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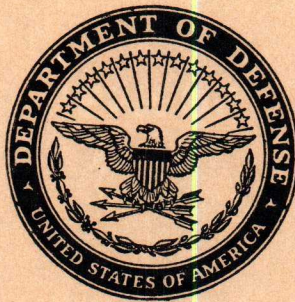


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MIL-HDBK-211
APPENDIX-A
12 January 1960

MILITARY HANDBOOK
ELECTRON TUBES, TECHNIQUES
FOR APPLICATION OF IN
MILITARY EQUIPMENT



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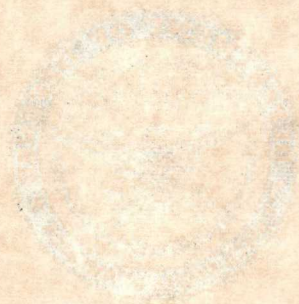
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FOREWORD

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1. INTRODUCTION

This publication is Appendix-A to Military Handbook No. 211, Techniques for Application of Electron Tubes in Military Equipment, which was published by the Government Printing Office in December, 1958.

Handbook No. 211 represents the first attempt to present within one cover all available application data pertaining to the receiving tube types designated for use in military electronic equipments (i.e., those receiving types listed in MIL-STD-200). The material includes not only general instructions in the interpretation of specifications and in the use of statistical design techniques, but also detailed data derived from MIL-E-1 specifications and from manufacturers' life-test records.

This Appendix goes beyond the handbook in dealing with various application problems which are commonly encountered in complex equipments. Part I discusses the design of circuits. Part II provides -- for receiving tube types which have been added to MIL-STD-200 -- the same type of application data which are given in Parts III and IV of the handbook.

2. APPLICATION NOTES

This part of the Appendix is a compilation of application notes based on experience in solving part-reliability problems encountered in the design of electronic circuits. The discussion describes the measures taken to prevent or overcome the most commonly observed tube-reliability problems.

2.1 Long-Life Assurance for Electron Tubes

This section discusses two important approaches to the improvement of tube life: (1) reduction of cathode operating temperature to the minimum value, and (2) reduction of bulb temperature.

2.1.1 The Effect of Cathode Operating Temperature on Tube Life

The effect of cathode temperature, and therefore of heater voltage, on the life expectancy of tubes has frequently been observed,* and the observations agree with what is known about the physical mechanisms involved in the relationship.

In studies of the phenomena involved in the deterioration of tubes, ARINC has cited both theoretical concepts and experimental data which show that the exponential relationship is very frequently observed in association with thermal effects. Figures 1, 2, 3, and 4 show, respectively, the effects of temperature on the formation of interface resistance and the decay of pulse emission, on heater burn-out, on heater-cathode leakage, and on insulation leakage in general. For the sake of simplicity, it might be said that all these phenomena, including emission decay, follow Arrhenius' Law, which states that the reaction rate (r) is an exponential function of temperature. Thus

$$r = A e^{-E/kT}$$

If the constant E (the activation energy of the phenomenon) is expressed in electron volts, the activation energy corresponds roughly to the work function of the Dushman equation controlling the emission of electrons.

In all the deterioration studies made by ARINC, activation energy has been estimated to have values between 1.5 and 3 electron volts. The estimates have a tendency to be lower than the true value because

* See, for example, Thomas H. Briggs, Electron Tube Operation as Influenced by Temperature and Voltage (Technical Report 56-53), Wright Air Development Center, January 1956.

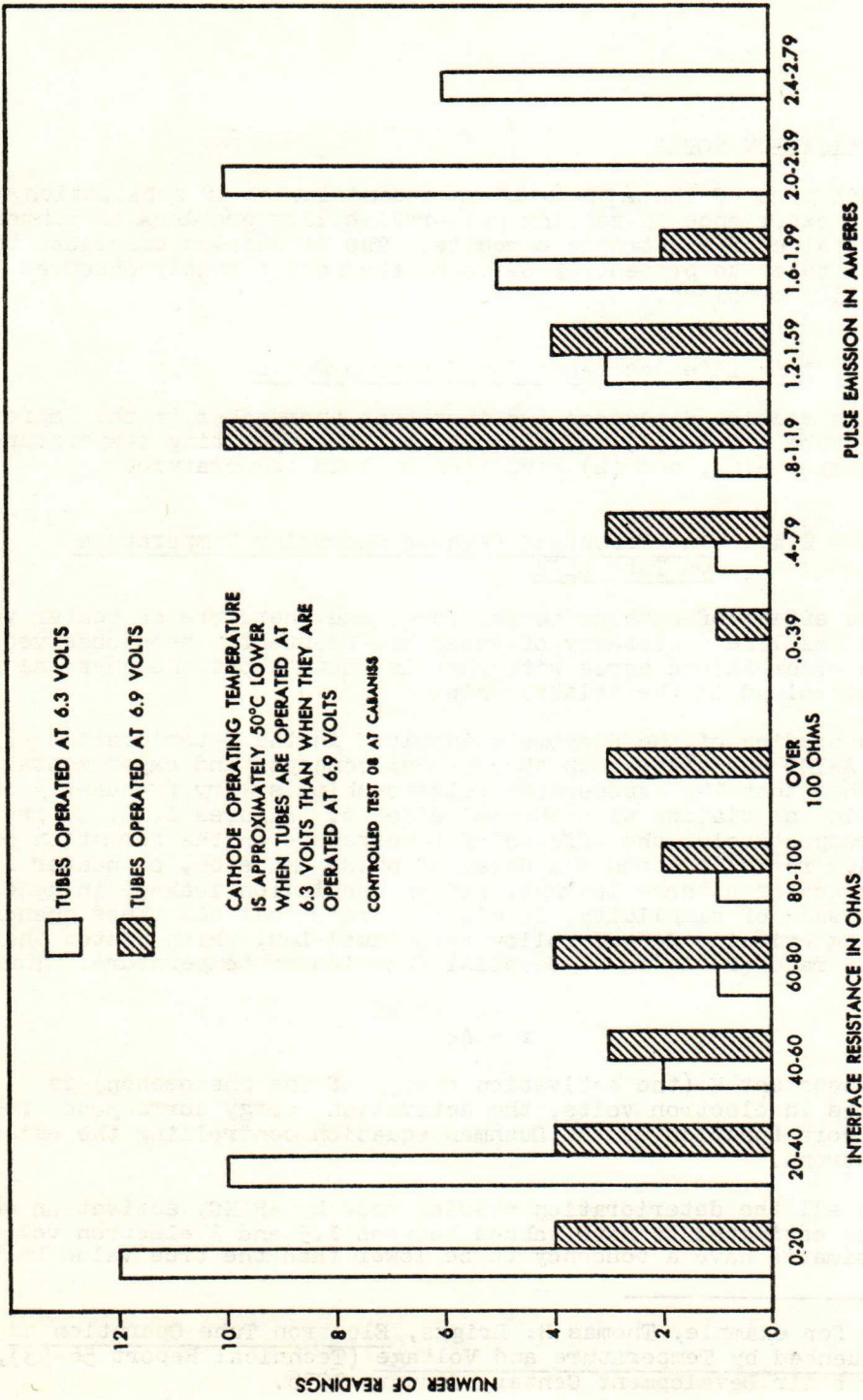


FIGURE 1
 TUBE TYPE 12AT7: INCREASE IN INTERFACE RESISTANCE AND DECREASE IN PULSE EMISSION, AS FUNCTIONS OF CATHODE OPERATING TEMPERATURE

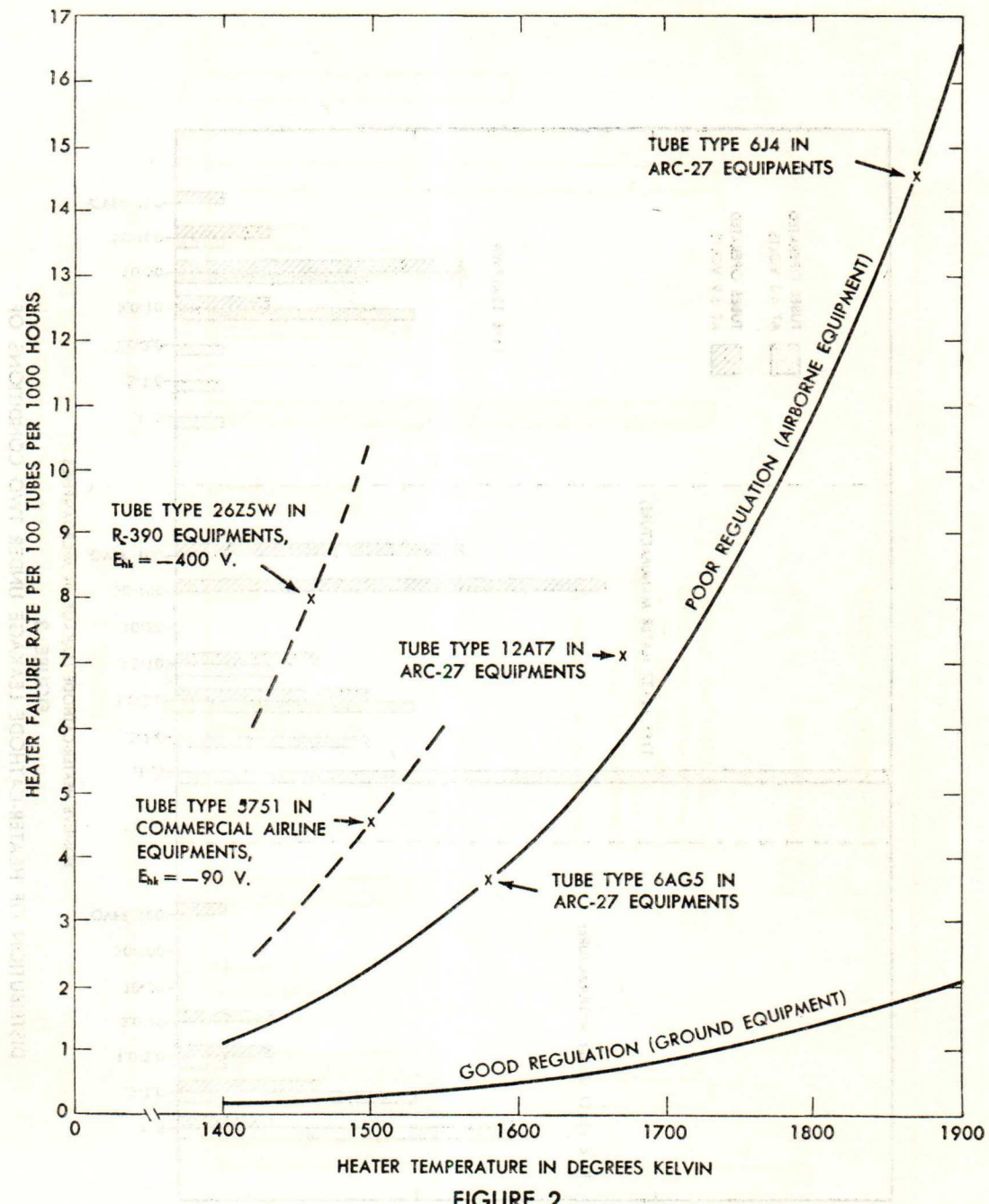
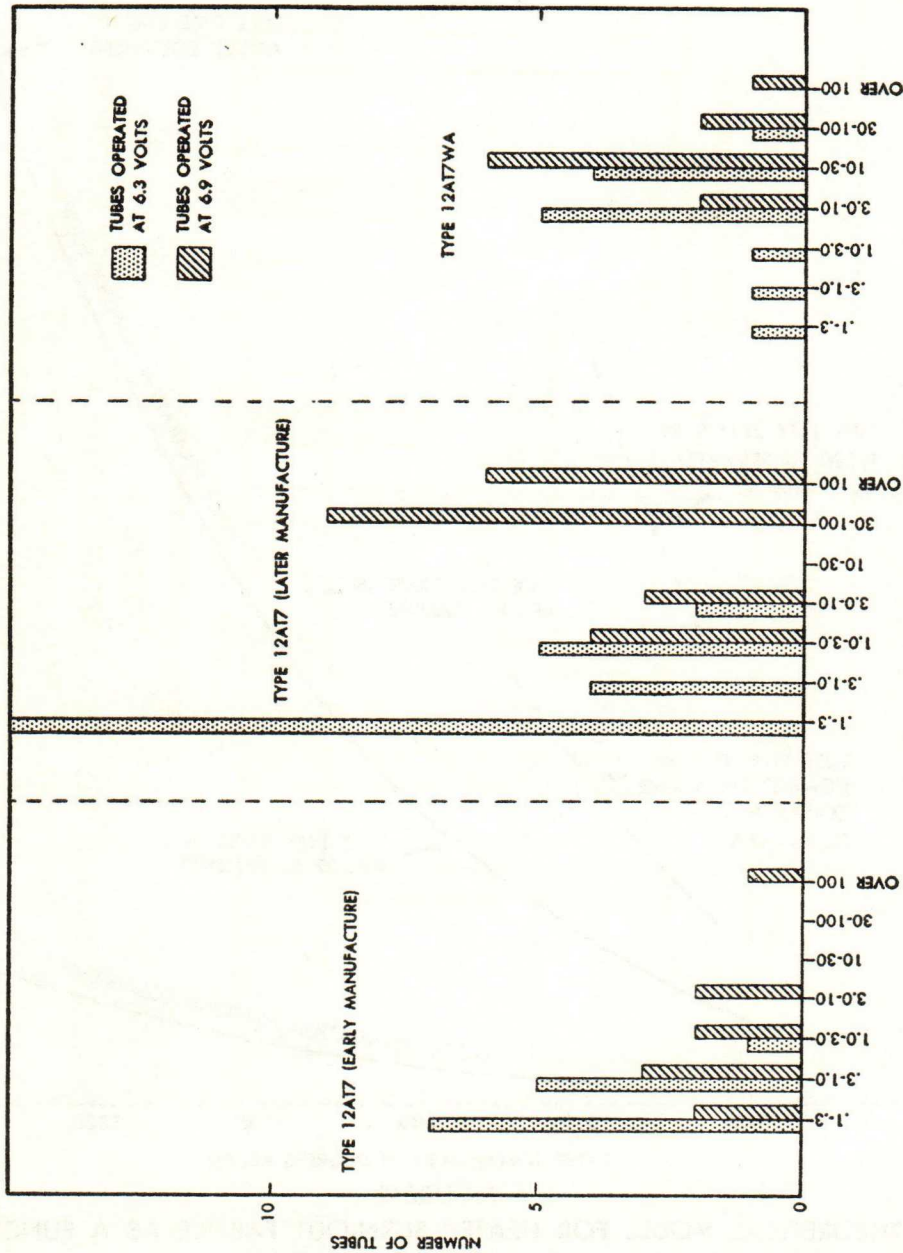


FIGURE 2
THEORETICAL MODEL FOR HEATER BURN-OUT FAILURE AS A FUNCTION
OF HEATER TEMPERATURE
(SHOWING EFFECT OF VOLTAGE REGULATION ON BURN-OUT FAILURES)



POSITIVE HEATER-CATHODE LEAKAGE, IN MICROAMPERES
FIGURE 3
 DISTRIBUTION OF HEATER-CATHODE LEAKAGE UNDER TWO CONDITIONS OF
 HEATER-SUPPLY VOLTAGE
 THREE VERSIONS OF TUBE TYPE 12A17—MEASUREMENT AT APPROXIMATELY 700 HOURS

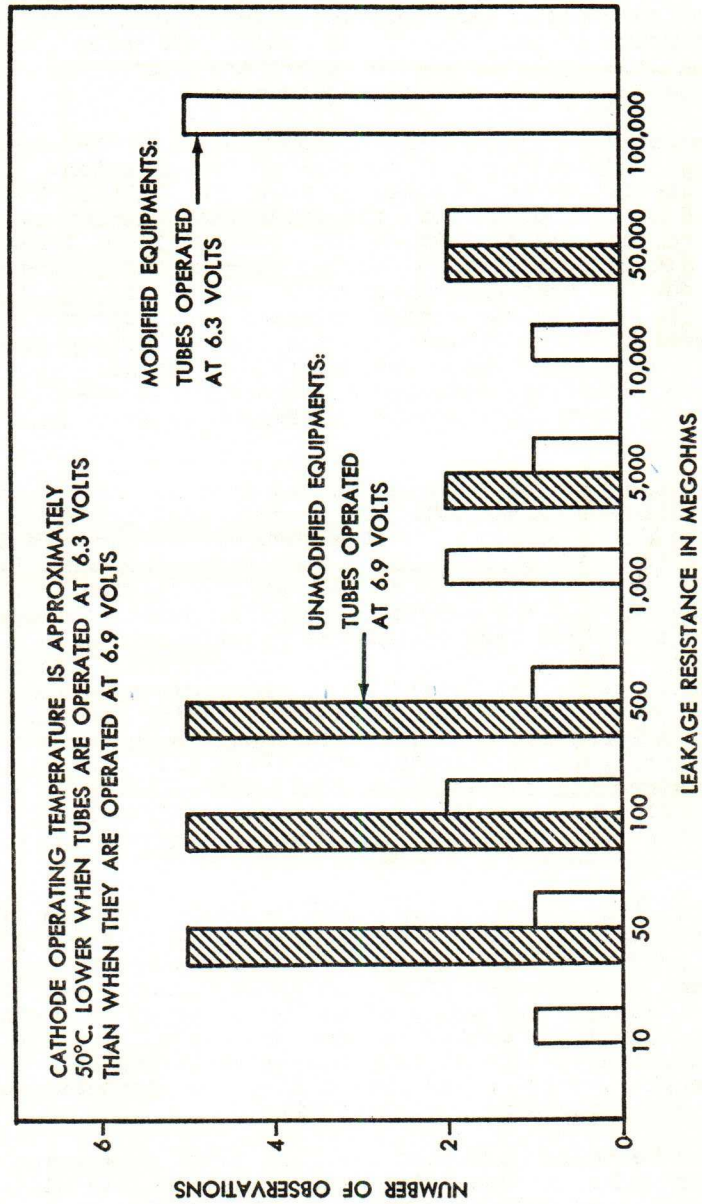


FIGURE 4
VALUE OF LEAKAGE RESISTANCE BETWEEN GRID AND OTHER ELECTRODES AS A
FUNCTION OF TWO LEVELS OF CATHODE TEMPERATURE,
AFTER APPROXIMATELY 700 OPERATING HOURS

of effects due to phenomena other than those studied. This situation implies that deterioration phenomena, in general, vary with temperature at a faster rate than emission does. The inescapable conclusion to be drawn is that if an attempt is made to improve emission by increasing the temperature of operation, deterioration effects will be encountered at a much earlier point in the life of the tubes. Therefore, the best way to obtain long life is to reduce the operating temperature to the minimum value compatible with emission requirements.

The major obstacle to the successful application of the principle stated above is the complete lack of control of the emission-temperature characteristics of present-day receiving tubes. Usually, tubes are operated at the point where the saturation current available at the operating temperature is between 100 and 1000 times larger than current density. It is possible, therefore, to make tubes passing usual specifications for most characteristics, but exhibiting differences as great as 10-to-1 in saturation-emission characteristics -- either at the operating temperature corresponding to the center value of heater voltage, or at any other temperature. It is also possible to make tubes whose saturation-emission characteristics are very similar at one temperature but significantly different at every other temperature.

To illustrate the type of information required by the designer, and usually not available to him, Figures 5 and 6 show the variation in transconductance which occurs with time when cathode temperature is varied by variation of heater voltage. The curves for zero hours show the previously mentioned effect of saturation emission on the value of transconductance. The curves for various periods of operation show the effect of interface resistance superimposed upon the effect of saturation emission. If the operating condition is that of a high-gain, resistance-coupled amplifier in which plate current is very near the cut-off point, transconductance is limited mainly by the formation of interface resistance. (Here it should be noted that the curves probably fit only the particular production lot from which the tubes were taken, since the operating regions under discussion are completely uncontrolled by specifications. However, in spite of wide variations among individual readings, the general shape of the curves is typical.)

The curves show that for tube type 5814, a heater voltage of 12.6 volts (the specified value) gives optimum operation only for a period of 500 hours. To achieve a life expectancy greater than 500 hours under the conditions of operation of the amplifier under discussion, it is necessary to decrease the value of heater voltage. For example, operation for 8000 hours at a heater voltage of 12.6 volts would result in a transconductance value of 1200 micromhos at the end of life; however, operation at 10 volts would result in a transconductance value of 1700 micromhos after the same period of time.

It should also be noted here that the data shown in Figures 5 and 6 were measured under the operating conditions given in military specifications. In the curves for zero hours, the difference between the transconductance values measured at 12.6 volts and 10 volts is not an indication of the difference which would occur under the operating conditions of the amplifier circuit. Under MIL-E-1 conditions, plate current is well above the cut-off value and saturation emission has a strong effect on transconductance. At conditions near cut-off,