RF POWER SOURCES

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Before discussing specific tube types it seems worthwhile to mention the basic differences between two of the fundamental structures used for many of the gridded high-power tubes, namely the single ended and double ended structures.

In the single ended structure, the simplest mode of operation is the quarter wave mode, with a voltage maximum along the axis of the tube. This structure ceases to be useful if the active length greatly exceeds 30°. Increasing the diameter of the tube is limited by "deadhead" capacitance. Also the possibility exists of circumferential modes.

The double ended structure is basically two single ended ones joined head on. Here the fundamental mode of operation is the half wave mode. If a certain length could be tolerated in a single ended structure at a particular frequency, twice this length would be tolerable in the double ended version, thus doubling the power generating capabilities of the tube. The "deadhead" capacitance no longer exists. Again, the existence of circumferential modes limits the diameter of these tubes. The double ended tube is the fundamental building block for the larger tubes. It can be scaled to any frequency between 200 Mc/s and 1200 Mc/s.

A sketch of a strip beam triode is shown in Fig. 1. The grid bars here are shaped to give very low grid current and consequently high power gain. Super-power triodes of this sort are made of unitized construction, that is, individually sprung cathode sections, frequently a unitized grid structure, and a common anode for electron optical and mechanical reasons.

The shielded triode concept is given in Fig. 2. Here, a shield tee is interposed between the grid and anode, and this is kept at cathode potential. Electronically this is like a tetrode whose screen is at zero potential. There is no need to bypass the shield tee, but it can be brought out to a separate flange. In this structure, the grid-plate capacitance is typically about 12 pf, the screen-plate capacitance about 300 pf, and the input capacitance about 1500 pf.

Two types of cathode bars are used for the high-power tubes. These are illustrated in Fig. 3. One is just a thoriated tungsten bar, the other an oxide coated nickel powder matrix. In the RCA triodes, all cathodes are rated at 4 amps/cm^2 peak emission for the thoriated tungsten cathode and 10A/cm^2(at the present time) for the matrix cathode.

Presently, the matrix cathodes are used only in tubes for short pulse work, while for longer pulse work, the thoriated tungsten cathodes are used.

A sample of high-power tube types in existence or under development at RCA is given below.

1) Type 5831. This single ended triode was one of the first high-power tubes. It is capable of 500 kw, cw operating up to 15 Mc/s. Some of these tubes have been under vacuum for more than 12 years, and lifetimes of up to 30,000 hours have been recorded. This tube will be used on the new Bevatron injector as a series regulator.

2) Type 6949. This is a single ended, shielded triode, and is capable of 600 kw, cw operation, up to 70 Mc/s. The tube is used in the Berkeley and Yale Hilacs, where it delivers about 1 Mw in pulses of up to 3 msec duration. The Berkeley machine operates at 15 pps. The Yale group has recorded lifetimes of the order of 10,000 to 15,000 hours. To summarize, this tube switches, at 40 kv, 300 amps of peak current in pulses of about 3 msec and will modulate 600 kw.

3) Type 6950/2039. This is a double ended version of tube type 6949. It is capable of 1.5 Mw peak power at 200 Mc/s, 2 msec pulses with a duty factor of 0.05. Average power is 75 kw. Lifetimes of 25,000 to 30,000 hours are on record.

4) Type 7835. This triode is intended for grounded grid operation exclusively. The internal structure for this tube is shown in Fig. 4. The grid wires are 0.003 inches diameter tungsten. This tube is being used with the injector for the Argonne ZGS. It has not yet been operated into a reactive load. It has been run into a dummy load up to 605 Mc/s, and at 400 Mc/s has produced 440 kw average power under pulse condition. In cw operation, this tube should deliver about 1 Mw in the 200 to 400 Mc/s region. This particular type is also being produced with the matrix oxide cathode for short pulse work. In this case it should be capable of 50 to 60 Mw pulsed operation.

5) Type 4612. This is another version making use of the same basic structure shown in Fig. 4. This particular type is used in the CEA, where it delivers 500 kw peak power at 475 Mc/s, for 8 msec pulses.

6) Types A2335 and A2344. These tubes are again frequency scaled versions of the tube type 7835. This particular one has not yet been pulsed, but is expected to operate at levels in the Mw range with 2 msec pulses, 6% duty factor. In cw operation this tube has delivered 70 kw average power at 825 Mc/s. Tube type A2335 is intended for cw service, tube type A2344 for pulse operation.

7) Type 2041. This is an "inside-out" tetrode of which the basic structure is indicated in Fig. 5. Again, a number of tube types, similar in construction,are available. This structure is used up to 1000 Mc/s, and is available with the thoriated tungsten or matrix cathode. This tube can handle 2 Mw peak power for short pulse operation and 250 kw peak

power for longer pulse durations. It is a grounded cathode tetrode with internal bypassing, resulting in higher gains at 200 Mc/s.

8) Type A15038. This is a coaxitron, a generic name given to a certain family of tubes. The coaxitrons are characterized by integral overcoupled, fixed circuits, with no tuning or movable adjustments whatever. These are broadband devices for fixed frequency applications. The tube type A15038 has an 18% bandwidth at the 3 db points, and is rated for 5 Mw pulse power, in 25 μsec pulses with a duty factor of .008, over a frequency range of 385 to 465 Mc/s.

9) The Stanford klystron. RCA is building klystrons of the Stanford design, to be used on the two-mile accelerator. This particular tube is a five cavity device, capable of 24 Mw peak power during 2.5 μsec pulses, with an average power capability of 21 kw. The tube operates at 50 db gain with 38% efficiency.

10) Type A2581. This is an air cooled tetrode capable of 1 Mw peak, 10 kw average power, at 450 Mc/s.

Discussion

G. W. Wheeler (Yale): I might say that we have lost up until now, only two out of nine tubes, type 6949, with four tubes operating. It is interesting to note that the two tubes that failed, did so at 5000 hours.

R. P. Featherstone (Minnesota): Would the peak emission value have to be derated at some stage during the lifetime of a tube?

M. V. Hoover (RCA): The rated peak emission is for the full lifetime of the tube with either type of cathode.

R. H. Rhéaume (BNL): What is the cathode temperature of the tube type 7835?

M. V. Hoover (RCA): 2000° K, which is, I think 1606° brightness temperature.

K. Batchelor (Rutherford): What filament current and voltage are required?

M. V. Hoover (RCA): For this particular tube, 4 volts at about 7000 amperes. This tube has a cathode area of 300 cm^2, the largest area we know of in any tube in this class.

J. P. Blewett (BNL): How much temperature rise do you allow on water in the tube cooling system?

M. V. Hoover (RCA): We are reluctant to operate with water coming out at higher temperatures than 160°F, because above this temperature, impurities would deposit on the anode.

R. H. Rhéaume (BNL): Would you comment a bit on evaporative cooling?

M. V. Hoover (RCA): We have had no need to work with it up until now. It is a compact, efficient energy transfer method. There is one negative aspect that I might mention. I have seen these systems rattle violently, and feel certain that this must give rise to microphonics.

R. B. Neal (Stanford): Could you have ruptures on the grid of the tube type 7835, and still continue to operate?

M. V. Hoover (RCA): Yes, I think you could. There would be small sections where the optics would be disturbed, of course.

R. H. Rheaume (BNL): Would you quote grid dissipation figures for pulse and cw operation of the tube type 7835?

M. V. Hoover (RCA): We do not know where the limits are. We will allow 20 kw average power, and they have been operated up to 40 kw. In practice, you do not need this much. To achieve 5 Mw at 400 Mc/s you need 160 kw of drive power, which is about 9 kw average power at 6% duty. I suspect that only about 1 kw shows up on the grids, the remainder being feed through power and circuit loss.

K. Batchelor (Rutherford): Do you normally use water as a cooling liquid?

M. V. Hoover (RCA): Ordinarily we use water; other coolants may be used, for example Fluorochemical 75, Ethylene Glycol mixtures, oil, etc.

J. W. Bittner (BNL): How would the performance of the tube type 7835 be affected if you use the usual grid structure?

M. V. Hoover (RCA): This could be made, but the gain of the tube would be considerably less. This is a favorable structure allowing us to go to higher frequencies. We know the electronics will run even through S-band frequencies with gains of 10 db and efficiencies of 50%, so all we have to do is scale the tube.

R. H. Rhéaume (BNL): Do you try to inhibit secondary emission from the tungsten grid of the tube type 7835?

M. V. Hoover (RCA): No, we have never noticed any sign of it in the characteristics. The grids are platinum-clad tungsten.

A. van Steenbergen (BNL): Some ceramics running at high temperature have a tendency to poison the cathode. Have you had any trouble of this sort?

M. V. Hoover (RCA): No, the ceramics are normally a safe distance from the hot areas in the tube structure.

R. P. Featherstone (Minnesota): Will the commercial versions of the coaxitrons have getter-ion pumps?

M. V. Hoover (RCA): Yes.

R. B. Neal (Stanford): What is the base metal for the matrix oxide cathode?

M. V. Hoover (RCA): A high nickel stainless tool steel. One of the brand names is Hastalloy B, but several brands are available. In substance, it is just a high strength stainless steel.

R. H. Rhéaume (BNL): Is a passive or active nickel powder used in the matrix oxide cathode?

M. V. Hoover (RCA): Very passive.

R. P. Featherstone (Minnesota): With a matrix oxide cathode, have you had any experience with Barium migrating onto the grid?

M. V. Hoover (RCA): Yes, if you put the matrix cathode in a tube with a grid which runs hot, you are wasting your time. All the tubes here run with cold grids, and we have not seen any evidence of re-emission yet.

J. P. Blewett (BNL): In view of the success of the earlier tubes, why did you put getter-ion pumps on the coaxitrons?

M. V. Hoover (RCA): They are used on the coaxitron because there is no space available inside for the regular getter.

R. H. Rhéaume (BNL): Do you plan doing any long pulse work with the matrix oxide cathode?

M. V. Hoover (RCA): We may try to do this for low repetition rate applications.

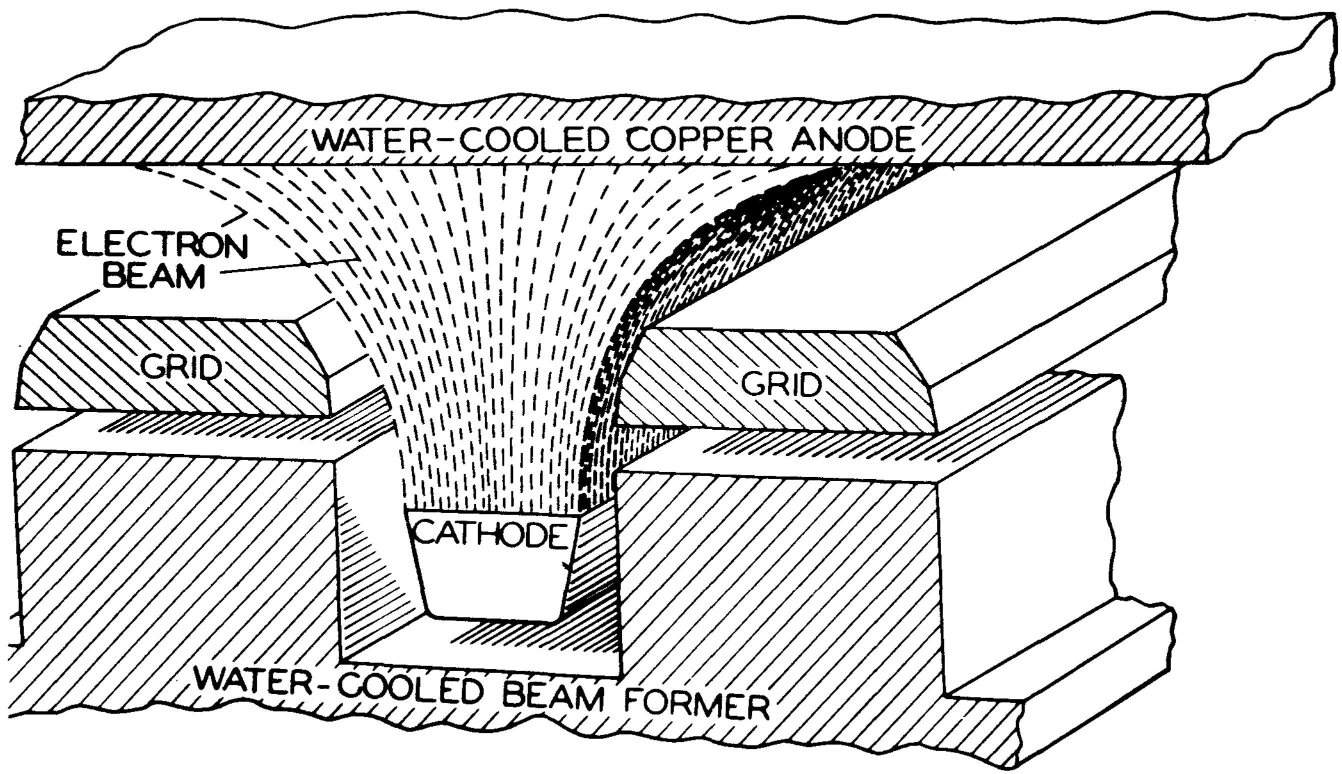

Fig. 1

Strip beam triode

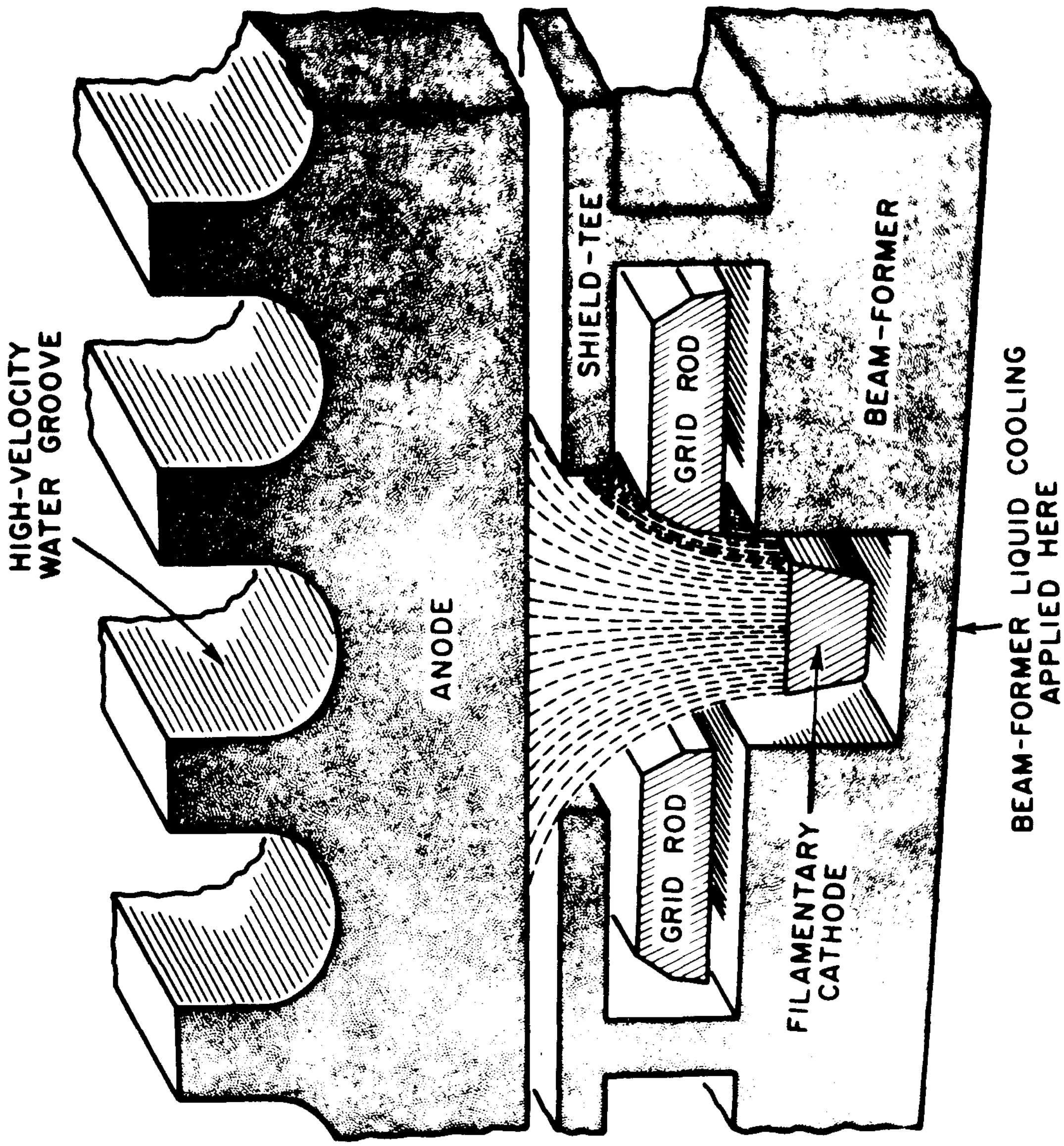

Fig. 2

Shielded triode

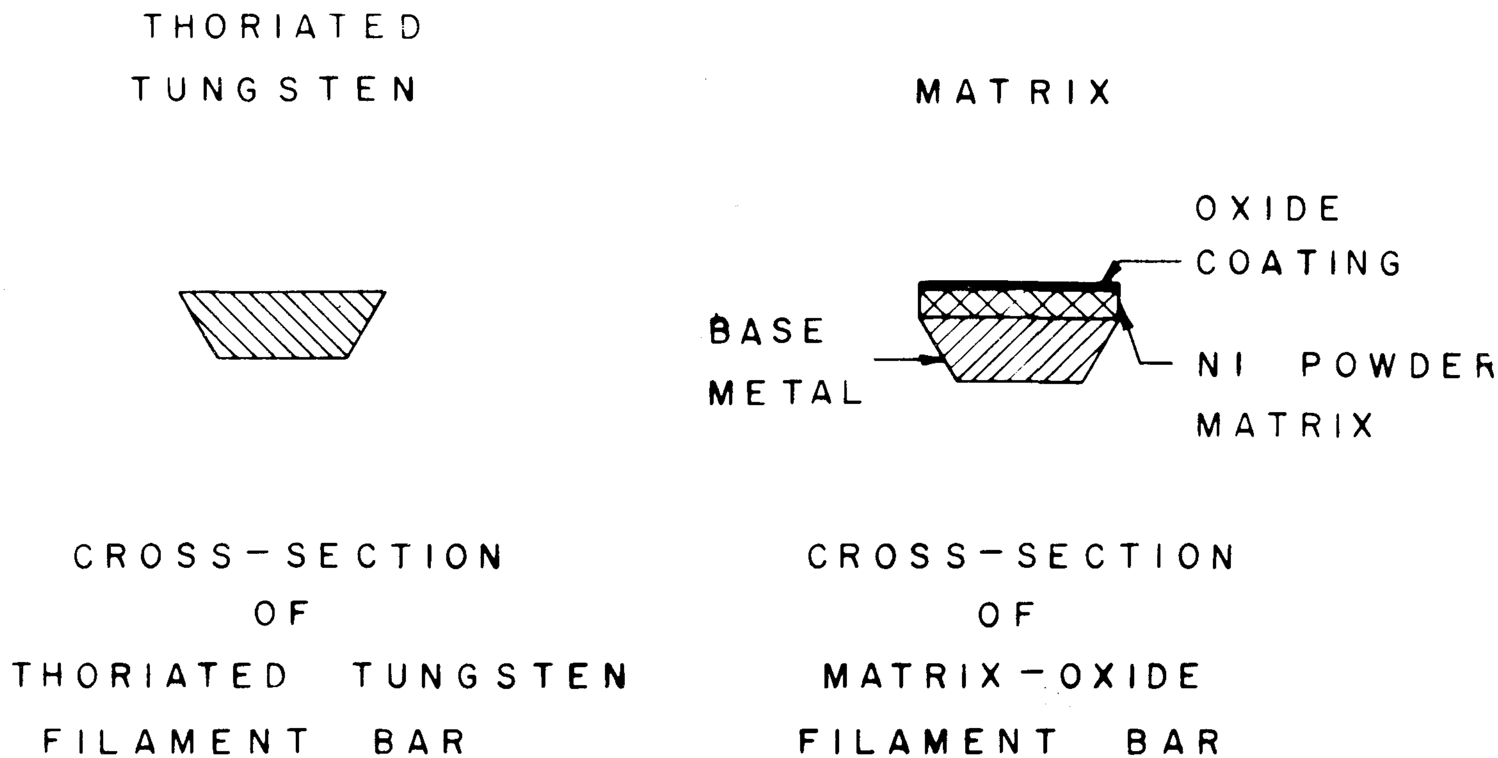

Fig. 3

Cathode bar structures

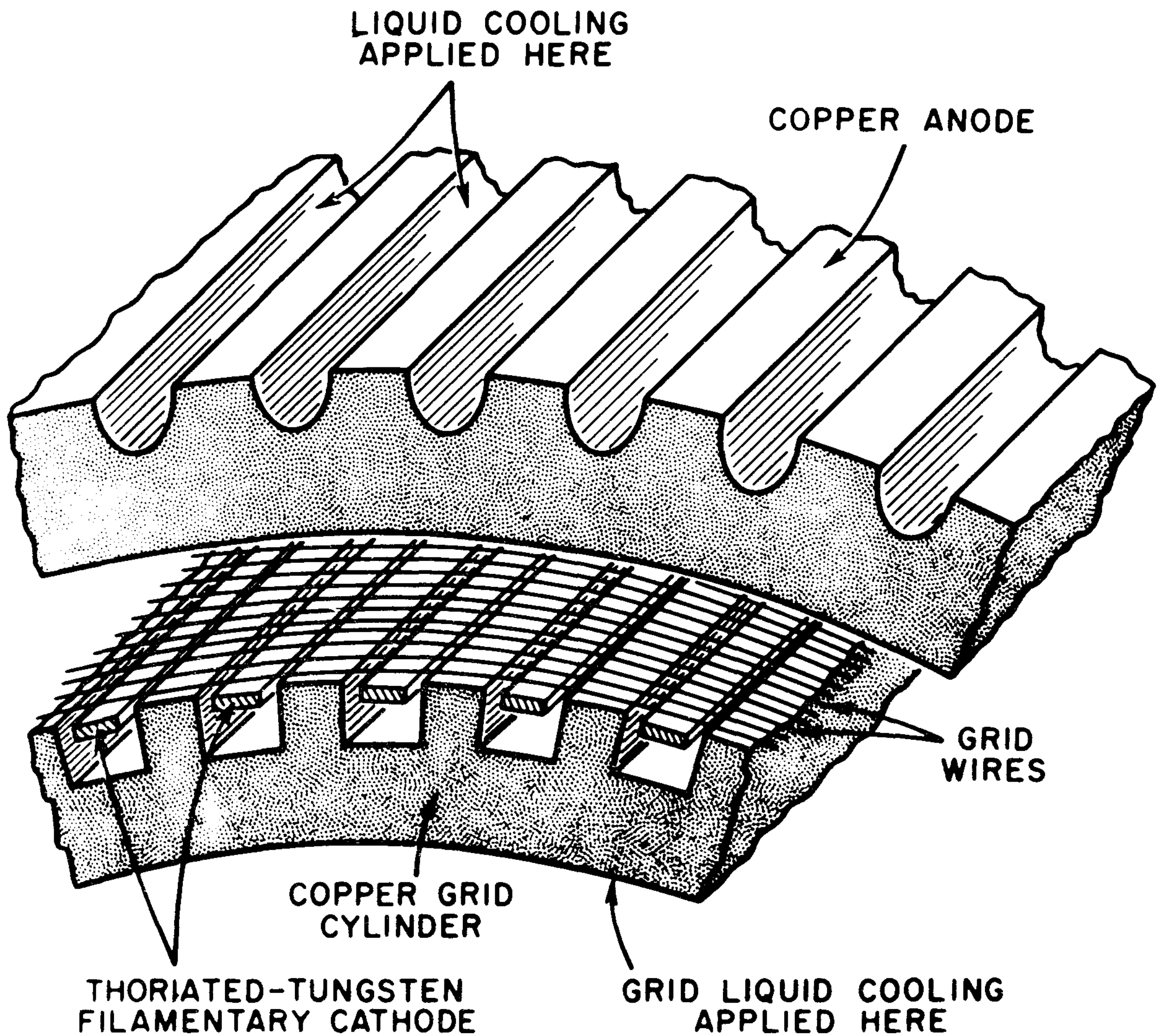

Fig. 4

Internal structure of tube type 7835

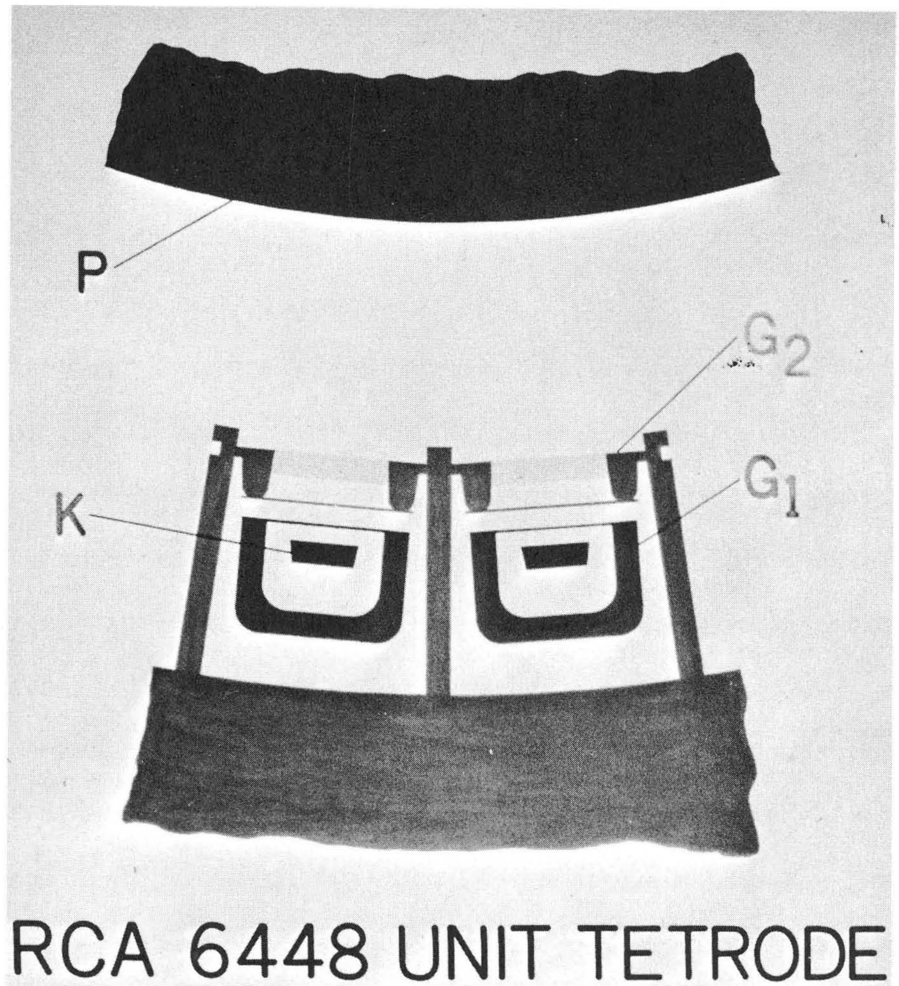

Fig. 5