric that triode amplifier tubes needed evacuation to operate properly and that a tube which performed well as a detector might not perform well as an amplifier and vice versa. Stokes notes that "Because the so-called 'soft' tube, i.e., one containing a comparatively poor vacuum, had been found to be considerably more sensitive than a 'hard' tube when used as a detector this fact actually hindered [the hard tube's] development as an amplifier."[5]

Prior to World War I, vacuum pumps were crude. Instruments for accurately measuring high vacuum and calibration standards were not readily available. Techniques for producing reliable metal-to-glass seals were not widely known. It is quite possible that unimpressive performance reported by some early researchers investigating "evacuated" triode amplifier tubes resulted from their failure to achieve and maintain an adequate vacuum during their experiments. Furthermore, the need for proper grid bias for vacuum triodes was a subtlety discovered only after considerable experimentation with triodes took place, and so operating points used in early experiments were probably far from optimal.

Systematic research on the physics of tubes at the major industrial research laboratories, particularly General Electric and Western Electric, finally led to an understanding of vacuum and gas-filled tube behavior so that the performance of detector and amplifier tubes could be predicted from first principles. By about 1920, it was clear that while fairly effective gas-filled detector tubes could be made, triodes intended as amplifiers should be highly evacuated.

As appreciation for the importance of achieving a high vacuum grew, tube engineers began to include getters in the vacuum tubes they designed. In 1920, though, this practice was not widespread. Tyne mentions that some of the tubes made by General Electric as early as the 1917-18 period employed getters, but GE was considerably more sophisticated than most other companies involved in tube technology at that time.[6] This reference to the use of getters is the earliest I have found. However, the idea of placing something inside a tube to influence the internal gas pressure appeared three years before that. A tube designed by H. J. Round of the Marconi Company circa 1914 utilized a pellet of asbestos in its tip "which could be heated, usually with a match flame, in order to modify the degree of vacuum as required."[7] From the cryptic description given, it appears that this asbestos pellet may have *given off* gas when heated rather than *absorb* gas as a getter would.

Stokes implies that gettering was not used to any significant extent until GE developed the thoriated tungsten filament in 1921. Traces of residual oxygen had a much more deleterious effect on the performance of thoriated tungsten than on previously used filaments. Langmuir and his colleagues at General Electric, observing this phenomenon, utilized a magnesium getter in order to realize reliably the potential of the new filament.[8] The first edition of Van Der Bijl's classic comprehensive book on tube theory and practice, *The Thermionic Vacuum Tube*, copyrighted in 1920, discussed the physics and technology of vacuum tubes and the effect of residual gases in great detail, yet the word "getter" was nowhere mentioned, which suggests that the use of getters was rare at that time.[9]

Types of Getters

In the early days of broadcasting, some receiving tubes of a given type used getters while others of the same type did not. For example, the early Westinghouse WD-11 "Aeriotrons" did not use a getter. Later, the "Radiotron" WD-11 tubes made by Westinghouse but sold by RCA used a lime getter (calcium oxide) applied on the sides of the glass stem inside the tube. You can spot one of the lime getter tubes by looking for a white powdery deposit on the glass at the point shown in Fig. 1.

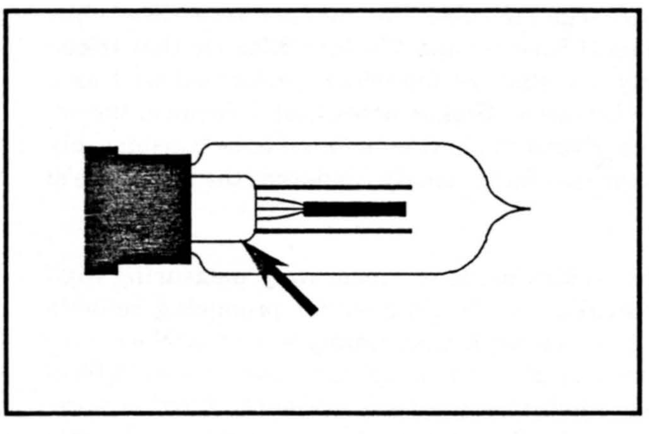

Fig. 1. Location of the lime getter in WD-11 tubes.

For a short period during the early 1920s, red phosphorous getters were used in tubes such as the UV-199 and UV-201A made for RCA by General Electric at their Nela Park plant near Cleveland. These tubes, often called "rainbow tubes," are highly prized by collectors because of the unusual iridescent colors in the tube envelope, typically reds and golds. At the same time, tubes made by General Electric at their Harrison, NJ, plant used magnesium getters which gave them the more familiar silvery coating inside the bulb. In fact, the vast majority of the UX-201A tubes manufactured throughout the twenties employed the magnesium getter. In most tubes of this period, the amount of magnesium used was sufficient to coat almost the entire inside of the tube envelope.

Not all colored tubes owed their colors to getters. Several companies employed gimmicks during the 1920s and 30s to boost tube sales. Companies such as Arcturus and Brightson marketed tubes made with blue glass. The color of the glass had nothing to do with gettering, unlike the rainbow tubes mentioned earlier, but was simply a marketing ploy. The blue glass tubes did look more impressive when lit than ordinary tubes, and the public may have thought that the blue glass somehow improved performance, a misconception undoubtedly encouraged by these firms.

As tube technology evolved during the 20s and 30s and indirectly heated cathodes replaced the simple thoriated tungsten filaments, getter technology also progressed. Higher vacuums were achieved. Getter geometries were optimized for various classes of tubes. New getter materials began to be used. For example, many of the more modern-type tubes used barium as a getter.

Gettering Technology

There are a number of criteria to consider when selecting a getter material and geometry and integrating the getter into the manufacturing process. An ideal getter would remove any gas molecule, but it is difficult to find a getter that is equally effective for all gases. Commonly used getters are chemically active substances such as magnesium, calcium, barium, strontium, phosphorous, aluminum, or combinations of these. Some of the gases that these getters are intended to remove cause more problems in tubes than others. Oxygen is particularly troublesome because it oxidizes the cathode material and alters the electron emission from the surface. Even inert gases can have adverse effects, since they ionize, producing electrons and positive ions. The positive ions neutralize the space charge and change the tube characteristics. They can also strike the cathode with sufficient force to sputter off active material and degrade the emission.

Some types of getters (e.g., the lime getter used in some WD- 11 tubes) were simply applied within the bulb and left to function, but metallic getters were usually "flashed" (vaporized by rapid heating) at the end of the evacuation process. This step occurred after a relatively long period of pump-down and bake-out.

When the glass bulb is heated during bake-out, the glass gives off trapped water vapor, carbon dioxide, and nitrogen. If the temperature is raised in increments during the bake-out process, additional gas is evolved at each step. There is a limit to how high the temperature can be raised, since it must be kept below the point where the glass softens and changes shape. Typical glass bake-out temperatures are in the range 300 to 500 degrees Celsius, depending on the type of glass used. The metal parts of the tube may be heated to higher temperatures than the glass envelope by techniques such as radio-frequency induction. Still other gases such as carbon monoxide may be evolved from the metal parts of the tube during the bake-out process. For metal- envelope tubes, the entire tube is usually heated to high temperatures in a gas-fired furnace.

Getters operate in more than one way.[10] In part, the gas molecules in the tube react chemically with the getter and in part the gases are adsorbed and trapped in a monatomic layer on the surface of the getter. The getter works not only at the time of tube manufacture, but continues to take up gas over the life of the tube. (Some authors refer to the getter as a "keeper" when performing the latter function.) Gases taken up by the surface of the getter may, in some cases, slowly diffuse into the getter material, thus permitting the surface of the getter to take up additional gas.

In receiving tubes, the getter is typically attached to the anode. In some tubes, particularly transmitting tubes, a separately heated auxiliary electrode is used for the getter. When the metal structure of the tube is heated during the bake- out and evacuation, the typical getter evaporates and is deposited on the inside wall of the tube. The getter must be carefully placed so that the evaporating material does not deposit in regions where it could cause problems. For example, a metallic getter must not be allowed to deposit on the glass stem between the lead wires lest it cause a high-resistance leakage path or even a short circuit. For high-power tubes, it is important to avoid coating too much of the glass surface since a mirror-like getter material such as magnesium will reflect the heat back into the tube and the tube will overheat.

Induction heating was often used to flash the getter material in glass envelope tubes, but induction heating cannot be used to vaporize the getter in metal-envelope tubes since the envelope shields the inside of the tube from electromagnetic fields. A commonly used gettering technique for metal tubes was to weld a tantalum ribbon between the metal envelope and the ground pin of the octal base. The ribbon was formed into a trough and filled with barium beryllіate. After pump-out, a high current was sent between the shell and the ground pin, heating the tantalum strip and causing the barium berylliate to react with the tantalum to form free barium, an excellent getter material.[11]

Conclusion

Without getters, vacuum tube technology could not have progressed as rapidly as it did, and the electronic age we know today would probably not have evolved in quite the remarkable way it did. The manufacture of the complex integrated circuits of today involves elaborate vacuum technology during the processing, and so perfecting the technology of evacuating and gettering vacuum tubes helped pave the way for the solid-state era.

References

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4. Aitken, p. 231.

5. John W. Stokes, *70 Years of Radio Tubes and Valves* (Vestal, NY: Vestal Press, 1982), p. 8.

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7. Stokes, p. 10.

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