PROCEEDINGS

of the

RADIO CLUB *of* AMERICA

Vol. 2 No. 1 September, 1921

Some Operating Notes on the Larger Sizes of Transmitting Tubes

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Presented at Meeting of Radio Club of America, Columbia University, March 30, 1921

A LARGE number of experimenters in radio communication have had experience in the operation of three-element vacuum tubes for reception, and a considerable number have used the very small sizes of transmitting tubes which generate a few watts of high-frequency energy. Comparatively few have had experience with the higher powered tubes.

Although the principles of construction and operation in the larger tubes are no different than in the smaller ones, many effects that are negligible in the latter are so magnified in the case of the larger tubes as to be very noticeable or give trouble.

Some of these points which in general are of importance only in the case of the larger tubes will be discussed; first, as regards installation and, second, as regards operation and care. Only points arising in the use of tubes in radio transmitting equipment will be considered.

It has been found that in the case of the larger tubes the majority of accidents to the tubes themselves and to the auxiliary apparatus occurs during the period of development of circuits, testing and adjustment rather than during regular operation. With most radio experimenters testing and circuit adjustment are the common state of affairs and routine operation or less secondary. Therefore a knowledge of some of the precautions to be observed is of particular importance to experimenters. The points to be observed apply mainly to tungsten filament tubes.

Installation

The tube should be mounted in the correct position which is usually specified. This is of importance because tubes have been exhausted, aged and tested in this position and the filament has taken a more or less permanent set. Operation in another position may change the characteristics or shorten the life.

In general tubes are designed to give rated output with natural ventilation. Ample free natural ventilation is essential. Forced cooling by a fan or blower, however, gives an added factor of safety and should be used if tubes are to be overloaded. This question of ventilation for the bulbs is of particular importance when groups of tubes are used. In such cases liberal spacing between tubes should be allowed.

Nothing should be very close to or touch the bulb. A light inflammable substance so placed may catch fire and a metal in contact with the glass is liable to set up a strain in the glass tending to start a crack.

The tube should be protected from any continual vibration, such as that from rotating machinery, by spring or rubber suspension mounting. Continual vibration is liable to shorten the life of the filament.

It is advisable to use A.C. for filament excitation. Its use gives an added factor of safety and prolongs the filament life. If an instrument is used for filament adjustment, use a voltmeter rather than an ammeter. In case a voltmeter is used the leads from its terminals should be brought right up to the socket connections as the drop in the filament wiring may be very appreciable, owing to the relatively heavy filament currents at low voltages. A step-down transformer is by far the preferable way to operate the filaments. The regulating rheostat should be in the high-tension circuit or power side and the return of the grid and plate circuits should be to a center tap on the low-voltage coil supplying the filament. In case such a center tap is not available a resistance not exceeding about 100 ohms may be bridged across the filament and the return connected to the center of this resistance. In the use of the center tap on the transformer coil at long wave lengths two by-pass condensers should be used, one connected between the center tap and each filament lead.

The circuits should be so arranged that this center tap on the filament coil and also the negative lead of the direct current high voltage source are both at ground potential relative to high frequency potentials. If this is not done heavy circulating high frequency currents will flow, cutting down the output and, in the case of higher powers, endangering the insulation of the filament transformer or circuit. If in combination with this bad feature the radiation ammeter is placed in the ground lead of the antenna circuit, the true antenna current may be only a fraction of that indicated by the meter.

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In arranging the oscillating circuit and coil system great care should be taken to thoroly insulate the grid and plate leads to the tube and the coil sections connected to these leads or any apparatus in them. The peak potentials, that, owing to poor adjustment, are possible between these two portions of the circuit, are sometimes very high and a breakdown between them may put full positive plate potential on the grid with disastrous results to the tube.

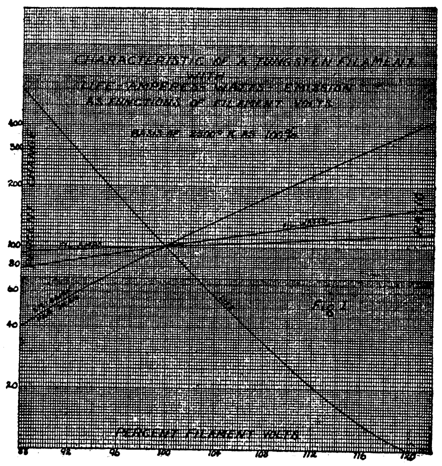
Tubes delivering 50 watts or more should be provided with a safety spark gap, mounted at or near the socket terminals, between the grid terminal and one filament terminal. As stated above a circuit condition may easily exist that causes a very high voltage to be set up between grid and filament. It is impractical to construct a tube and base to withstand these abnormal voltages which only occasionally occur and only with an improperly arranged ciruit. Therefore the use of such a spark gap is a very important protective feature. For a 50 watt size of tube a 1/16″ gap is suggested and a ⅛″ gap for a 250 watt tube. The closer the gap the greater the factor of safety but too close a gap may often spark over causing an indistinct signal or poor articulation in the case of telephony.

In the parallel operation of tubes, trouble is often experienced with local ultra-high-frequency oscillations in the plate and grid circuits which prevent the realization of full output and cause excessive plate and grid currents. In order to avoid this effect it is recommended that an inductance of a few micro-henries (10 turns in one layer on a one-inch diameter is suggested) be inserted in one or more of the individual grid leads of each tube as close to the grid terminal of the socket as possible. The protective gap mentioned in a previous paragraph should be between the above coil and the grid terminal of the socket. The best arrangement is to mount the gap directly on the socket terminals and one terminal of the coil directly to the grid terminal of the socket.

A fuse and a D.C. milli-ammeter in the plate lead wire are of great value when adjusting the circuit. The fuse should be one that will blow at about double the rated value of plate current.

The most commonly used method of modulation employed in a vacuum tube radio transmitting equipment utilizes a tube as a modulator in addition to the oscillator tube, the plate current for these two tubes being fed thru an audio-frequency reactor.

In a radiotelephone transmitting equipment the degree of modulation is of equal importance to the amount of antenna current as far as the strength of the received speech is concerned. The antenna ammeter does not usually indicate whether the output is being modulated in the normal manner. One simple method of keeping a check on this is to insert a miniature lamp in the plate circuit of the modulator. This flashes up when the microphone is spoken into and acts as an indicator of the operation of the microphone and modulation circuits. A type of lamp should be chosen that will show a low degree of brilliancy with the plate currents obtained on the tube used. Even for the 5 watt size of tube such lamps are easily obtainable. Automobile types of miniature lamps are recommended.



In most cases direct current is utilized for the plate voltage supply, and is obtained from a small generator or group of generators or by means of some form of rectifier at commercial A.C. frequencies.

If the high voltage is obtained from a D.C. generator or generators, it is advisable to use some sort of protective device for the armature windings. For small machines of 500 volts or under a condenser of about ¼ microfarad across the armature terminals is sufficient.

For voltages above 500 and D.C. power outputs greater than 100 watts, aluminum cells in series (one for about each 300 volts of potential) should be connected across the armature terminals. A fuse should be placed in the plus armature lead between the armature terminal and the point of connection of the aluminum cells, but no fuse should be in the cell circuit directly as there would then be no indication if it were blown, and the generator would thus be left unprotected.

These cells consist of two aluminum plates in a saturated solution of borax. The plates should be formed (oxidized) by voltage treatment in a similar way to the treatment of the aluminum plates in an electrolytic rectifier of the usual type.

If a two-element vacuum tube or a pair

of them are used as rectifiers, the operating suggestions given in a later section apply also in general to the operation of these tubes. The filament should also be operated on A.C., but the center tap connection is not of any great advantage in this case. The various forms of rectifier connections and smoothing out arrangements form a subject too large to be included in the scope of this paper.

Operation

It is very desirable to operate the tungsten filaments of transmitting tubes at constant voltage rather than constant current. The filament life at constant voltage is approximately three times the life at constant current.

The emission during life at constant voltage drops slightly, but this can be easily taken care of in design if it is desired to maintain absolutely full output to the end of life. The filament current at constant voltage decreases 5 to 10% during life. For this reason it is not possible to obtain full life from a filament when an ammeter is used for adjustment.

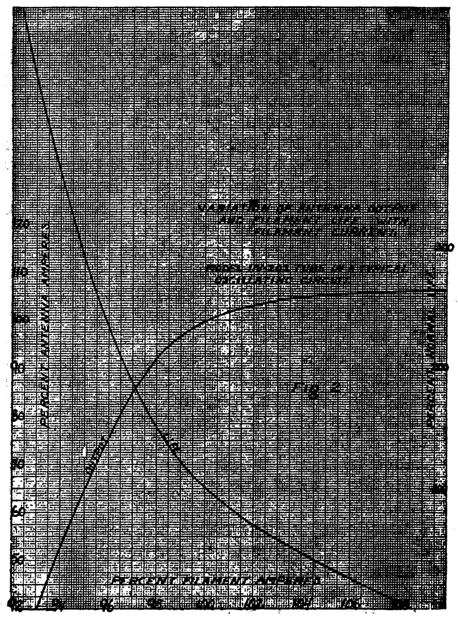
The variation of life and electron emission with filament voltage is shown in Fig. 1. These curves show the poor economy in forcing a tube, because it will be seen that to double the emission reduces the life to one quarter. Conversely it shows the advantage of operating a tube conservatively for by reducing the electron emission to one half, which allows half rated output, the life is quadrupled. This is even more forcibly shown in Fig. 2 which shows the variation of high frequency output current (radiation current) for a 5 watt tube in a typical oscillating circuit, plotted against filament amperes. At low filament temperatures the output is entirely limited by the electron emission whereas beyond a certain point increased emission does not appreciably increase the output which becomes limited by other factors in the tube. A life curve with filament current is plotted on the same sheet and shows that, in order to gain an increase of 5% above rated output by filament temperature increase alone, the life is decreased to approximately 40% of the normal.

In making filament adjustments the three following points should be kept in mind:

(1) Do not materially raise the filament current to get a small increase of output. The curves of Fig. 2 show the poor economy of this. Considering operation over a period of one year it would be more economical to operate conservatively two tubes in parallel and get even a greater output than from the one running with an excess filament temperature.

(2) For long tube life the best circuit adjustment is the one showing the lowest volume of plate current. It is for this purpose that an ammeter in the plate circuit was suggested in a previous paragraph. It is well worth while to experiment with various circuit adjustments in order to get a satisfactory output with a minimum input current. Expressed in another way this simply means getting as high an oscillator efficiency as possible. If a milliammeter is not available for use in the plate circuit, a miniature incandescent lamp may be employed during adjustment and the lowest current judged roughly by the filament brilliancy.

(3) The maximum rated filament voltage of the tube should not be exceeded for any length of time. In all cases the filament should be maintained at as low a temperature as possible, consistent with satisfactory results. As noted in a previous paragraph the filament current at constant filament voltage decreases during life; therefore adjustment by current is sure to result in abnormal temperature of the filament as its life progresses. All tubes are given a certain rated filament current plus or minus an allowance at a rated voltage. This, as above stated, can apply only to a tube when it is new as the filament resistance increases during life. This rating denotes or should denote the filament voltage at which the tube will give rated output at rated plate voltage thruout its average life under specified conditions. Therefore it is a distinct advantage if the user can obtain the result he desires by operating the filament at a voltage under normal. Operation at 95% normal filament voltage should double the



life of the tube. Under many conditions this is possible. Under some abnormal conditions the user must expect and accept a shorter tube life.

This question of rating is a difficult one, but not entirely unlike the rating of other electrical apparatus. Consider the case of a direct current motor rated 1 H.P. at 110 volts. This rating is fixed by a commonly accepted set of standardization rules which govern permissible temperature rises and other factors. Both the manufacturer and the user know that probably 2 H.P. is obtainable from the motor, but both also know that if this overload is persisted in disastrous results are sure to follow sooner or later and the useful life of the motor greatly shortened. Also both know that the motor will operate at an over-voltage, say 150 volts, but they also both know that this lowers the factor of safety of the commutator and that a flashover or bad sparking is almost sure to result. Eventually vacuum tube ratings will also be fixed values, but this standardization must await a wider understanding of the technical features involved before it reaches the same status as in the case of highly standardized forms of electrical machinery.

It should be remembered that the variations of life, electron emission and other factors do not bear the same proportionality to filament current as to filament voltage. This is due to the temperature co-efficient of resistance of the filament resulting in an increase of resistance with an increase of current. Owing to this factor a 5% change of filament voltage causes about a 3% change in filament current in the useful range of filament temperatures.

It may very often seem that the currents used for the filaments of transmitting tubes are unduly high.

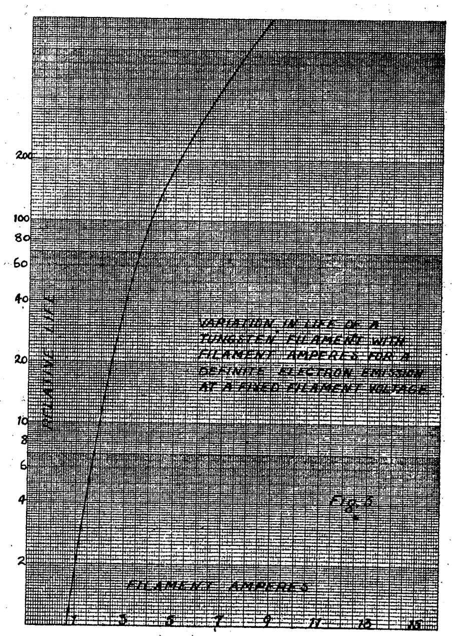
If a certain form, power output, filament voltage and plate voltage are assumed then Fig. 3 shows the theoretical variation in life that is caused by changing the filament sizes so as to utilize a different filament amperage. This figure shows, for instance, that if in a tube having a 2 ampere filament, a 5 ampere filament were substituted the filament watts would go up 2½ fold, but the life should increase about 17 fold. This curve is theoretical and the increases in life show could not be fully realized, because of certain practical limitaions, except over small changes of filament current, but it does point out why high filament currents are so advantageous.

In experimenting with different circuits and circuit adjustments it is advisable to first operate at one-half or one-third normal voltage. In case of abnormal adjustment or faulty connections the tube itself then has a much larger factor of safety against destruction.

This same precaution should also be observed when the set has not been operated for some time. Then in case some part of the circuit has, thru accident, been changed no harm will come to the tubes and the voltage may be turned off and the circuit corrected.

Most well-made tubes will stand a great overload on the plate for a few seconds, but a continuation of an abnormally high plate temperature is sure to deteriorate the vacuum.

Most transmitting tubes have a definite plate voltage rating. As in the case of a filament voltage rating this voltage should



be the value which will give rated output thruout the average life of the tube. It is to the interest of the manufacturer to make this voltage as high as possible as it allows a higher power rating of the tube, but in all cases some factor limits this voltage. These factors are usually electrolysis of the glass of the seal, dielectric strength in the base or stem, overheating of the metal parts or glass due to the increased energy to the plate, or puncturing of the glass.

On the small types of tubes in which all the leads are brought thru a common stem, electrolysis in the seal of this stem is the factor usually limiting the plate voltage. At plate voltages above rated value electrolysis causes leakage of air thru the seal and thus unduly shortens the life of the tube. Even at rated voltage a slight but harmless amount of electrolysis takes place which can be detected by a blackening of the grid lead in the glass of the seal.

This blackening is due to electrolytic deposition on the grid lead which is the negative electrode for the electrolysis. At higher plate voltages where this electrolysis is more severe the glass of the seal in the vicinity of the grid lead changes to a dark brown color.

In a radio-telephone transmitting circuit of the usual type a modulator tube is employed and a buzzer is often substituted for the microphone when it is desired to send out interrupted continuous waves. This imposes very severe voltage strains on the oscillator tube and if an overvoltage is also applied to its plate the voltage between grid and filament may be excessive. The protective gaps described in a previous paragraph are a safeguard against breakdown due to this voltage.

Unless the constants of the oscillating circuit are changed the plate current will go up when the plate voltage is increased causing the energy loss to the plate to be rapidly increased. This, of course, is liable to cause deterioration of the vacuum.

Puncturing of the glass occasionally is met with and is caused by the heat of electron bombardment or dielectric losses softening the glass or it may be caused by excessive voltage when the glass is a dielectric. In most types of tubes, if puncturing does occur, it will take place thru the stem between the leads inside the stem and the sleeve on the outside which supports either the grid or plate structure. Such puncturing is much more liable to occur when the glass is very much heated due to overload. It is most effectively provided against by the protective spark gap previously mentioned which should be set as close as possible and still permit normal operation. Puncturing of the bulb itself is rare at plate voltages under 5000.

Some of the principal precautions to be observed in the use of power tubes have been explained. The experimenter with the larger sizes of tubes will find many interesting conditions and discover many new phenomona. However, he must be careful and use good judgment or an undue destruction of tubes and apparatus is almost sure to result.