# Forced air cooling of power valves.

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### Introduction

When using power transmitting tubes, it is essentail to provide sufficinet cooling air to cool the tubes properly, taking into account the inlet air temperature, the air flow rate, valve dissipation and the operating altitude. The air flow requirements for maximum anode dissipation, at sea level and with an air inlet temperature of 25°C are usually given on the valve data sheet, although sometimes they are given for other conditions, such as for a inlet teperature of 50°C. Both Eimac and Burle, two valve manufacturers, produce publications that have rules detailing how to calculate the air flow requiremnts under different conditions, although some of the more informative data sheets have data for diffeent anode dissipations, air inlet temperatures and altitudes. However, after testing these rules on tubes for which there is plenty of data published, it soon became apparant that the suggested rules do not accurately model the air flow requirements stated on the data sheets from Eimac. The reasons are simply the suggested models are inaccurate. This describes my attempts to model the air flow requirement more accurately, with the result that air flow requirement predictions using these models are quite close to the data sheet values. Since some data sheets give little airflow information, this can be useful if data under other conditions is required.

Although it is nevewr a reccomended practice, especially for linear service, amateurs do have a habit of exceeding the ratings of tubes. If for instance the anode dissipation is slightly exceeded without overheating the tube, no short term damage is likely to result, although it will reduce the valves life. However, if the extra dissipation means the maximum ratings of the ceramic/metal seals are exceeded, the damage is likely occur rapidly. The formulae presented here do allow for the calculation of airflow requirements above the normal rated values, so if this dubious practice must be done, at least it will be done with some thought.

### Problems using the modesl of Eiamc and Burle.

Firstly, two important facts should be understood.
1) It is the mass of air that effects the cooling properties, not the volume.
2) The only requirement is that the tubes are cool.

## Altitude correction

Both Eimac and Burle state that the air flow should be increased with altitude to compenstate for the reduced air density and so the reduced mass flow rate for a constant volume flow rate. The correction factor is impirical, taking account of the air density variation with altitude. I read the correction factors from a graph given by Burle between sea leve and 20,000 feet, and fitted a second order polynomial, which gives the altitude scaling factor for air flow as a function of altitude in feet.

Hence sea level air flow rates should be multiplied by approximately 1.2 for an altitude of 5,000', 1.46 for 10,000', 1.77 for 15,000' and 2.17 for 20,000 feet. If the data sheet volume flow rates for sea level data are multiplied by these factors, the figures will agree closely with those given on data sheets that have data for various altitudes. In essence calculating the flow rate at various altitudes presenets no problems.

## Back pressure

The back pressure developed is approximately proportional to the square of the flow rate, with constant density of air, so we might expect the back pressure to be scaled by $F_A^2$, However, if the air density at some altitude is lower, Graphams law

## Inlet air temperaure corrections

Both Burle and Eimac give a correction factor $F_T$ for air inlet temperatures different by an amount $\Delta T$ from those os the data sheet. The correction factors are:

| $\Delta T$ | $F_T$ |
|---|---|
| +30°C | 1.1 |
| +20°C | 1.07 |
| +10°C | 1.03 |
| 0°C | 1.00 |
| -10°C | 0.97 |
| -20°C | 0.93 |
| -30°C | 0.90 |

Data on the Eimac 3CX5000A7 (a 5 kW anode dissipation triode) at an inlet temperaure of 20°C and 5 kW anode dissipation at sea level indicates 181 cfm of air flow is required[1]. Hence we would expect at an inlet temperature of 50°C (30°C above the reference of 20°C), the air flow rate should be multiplied by 1.1, giving 199 cfm. In fact the data sheet says 363 XXX, which means calculations based on the table above gave an error of XXX %.  Here are my attempts to do better.

Assume the anode is of unit length, with the lower end at x=0 and the upper end at x=1. Air enters at $T_{in}$, and leaves at $T_{out}$, where obviously $T_{out} > T_{in}$. There is a simple relationship between the inlet and outket air temperatures of the air by a valve:

where k is a constant (1.76 at 20°C and 1 atmosphere pessure), P is the dissipation in Watts and F is the air flow rate in cubic feet per minute.

The air temperature does not follow a linear progression from $T_{in}$ to $T_{out}$, but instead follows an exponentail one of the form:
The value of a is easily found, by re-arranging the above equation and taking the natural log of both sides:
The flow of heat from the valve is directly proportional to the difference between the valve itself at a temperature $T_{valve}$ and the air temperature in the anode structure. However, since the air temperature in the anode is not constant, but varies with position, we will use the average temperature. The average air temperature is not simply $(T_{in}+T_{out})/2$, as one might first think, since the air temperature does not vary linearly with position. The average air temperature can be found from calculus, as:
So the heat flow to the air is given by:
where C is a constant of proportionality.
If the air inlet temperature is increased,

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[1] The current data sheet does actually state 209 cfm is required, but 181 cfm at an air inlet tep of 35°C. Obviously, at least one is wrong! Eimac have admitted that these two figures are transposed.