Metal Ceramic Tubes to Withstand 500 C and High Vibration

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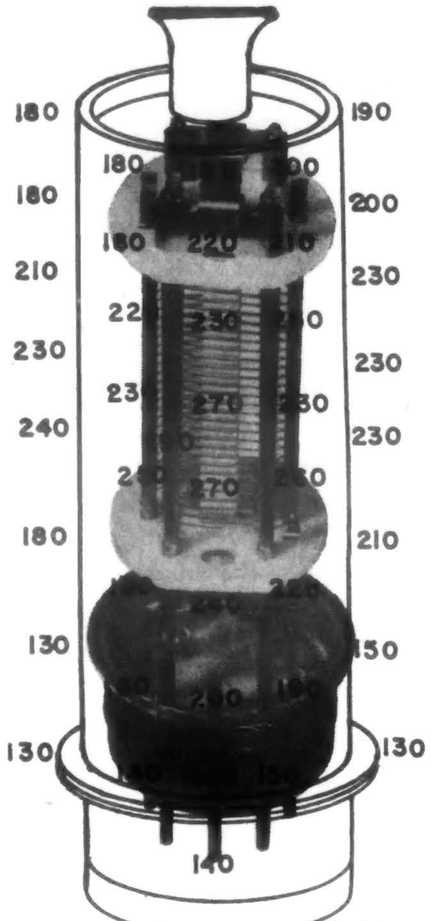


Fig. 1. Temperature distribution about external anode tubes made of .020 in. thick monel. (Temperatures in deg C.) $E_f = 6.3$ vac, $E_b = E_{c2} = 250$ vdc, $I_b = 65$ madc.

FLIGHT at sonic speeds and guidance of missiles beyond the convecting gasses of the earth's atmosphere has not only increased the complexity of electronic control gear, it has also presented new problems in heat dissipation and high-vibration environments. Control of the environment requires weighty equipment where an almost insurmountable problem already exists in merely carrying the jet or rocket engine, the fuel and basic pay load to its objective. The development of components capable of operation in the environments encountered without the aid of pressurizing and cooling is obviously desirable and almost mandatory.

Current estimates of environmental requirements include swept-frequency or random frequency vibration with frequency components up to 2000 cps at levels of 20g and ambient temperatures of 500 C.

The operation of tubes in the environments described, gives rise to a number of problems:

- If ambient temperatures of 500 C are encountered, envelope temperatures must exceed the ambient by some gradient temperature between the internal element temperature and the ambient. Conservatively, in a conventional glass tube, the differential temperature would be 100 C for a bulb temperature of 600 C. Operation of glass envelopes at 600 C is impractical for a host of reasons, including electrolysis, deterioration of seals, diffusion, mechanical limitation, etc.
- The vibrational requirements preclude the use of large structural masses and a situation results where large dissipating surfaces are desirable for heat dissipation but are undesirable for vibration reasons.
- A high vacuum tube must be processed at temperatures considerably in excess of any operational temperatures or outgassing of internal parts and surfaces will occur resulting in deterioration in cathode activity among other effects. The processing temperatures required eliminates the use of any glass currently available that is otherwise adaptable to tube manufacture.
- At temperatures above 250 C the use of conventional barium getters becomes marginal, at 500 C it becomes impossible. If some internal surface of the tube could be maintained at 700 C or higher, zirconium getters conventionally used in small power tubes might be used; but operation at various temperatures below 700 C would most certainly happen in most applications. There is also a problem of transient outgassing of hydrogen at 400 C with zirconium.
- With a wide range of envelope temperatures, a variation in cathode temperature may be expected and the need for automatic compensation in heater input for changes in ambient temperature is probable.

The approach to the problems outlined above and described herein consist of replacing the glass envelope in a conventional tube with a metal-ceramic envelope, using the envelope as the anode and providing a suitable getter to replace the barium flash getter. The reasons for this approach and its advantages follow:

- The use of a metal envelope provides better heat radiation than can be gained with a refractory. Further by using the envelope as the anode the greatest possible radiation area is achieved. Inasmuch as the anode usually has the greatest mass of any element, it is desirable not to require its support with the structure by ceramics or micas which may fracture or wear under vibration. A number of metals were investigated for use in envelopes and the choice of monel was made mostly on the basis of its oxidation resistance.

To complete the envelope, a stem of alumina ceramic closely resembling the glass button of a conventional tube is used. The ceramic is coated using a moly-manganese technique. The stem shown in Fig. 2 has two piece leads, the inner portion of moly provides a vacuum tight seal which remains in compression. The outer section of monel completes the circuit through the brazing material and provides an oxidation resistant base pin.

A flare is sealed to the outer periphery for subsequent heli-arc welding to the metal envelope. (See Fig. 2)

- The use of the stem enables the assembly to proceed by making cages, and mounts in the conventional manner, replacing the header sealing machine with a heli-arc sealer and evacuating in a conventional exhaust machine. Processing temperatures in the neighborhood of 1000 C can be used. Fig. 2 shows a typical mount.
- Various getter techniques have been tried including parts made of titanium and zirconium or parts coated with titanium, zirconium or Ceralloy powders. The results of many of these tests were inconclusive and the constant suspicion of getter materials or coating processes led to the development of a technique for quantitatively measuring the gettering ability of various coated parts. A closed glass system was provided which could be baked-out and subsequently filled with CO_2. The system contained approximately 2 liters of volume and comparison measurements were made by admitting a pressure of 50 microns of CO_2, heating the getter and plotting rate of pressure decrease for various getter temperatures. (See Fig. 3)

Results of tests in this system confirmed much

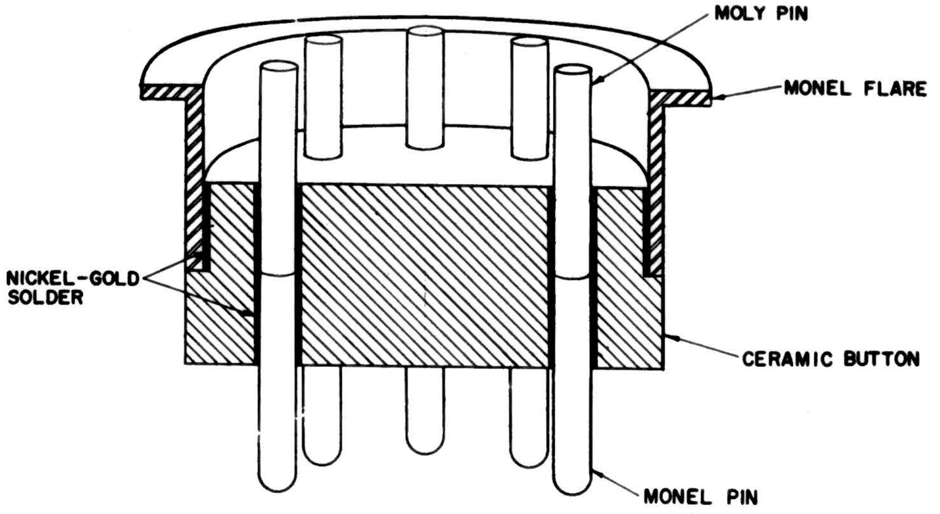
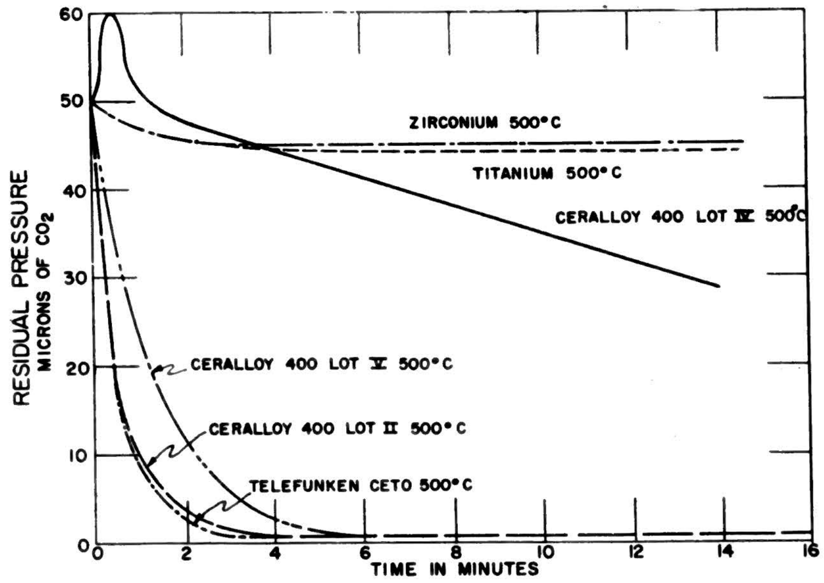


Fig. 2. Alumina ceramic stem of the metal ceramic tube. The moly portion of the pin provides a vacuum tight seal which remains in compression.



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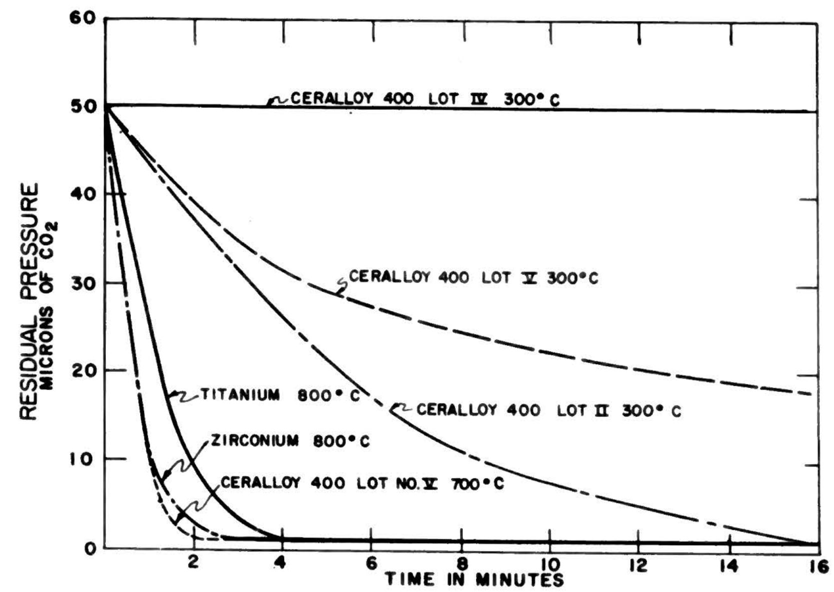

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Fig. 3. (a and b) Residual Pressure Vs. Time—These graphs show the rate of pressure decrease as a function of getter temperature for different getter materials.
a) Effect of low and high getter temperatures (300 C Lot IV was bad.)
b) Getter temperature = 500 C.

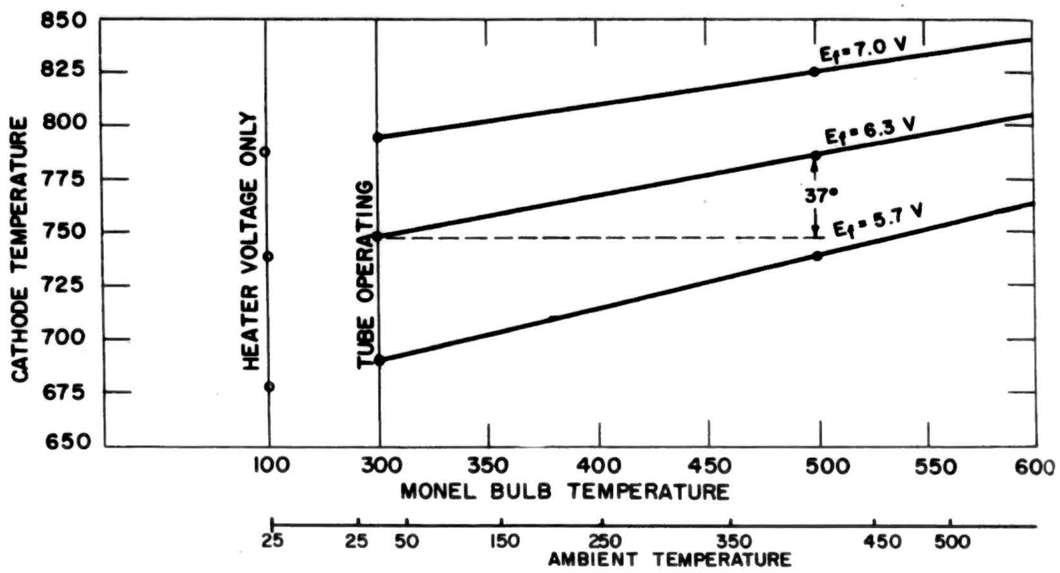

Fig. 4. Cathode temperature variation as a function of ambient and bulb temperatures (deg C). $I_f = 800$ ma at 6.3 vac, $I_b = 65$ madc.

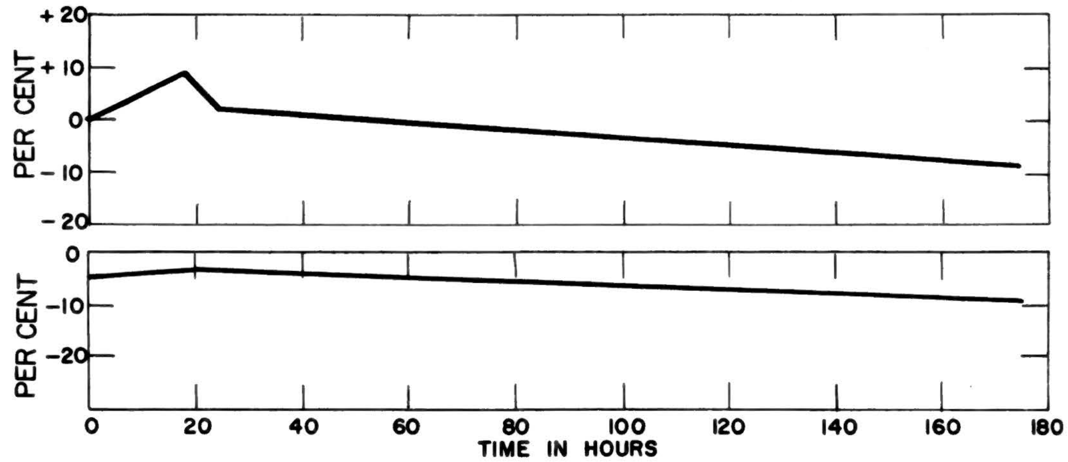

Fig. 5. Transconductance vs. time in a 500 C ambient a) Per cent change from initial value with $E_f = 6.3$ vac b) Per cent change from value at normal filament voltage with $E_f = 5.7$ vac.

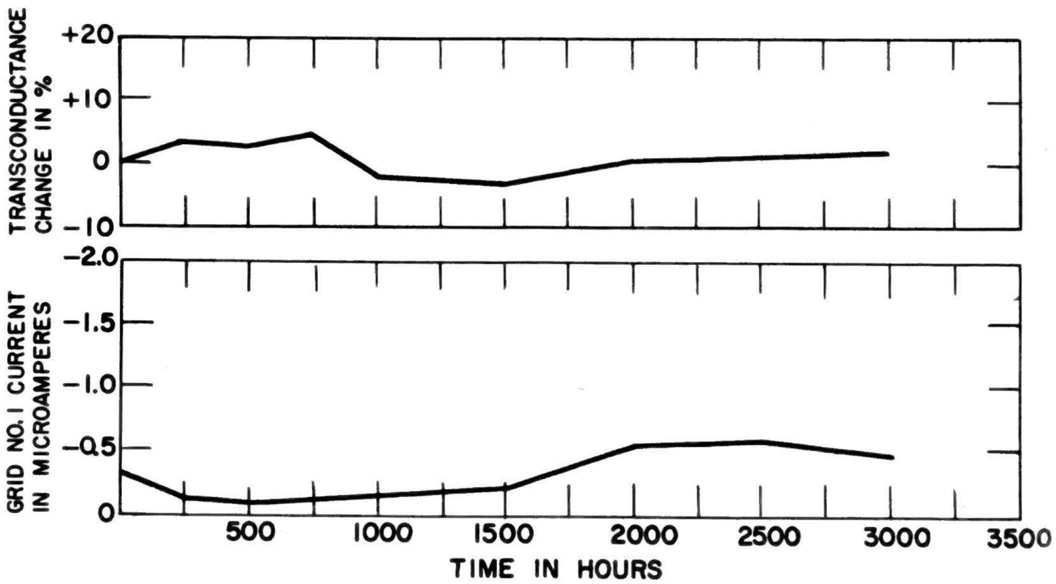

Fig. 6. Room temperature life tests.

of the information gleaned from literature indicating Ceralloy (or Ceto) as the best getter for this application. The Ceralloy getter, when properly manufactured and processed shows great promise. Tests of a good lot of this getter showed that 1500 liter microns could be gettered in a matter of minutes in the temperature range from 300 C to 700 C. Some gettering, at the slower rate, was observed at temperatures down to 100 C.

The Ceralloy getter is either sprayed on various element surfaces or sprayed onto a metal flag which is welded in a strategic place in the tube. The minimum 100 C for gettering has been found to exist in tubes due to radiation from the cathode alone.

Due to the opaque nature of the subject tubes, exact variations of cathode temperature due to changes in ambient temperature have been difficult to measure. Fig. 4 shows within reasonable experimental error the variation of cathode temperature with both ambient and bulb temperatures. In the case of the ambient temperature, measurements were made midway in the 1/8 in. clearance between the tube envelope and an enclosing oven, opposite a point roughly midway between the bulb hot spot and the dome of the envelope.

The variation in cathode temperature is lower than was expected. However, at the 400 C ambient, the external anode is not appreciably hotter than the vacuum and glass insulated internal anode of a conventional glass tube when operated at full dissipation in a room temperature ambient. This fact permits high ambient rating without heater power derating.

Tubes of the type described herein have been operated for several thousand hours at room temperature ambient and up to 200 hours at ambients in excess of 400 C. Several tubes have been operated at —60 C for 100 hours. Curves of various characteristics for the high temperature and room temperature life tests are shown in Fig. 5.

The room temperature data is averaged for 14 tubes in the group which were tested to 3000 hours. Much larger groups were tested to the 1000 hour point and removed to provide space for succeeding groups. This additional data in the majority of cases merely confirms the 1000 hour data shown (Fig. 6).

The high temperature data is provided for 172 hours. The equipment required for this test is fairly involved and at the time of writing is limited to engineering test quantities. Gas current readings throughout the test remained below 0.2 microamperes which was characteristic of high temperature life tests run for short periods.

From a paper presented at the 1957 National Conference on Aeronautical Electronics, Dayton, Ohio.