

M E M O R A N D U M

TO: Jim Gallagher

FROM: Michael Munroe

DATE: 6 April 94

SUBJECT: Cooling Systems

COPIES:

In the typical vertical load VME or Eurocard enclosures that have become popular over the past five years three basic cooling schemes have prevailed. They are all front to rear cooling schemes where the air is drawn in from the front (and sometimes sides) and exhausted through the rear. Other schemes are employed particularly in top or horizontal load units, however, in front vertical load units which are by far the most common, these three designs are the most often used.

1. Pressurized plenum via tube axial fans (rectangular muffin fans)
2. Evacuation cooling via tube axial fans mounted on a rear wall in an exhaust configuration.
3. Evacuation cooling via backward curved impeller blowers mounted in an exhaust plenum which directs air out the rear of the enclosure.

The evolution of the vertical front load VME system enclosure has basically followed the three designs above in the order listed with the most sophisticated systems today employing method three with the backward curved impeller blower.

The development of these cooling systems has been driven in a large part by two constraints. One, applications have required that vertical rack space be kept to an absolute minimum so that as many units can fit into an equipment rack or equipment bay as possible and two, that each generation of boards has needed to dissipate more power (heat) while at the same time the double stacking of components and use of mezzanine boards has reduced the free space between adjacent cards. (If this trend continues VME boards could almost become "bricks" .8" wide which would allow no air at all to pass directly between adjacent cards - let's hope not).

The implication of these two constraints is that the space below the card cage area where air is typically free to enter the card cage area and above the card cage area where the air usually leaves the card cage area are usually held to a minimum and therefore the air must make a ninety degree bend in very tight quarters which increases "resistance" to air

flow and means that the air movers must perform more real work.

There are two prime characteristics of both backward curved impeller blowers and tube axial (muffin) fans that are helpful in understanding any such discussion. The first is that rectangular tube axial fans are relatively inexpensive costing often one tenth as much as the typical backward curved impeller blower. The fact that usually at least three are used in an application that might be met by one backward curved impeller blower reduces that advantage to approximately 30 percent of the cost. The second point is that the performance of tube axial fans drops off rapidly as static pressure (the over all resistance of an enclosure to air flow) increases. That is, if the static pressure increases from zero (inches of water) to .20 inches of water a typical 4.5" square 112 CFM muffin fan will drop from 112 CFM to almost zero CFM. However a typical 365 CFM backward curved impeller blower under the same conditions will still move cooling air at approximately 300 CFM when the tube axial fans have virtually stopped moving air.

The reason tube axial fans can continue to spin without actually moving air through an enclosure is intrinsic to their design. A 112 CFM, 4.5" square, 1.5" thick has five or six radial blades. When the static pressure increases the blades just churn the air much like a car's wheels spinning in the snow. The space between the blades allows the air to return as soon as the blades push it out and the air just cavitates as the blades create a turbulence in a motionless column of air. In a backward curved impeller blower centrifugal force drives air out very efficiently through narrow blades and the physics of the situation make it extremely difficult for any "rogue" air to return through the impeller.

These two characteristics of both types of air movers mean that when comparing the specifications of two enclosures one with a 230 CFM blower and the other with three 112 CFM tube axial fans ($3 \times 112 = 336$ CFM) the enclosure with the 230 CFM backward curved impeller blower may move much more air through the card cage area than the 336 CFM tube axial fan assembly under common practical conditions.

In the above illustrations, I have been speaking mainly of type two and type three exhaust designs. The pressurized plenum described as the type one has by far the poorest performance of all. Let me briefly explain. Take a typical industry 8U (14" high) enclosure holding 6U (10.5" high) VME cards. Approximately 3.5" of vertical height are available for the fans, intake plenum and exhaust plenum. This space may be apportioned as follows: 1.5" for fan assembly, 1" for exhaust plenum and 1" for the intake plenum. In practice the fan assembly with its associated metal work usually takes up more space and you are lucky if you have as much as .75" for each of the two plenums. A pressurized system as described depending on tube axial (muffin) fans as the air movers

already has considerable static pressure to degrade its performance even if the boards are generously spaced and the remainder of the air path is unobstructed. In addition to the lack of space allotted to the air plenums some space must be allotted to a mixing region or the design will be further plagued by dead spots. Of course this mixing space will further reduce the available space for the intake and exhaust plenum. In early "low performance" systems this design was adequate and it is still favored by manufacturers who favor a "modular" European enclosure approach because the number and variety of the sheet metal elements needed to support a variety of configurations is minimal and can be implemented with little engineering assistance.

The typical type two exhaust design with three or more tube axial fans mounted on the rear wall of the enclosure, has the advantage of leaving the full space above and below the card cage area for the exhaust and intake plenums and also requires minimum supporting sheet metal elements or design time to implement. However with peripherals, densely loaded CPU cards and air paths obstructed by power cables and disk drive data cables the air path usually is sufficiently obstructed to significantly degrade the performance of the sensitive tube axial fans. In a typical type two exhaust design it is not unusual to see a system impedance equal to .15" H₂O of static pressure. In this situation you can refer to the performance curves of the tube axial fans and will see that their performance is seriously degraded.

The type three exhaust design is more difficult for the engineer and designer to implement and somewhat more costly to manufacturer due to the number of necessary sheet metal parts needed to support the blowers and create an efficient air plenum. A costly CAD system that supports solid modeling is useful to create a clean first pass design and engineers have to have a rigorous understanding of airflow physics to design properly proportioned plenums and chose correctly sized blowers. However the resulting designs will in general perform much better, keep systems cooler and maximize the available rack space for other equipment. In addition the backward curved impeller blowers are available in AC or DC designs with and without hall effect sensors for power supervisory control systems.

Executive Summary

Advanced vertical front load VME enclosure systems generally have one of three cooling designs:

1. Pressurized plenum via tube axial fans (rectangular muffin fans)
2. Evacuation cooling via tube axial fans mounted on a rear wall in an exhaust configuration.
3. Evacuation cooling via backward curved impeller blowers mounted in an exhaust plenum which directs air out the rear of the enclosure.

Type one enclosures were popular in the early days and still used by some of the manufacturers with a modular approach or limited in house design capability. The type three systems while more challenging to design properly and somewhat more expensive to manufacture perform better due to the more desirable characteristics of the backward curved impeller blower.

Backward curved impeller blowers continue to move air even when the system has considerable impedance (static pressure) caused by limited plenum space, air passages obstructed by cabling and densely loaded plug in boards that further reduce air space.

Buzzwords

Plenum- the cavity space provided in a mechanical design specifically for air to move through.

Static Pressure- a measurement used to define the impedance or resistance of an air path, typically used to characterize the total resistance seen by the air movers in an enclosure system.

Tube Axial Fans- The most familiar air movers to most people often referred to by the trade name Muffin fans. They have square housings around a multiblade impeller and are usually no thicker than 1.6" thick.

Curved Impeller Blower- A highly efficient air mover that appears similar to a squirrel cage blower. It is characterized by a metal cage with thin vertical webs which is supported and partially encloses the motor portion which also provides the mounting locations. In operation air is drawn into the center of the impeller and driven outward through the blades by centrifugal action.

CFM- Cubic feet per minute. A measure of the volume of air that moves through a space in a given period of time.

Specsmanship- The art of creating an inexpensive design that meets on paper the numerical requirements of the customer but which may fail to perform adequately in the application.