Blower - a program for calculation of forced air cooling requirements of power valves.

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I have written a program to calculate the amount of cooling air required to cool power tubes - the sort amateurs use in amatuer built high power amplifiers. You start by finding the volume flow rate required (in cubic feet per minute) and the back pressure of the tube (in inches of water) from the *valve data sheet* under some conditions of anode dissipation (usually maximum for the tube), inlet air temperature (usually 25° C) and altitude (usually sea level). You can then calculate the cooling requirements for any dissipation (even above the rated anode dissipation), any altitude (up to 30,000 feet) and any inlet air temperature (up to 100 °C, if you so desire) and for any safety margin you wish (I recommend you try to use a 50 deg C safety margin). It then calculates the flow rate required and the back pressure that fan must overcome. The program has the cooling requirements for a number of tubes known internally, which include the Eimac 4CX250B, 4CX250K, 4CX350F, 4CX1000A, 4CX1500B, 3CX1500A7, 3CX5000A7, Y831 and the Burle 7213/7214. You can enter the data for any tube, but you will need the manufacturers data sheet.

WARNING

1) This program has been *quickly* checked for errors, but it probably does contain bugs. If there is an error, it could result in you under specifying the cooling air and destroying your valve! No warranty is given for this software. Use at your own risk. The software is copyrighted by David Kirkby G8WRB but may be used for amateur (non commercial) purposes free of charge. Since it is not fully tested, I can not recommend its use for commercial purposes, so will not authorise its use for this.

GETTING IT

If you want the program, please ftp to medphys.ucl.ac.uk use
username =anonymous
password= your e-mail address
and get the file:
davek/blower/blower.zip

By getting the file, you are accepting all the risks of the program. Please don't complain - your getting it for free!

The program is written in C, runs on a PC under DOS. The source code is included. Your PC will have to have ANSI.SYS or equivalent installed, since this is used for cursor control.

At the time of writing, I had mislaid my data sheets for the 4CX250B and 4CX350F, so the data on these is guessed - if you have it, can you mail me. The data for the 3CX5000A7 is subject to some doubt, as the data sheet specifies less colling air for an inlet temperature of 35 deg C than for 25 deg C! I *think* I have spotted the error, but I am contacting Eimac about this.

As the manufactures of these tubes state, the temperature of the tube is the only requirement, so please check this - don't rely on the program!

Using.

The use must specify a number of items which must be obtained from the data sheet. The program does not attempt to guess the cooling requirements.

Theory

When using power transmitting tubes, it is essentail to provide sufficinet cooling air to cool the tubes, taking into account the air temperature, the air flow rate, and the 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 data sheet. Both Eimac and Burle produce publications that detail how to calculate the air flow rate under different conditions, altohugh some data sheets have data for diffeent anode dissipations, air minlet temperatures and altitudes. However, after using the rules, it soon became apparant that they do not accurately model the air flow requirements on data sheets from Eimac. The reasons are simply the suggested models are not accurate. This describes my attempts to model the air flow requirement more accureatly, with the result that air flow requirement predictions using these models are quite close to the data sheet values. Since not all data sheets give airflow requiremets under various conditions, this can be useful.

**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) ..

Both Eimac and Burle state that the air flow should be increased with altitude to compenstate for the lack of air pressure and so the reduced mass flow rate for a constant volume flow rate. The correction factor is imperical, taking account of the density vaiation of air pressure with altitude.

The basic steps in evaluating the airflow requirements are to:

1) Use the data on the data sheet taken at an inlet temp of $T_{in}$, altitude A, and dissipation W as a starting point. Some volume flow rate F at some back pressure P will be specified.

2) Find the operating altitude $A_1$ and multiply the airflow by some factor $F_A$, where $F_A$ takes account of the lower air pressure (and hence density) at altitude $A_1$.

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 pressure), 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.