

In metric units:

$$V = \frac{0.0458 \text{ g/sec}}{(0.00105 \text{ g/cm}^3)(0.0588 \text{ cm}^2)} = 741 \frac{\text{cm}}{\text{sec}} \quad (6.99a)$$

Also:

$$L = 6.2 \text{ in} = 0.516 \text{ ft} = 15.7 \text{ cm (length)}$$

$$D = 0.0761 \text{ in} = 0.00635 \text{ ft}$$

$$= 0.193 \text{ cm (ref. Eq. 6.87) (hydraulic diameter)}$$

$$g = 32.16 \text{ ft/sec}^2 = 386 \text{ in/sec}^2 = 980 \text{ cm/sec}^2 \text{ (gravity)}$$

A dimensional analysis shows that Eq. 6.82 will produce the static pressure loss in terms of the height of a column of air. The pressure loss is desired in terms of the height of a column of water. Therefore, the ratio of the air density (ρ_{air}) and the water density ($\rho_{\text{H}_2\text{O}}$) is used for the conversion, as shown in Eq. 6.100.

$$H_L = (4f) \left(\frac{L}{D} \right) \left(\frac{V^2}{2g} \right) \left(\frac{\rho_{\text{air}}}{\rho_{\text{H}_2\text{O}}} \right) \quad (6.100)$$

For English units, with dimensions in inches:

$$\begin{aligned} H_L &= (4)(0.0252) \left(\frac{6.2}{0.0761} \right) \frac{(290.4)^2}{(2)(386)} \frac{(0.0656 \text{ lb/ft}^3 \text{ air})}{(62.4 \text{ lb/ft}^3 \text{ H}_2\text{O})} \\ &= 0.94 \text{ in H}_2\text{O} \end{aligned} \quad (6.101)$$

In metric units:

$$\begin{aligned} H_L &= (4)(0.0252) \left(\frac{15.7}{0.193} \right) \frac{(741)^2}{(2)(980)} \frac{(0.00105 \text{ g/cm}^3 \text{ air})}{(1.0 \text{ g/cm}^3 \text{ H}_2\text{O})} \\ &= 2.39 \text{ cm H}_2\text{O} \end{aligned} \quad (6.101a)$$

The foregoing static pressure losses are only for the heat exchanger. If the complete static pressure loss through an electronic box is desired, other flow losses, such as entrance effects, turns, expansions contraction, and exhaust effects, must be added to obtain the final picture, as discussed in Section 6.7.

If the total pressure is required for the heat exchanger section, the velocity head must be added to the static head as shown in Eq. 6.3. The velocity head relation for English units is shown in Eqs. 6.2 and 6.4, where the

velocity must be in ft/min. The velocity head in English units becomes:

$$H_v = \left[\frac{(24.2 \text{ ft/sec})(60 \text{ sec/min})}{4005} \right]^2 = 0.13 \text{ in H}_2\text{O} \quad (6.102)$$

The velocity head in metric units is obtained from Eq. 6.5a as follows:

$$H_v = \left(\frac{741}{1277} \right)^2 = 0.33 \text{ cm H}_2\text{O} \quad (6.102a)$$

The total pressure loss through the heat exchanger, in English units, becomes

$$H_t = H_v + H_L = 0.13 + 0.94 = 1.07 \text{ in H}_2\text{O} \quad (6.103)$$

In metric units:

$$H_t = 0.33 + 2.39 = 2.72 \text{ cm H}_2\text{O} \quad (6.103a)$$

Equation 6.84 could also have been used to determine the static pressure loss in terms of $\sigma \Delta P$.

$$\sigma \Delta P = 0.226(4f) \left(\frac{L}{D} \right) \left(\frac{W}{A} \right)^2 \text{ (ref. Eq. 6.84)}$$

$$\text{where } W = \frac{0.408 \text{ lb/min}}{67.5 \text{ ducts}} = 0.00604 \text{ lb/min (ref. Eq. 6.86)}$$

$$L = 6.2 \text{ in} = \text{length of duct}$$

$$D = 0.0761 \text{ in} = \text{hydraulic diameter}$$

$$A = (0.192)(0.0475) = 0.00912 \text{ in}^2 \text{ (ref. Eq. 6.87)}$$

$$f = 0.0252 \text{ (ref. Eq. 6.97)}$$

$$\sigma \Delta P = 0.226(4)(0.0252) \left(\frac{6.2}{0.0761} \right) \left(\frac{0.00604}{0.00912} \right)^2$$

$$\sigma \Delta P = 0.813 \text{ in H}_2\text{O}$$

$$\sigma = \frac{\rho}{\rho_{\text{std}}} = \frac{0.0656}{0.0765} = 0.858 \text{ (ref. Eq. 6.65 and Eq. 6.98)}$$

$$\Delta P = \frac{\sigma \Delta P}{\sigma} = \frac{0.813}{0.858} = 0.94 \text{ in H}_2\text{O}$$

This checks with Eq. 6.101.

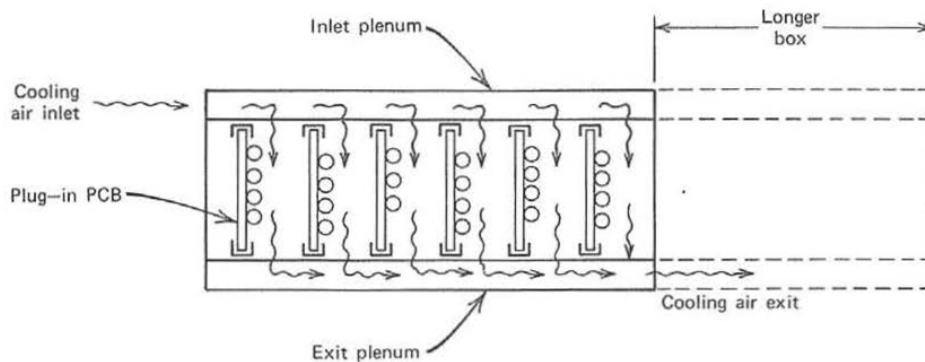


Figure 6.42 Parallel air flow system with an inlet and an exit cooling air plenum.

6.27 UNDESIRABLE AIR FLOW REVERSALS

Under certain sets of conditions it is possible for the air in a forced convection system to reverse its flow direction. If this happens, the cooling efficiency can be sharply reduced and overheating of the electronics may result.

This type of situation can develop in a parallel flow cooling system which incorporates a cooling air distribution plenum as shown in Figure 6.42.

The purpose of an inlet air distribution plenum is to provide a uniform air flow to the PCBs in the system. Ideally, the static pressure will be high and the velocity pressure will be low. A high static pressure will distribute the air equally to all of the PCBs. A low velocity pressure means a low velocity, which results in small entrance and turn losses.

If the box length is increased and the number of PCBs in the system are increased, or if the power dissipation in the system is substantially increased, additional cooling air will be required. If the cross section flow area of the air inlet plenum is not increased, the velocity of the cooling air

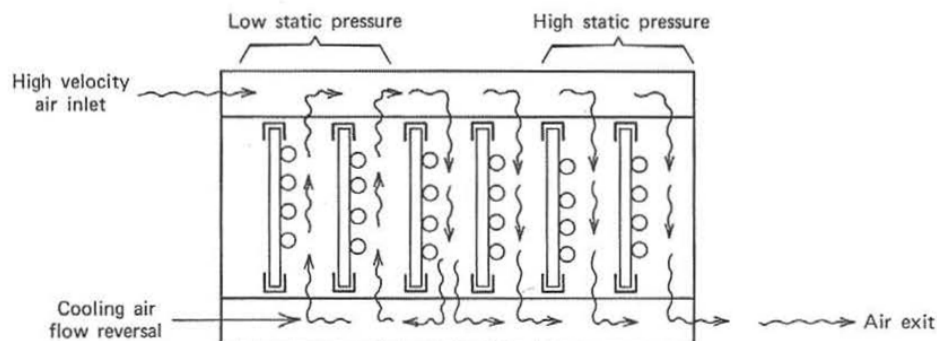


Figure 6.43 Air flow reversals may occur if the cooling air inlet velocity is too high.

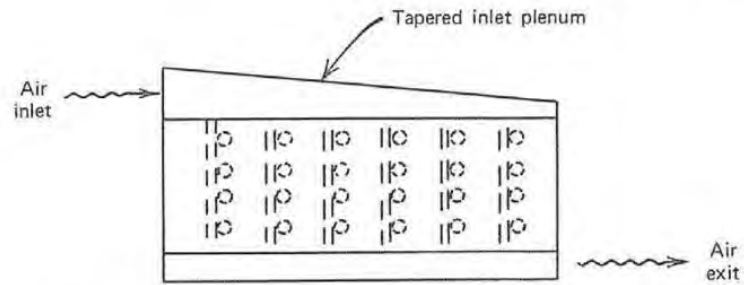


Figure 6.44 Tapered air inlet plenum on an electronic box.

flow must be increased to provide the additional air. As the velocity is increased, the static pressure will decrease. A high air velocity can result in such a low static pressure at the air inlet that it is well below the outside atmospheric pressure. When this happens, a flow reversal may occur. The air will then be drawn in from the exit plenum, as shown in Figure 6.43.

To prevent flow reversal, the inlet air plenum cross section area should

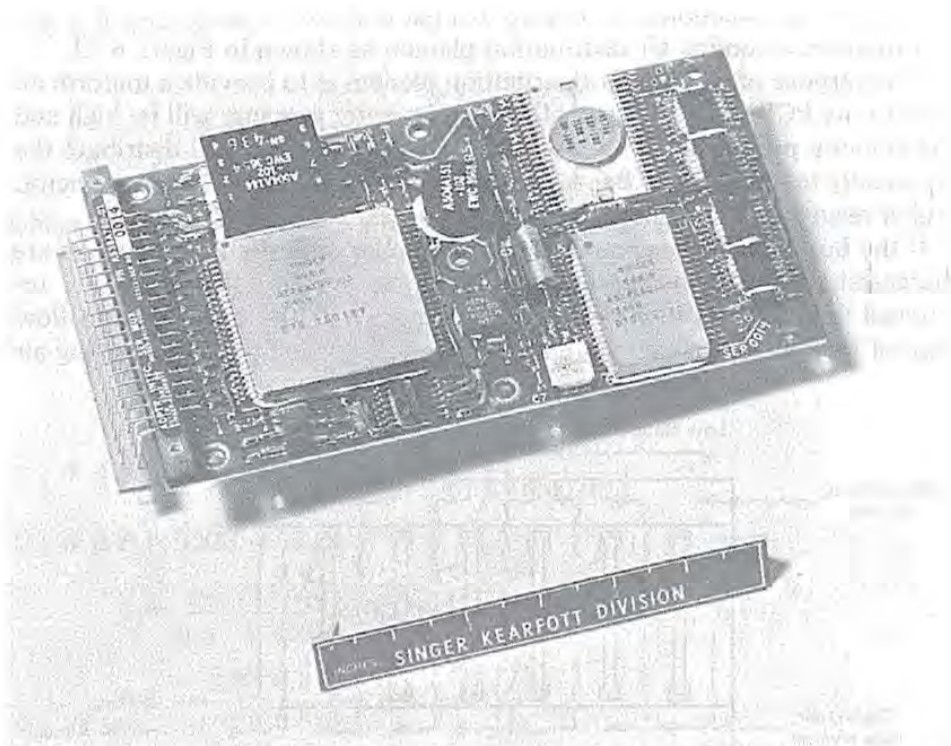


Figure 6.45 Electronic components are cemented to an aluminum core board with RTV cement to improve the conduction heat transfer. (Courtesy Kearfott Division, The Singer Company.)

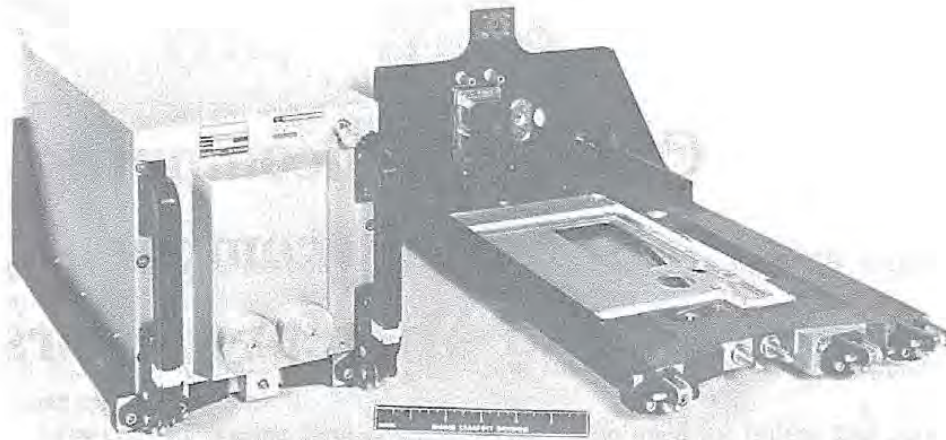


Figure 6.46 Inertial navigation assembly with a mounting rack that has a cooling air plenum in its base. (Courtesy Kearfott Division, The Singer Company.)

be greater than the sum of all the individual PCB inlet ports used to supply cooling air to the PCBs.

A tapered inlet plenum can also be used for the cooling air, as shown in Figure 6.44. The taper should be gradual so that the cross section area of the plenum at any point is greater than the total cross section area of the downstream air inlet ports to the PCBs.

Figure 6.45 shows a circuit board with many discrete and hybrid components held in position with RTV cement.

Figure 6.46 shows a mounting rack and an inertial navigation system that is packaged in a $\frac{3}{4}$ ATR short chassis.