A Note on the Stability of Electron Multipliers

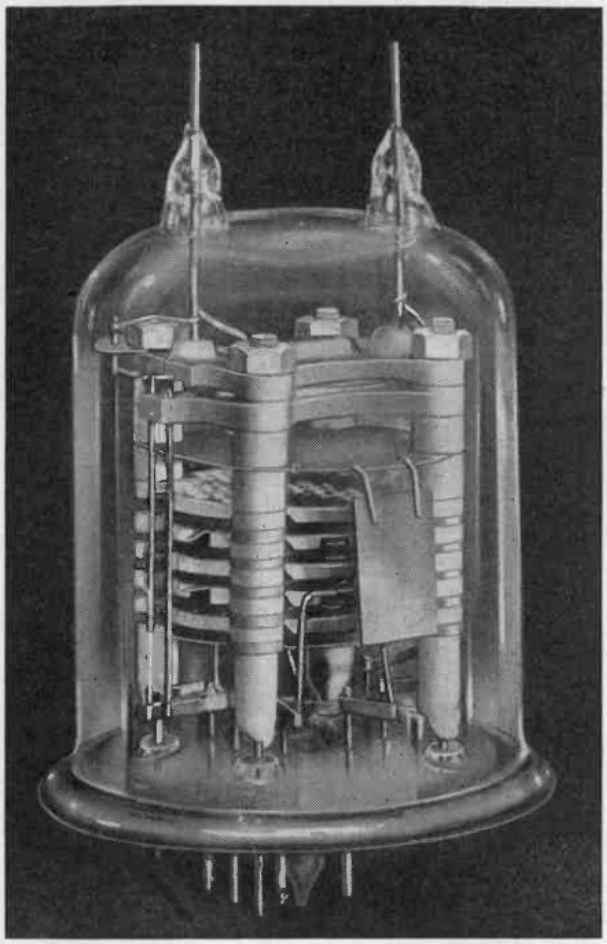
by F. J. G. van den Bosch, D.Sc., I.E.M.
(Messrs. Vacuum Science Products)

At the Annual General Meeting of the Television Society, held on October 4th, at the I.E.E., Dr. van den Bosch read a paper on "Recent Developments in Electron Multipliers, with special reference to the Augetron." The paper in full is being published shortly in a special number of the Society's Journal, and the following extract is reproduced by arrangement. Readers wishing to obtain copies of the full paper should apply to the Editor of the Journal, Mr. W. G. Mitchell, "Lynton," Newbury, Berks.

WHEN examining the properties of any particular electron tube, it is, of course, necessary that the stability of the tube should be sufficient to permit a repetition of results, but a clear distinction should be made between three different kinds of varying results. Any phenomena of instability observed may be due either to unsatisfactory testing equipment or method of testing, or, secondly, through some fault in the assembly of processing of the tube, or finally to some fundamental instability of the electric effects upon which the entire functioning of the tube is dependent.

In order to study secondary emission problems the simplest case is probably that of the photo-electric multiplier in which all the surfaces are of similar chemical composition, and where there is little likelihood of poisoning effects. It will then be found that with moderate illumination (and hence a conservative value of maximum current handled) the characteristics of the multiplier will be exceptionally stable. It is reasonable to assume that under such circumstances any instability observed must be due to some subsidiary poisoning effects complicating the main issue. Actually, the stability attained in a photo-multiplier is very remarkable since in the case of a six-stage multiplier, where the overall gain is the sixth power of the individual average stage gain, a 10 per cent. change in secondary emission ratio would produce nearly a twofold change, and a 10 per cent. change occurring in overall multiplication, which incidentally is easily detectable as a serious instability, only needs about 1.6 per cent. change in average.

Instability is far more likely to be encountered in electron-multipliers where the primary cathode consists of a thermionic cathode, as is the case in the thermionic multiplier. It is unusual in radio valve work to demand very great stability, since in the normal circuits employed a considerable variation in stage gain of a valve amplifier can be tolerated before its effects are detectable by ear. Variations of the order of 5 or even 10 per cent. drift in anode current are not a serious drawback, but in the case of the multiplier with its high slope and high sensitivity the optimum working point on the grid characteristic is of major importance. What we have in mind here is the variation in contact potential caused during running as a result of slow evaporation of metallic barium from the thermionic cathode and its subsequent deposition upon the wires of the nearby grid. A change of as much as 1 volt is possible as a result of this effect and since the optimum working grid potential is critical to within 1/10 of a volt it is obvious that trouble might be anticipated here. However, we have so far not had any difficulty in this direction, as the design of both cathode and grid has been directed to minimise this inconvenience. It is one advantage that the Augetron has over other types of secondary emission tubes so far developed in that its "gun" design has been particularly directed to overcome the inherent disadvantage of using ordinary thermionic cathodes.



The new "Augetron" electron multiplier. A photo-electric type is also available.

It is difficult to say what other changes in conditions at the "gun" assembly end can cause variations at the output end as regards multiplication and mutual conductance. It should be very difficult for small variations in the total emission of a thermionic cathode to have any influence upon these factors, since provided the thermionic cathode is reasonably efficient, its limitation will be completely caused by space charge, and hardly at all by temperature. A more probable cause of trouble is the evolution of gas, mainly oxygen, from the thermionic cathode or from metal parts. A small liberation of gas is likely to have disastrous effects upon the sensitised secondary emitter surfaces. The gas will be ionised and the positive ions will bombard the thermionic cathode resulting in cathode deterioration and subsequent further gas evolution. When the gas pressure is extremely small it usually ionises between the secondary cathodes and generally starts between the last secondary cathode and the collector. Their bombardment will obviously result in serious damage to the sensitised layer. These small gas evolutions sometimes disappear, being "cleaned-up" by the cesium of secondary cathodes acting as a getter; this will be, of course, at the expense of the sensitivity of the secondary emitter. It is probable that there is always a slow evolution of gas from any oxide cathode, and from this point of view, especially in secondary emission tubes, it is advisable to keep the area of the cathode and the emitting surface down to a minimum in order to avoid this as much as possible. Another effect to be considered is the gradual damage to the first secondary emitter by the slow evaporation of barium metal from the thermionic cathode on to this emitter. This effect is the main reason why secondary emission valves may be unreliable during life and why in some con-

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structions of single stage secondary emitters the secondary emitter is sometimes shielded, where the thermionic cathode employed is of normal dimensions rated to give an electron current of 10 or more milliamperes. In the case of the Augetron multi-stage electron-multiplier, however, the initial current is less than 10 microamperes and hence with a small thermionic cathode the amount of barium to settle is small. This in any event has to pass through the opening of the accelerator plate, which has been reduced to a minimum, so that this and only the first secondary emitter will be affected by this phenomena. If, however, such poisoning actually took place this would result in a gradual decrease in the secondary emission ratio of the first secondary emitter and would not affect the remaining secondary emitters a definite advantage of the multi-stage secondary emission tubes. We have not so far observed this phenomena in Augetron tubes during life tests.

Apparent instability may be caused by unsuitable test equipment. Voltage supply should be perfectly stable so as not to affect voltage distribution resulting in variations in secondary emission. When testing an Augetron with thermionic cathode for pure static tests care should be taken to protect the multiplier against self-oscillation by shunting both grid and cathode with a condenser of .001 mfd. In doing so, using as short leads as possible, it should be remembered that the Augetron is a high-gain and very sensitive tube, and therefore oscillates very easily.

When instability is observed it is as well to run the tube in darkness and observe for either a gaseous glow, which has been mentioned already, or for fluorescent effects. These fluorescent effects may be caused by the building up of electric charges upon insulators in the vicinity of the electron stream, which may result in some irregularity of behaviour. The actual nature of the charges on insulators is very complex and the actual potential at any point will depend on the instantaneous value of secondary emission of that portion of the surface. It is possible for an insulator to attain by virtue of secondary emission a positive potential, and these potentials are obviously irregular and subject to very sudden changes. In the Augetron steps to obviate this possibility have been taken with success.

When examining secondary emission tubes for instability it will be found that there is in most cases a minimum condition for which the tube will remain stable, and it must be these conditions which will lead to the cause of the instability. In the case of the Augetron all possible constructional or processing causes for instability having been obviated it will be generally in the circuit arrangement or the apparatus in which the Augetron is used which will cause instability.