175HQ - Amplifier For Submarine Telephone Repeaters

- Click on the images to enlarge.

‘On the ocean floor…life begins at 5000 hours’ says a Bell Telephone ad in Electronics, August 1955. This tube was so special that its life could start only after 5000 hours ageing full ratings, equivalent to the whole span life of a high-rel tube or to five average lives of any receiving tube.

The history of submarine communication cables dates back even before 1850, but the transmission of telephone channels in long submerged lines asked for line repeaters, capable of reliable and uninterrupted operation for many years. The 175HQ was designed to grant 20 years life to the entire submerged section of the TAT-1 transatlentic system, containing 306 tubes in its 102 bubble repeaters.

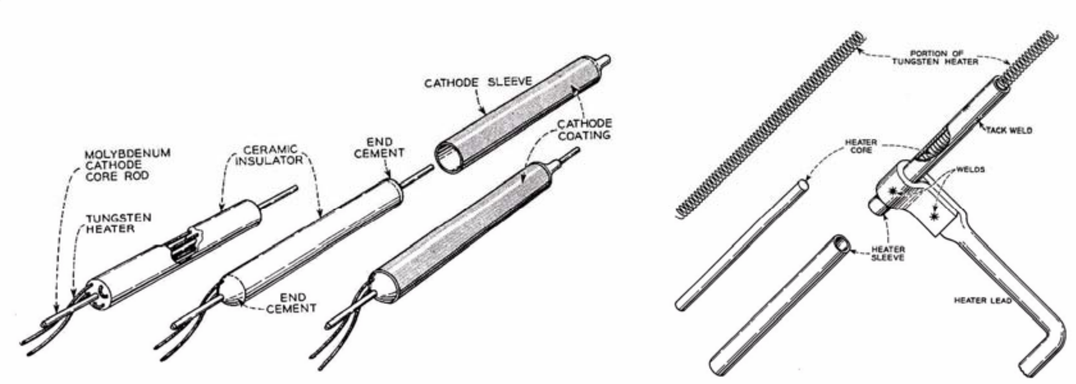
At Bell Labs. the work on tubes for transatlantic repeaters was started since 1933, first on filamentary tubes capable of useful life around 6 or 7 years, then on unipotential cathode triodes and on pentodes shortly later. The developmental work was restarted after the war. Long life was a common requirement in telephone repeaters, but here the repeaters were laid on the ocean floor, some 3000 meters under the ocean surface. Any single failure would have required long and extremely expensive operations. The design of this tube was then accurate in each particular detail. All the design and production steps were run at Bell Labs.

18 units out of a first production run were used in a field trial in the Key West – Avana telephone cable laid in 1950. Even if no failure or performance drift were evidenced in the cable for over 6 years, the tin plated leads of the early production were found to be capable of growing potentially harmful ‘wiskers’. Modified production runs were launched, starting from 1953, to provide tubes needed for the Newfoundland-Scotland transatlantic cable, for the Washinghton-Alaska cable and even for a cable to be laid between California and Hawaiian Islands.

The basic design assumptions in the development of such a tube were to operate at relatively low anode voltage, 60 volts, and to keep the cathode temperature and the same cathode current density as low as possible, in order to obtain a stable emission through the expected life. After years of investigations and of comparative tests on emission and stability of cathodes operating at temperatures well under the values commonly used before, it was decided to operate at 670 ºC, corresponding to a cathode power of about 4 watts. A coated cathode surface of 2.7 square centimeters was provided, resulting in a current density of about 0.7 milliampere per square centimeter at 2 milliamperes cathode drain. By comparison in conventional tubes typical current densities in the order of 50 milliamps per square centimeters can be found. Electrodes were well spaced to prevent shorts, resulting in an acceptable Gm of 1,000 micromhos at 2 milliamps.

All the details in the tube were carefully designed, thoroughly tested and subsequently modified wherever even the smallest potential trouble was evidenced. The flexible leads were made of gold-plated stranded beryllium copper, the control grid being brought out through the opposite end from other leads.

The some 36 inches of tungsten heater wire were helix-wound, threaded through six peripheral holes of an alumina insulating cylinder and eventually cemented in a single heater block. The cathode sleeve was then slipped on the heater and welded to a molybdenum rod, used as mechanical support and as connecting lead for the cathode itself. To prevent stresses and weak points, the heater helix was welded to the internal walls of small nickel terminating sleeves. Click on the image below for details.



Cathode-heater assembly and heater wire termination

The precise bulb was sized to firmly hold the upper mica spacer. The tube in its shock adsorbing rubber mount could safely withstand a single 500 g one millisecond shock, five times the maximum expected value.

As said before, the entire system was designed with the objective of 20 years of uninterrupted service. With some 6000 components in the submarine repeaters, including the 306 vacuum tubes, the average failure rate should not exceed 1 in a million. Actually the system operated with not even a single failure for about 22 years, until it was withdrawn from active service.

The 306 tubes totaled some 50 million hours, resulting in an observed mean time between failures or MTBF in excess of 5700 years, equivalent to 57 centuries! Not bad for a vacuum tube and I wonder how many solid-state devices can ensure today the same reliability.

Here is the full article from the BST Journal describing this outstanding tube.

Photo gallery.