10.0 INDUCED ENVIRONMENTS

10.0.1 (Reserved)

10.0.2 (Reserved)

10.0.2 UNIQUE MISSION SPECIFIC REQUIREMENTS

10.0.2.1 ORBITER UNIQUE REQUIREMENTS

10.0.2.1.1 Airlock Venting Plume Environment

Atmospheric air shall be vented from the ISS external aiorlock during EVA activities. The payload shall be subjected to pressure loads or moments due to air jet impingement.

A conventional pipe flow outlet with a check valve upstream is used in the external airlock and the Orbiter cabin for overboard venting located as shown in Table 10.0.2.1.1-1.

The data presented herein is specifically applicable only to the Orbiter/External Airlock configuration to be flown on STS-88.

10.0.2.1.2 Air Jet Pressure Environments

The impingement force on a small surface Delta-S can be computed by using the Newtonian impact theory (see Figure 10.0.2.1.2-1). The dynamic pressure defined in the subsequent sections depends on the chamber pressure, the vent size, and the distance of the impingement point from the vent. The moment for the surface can be obtained as the product of the impingement force and the moment arm. Integration of all element surfaces will generate the resultant force and moments for the whole surface.

10.0.2.1.3 Dynamic Pressure for the Pipe Flow

The air flow expands to a near vacuum environment. The source flow model is used to compute the air flow properties that will be used for generating the pressure environments. The air is treated as flowing from an orifice without the effect of the boundary layer on the pipe wall. An assumption is also made that the freezing condition of the fluid particles is set at the maximum Prandtl-Meyer expansion turning angle. These assumptions produce conservative results of the fluid dynamic pressure at high expansion angles. The source flow model, presented herein, provides a spatial distribution of the jet properties that is derived from the conservation of mass and energy, and is based on a series of NASA/JSC Chamber plume tests and the Direct Simulation Monte Carlo (DSMC) computations.

The fundamental assumption of the source flow model is that the fluid properties of a highly under-expanded jet, at a large distance R, can be written as shown in Equation (2) as below.

The source flow model for the dynamic pressure distribution can be derived as shown in Equation (3) as below.

Since the plot variables are non-dimensional, these results are applicable to variable pipe sizes and chamber pressures. In addition , the flow rate is directly proportional to the chamber pressure under a constant chamber temperature, hence the results in Figure 10.0.2.1.3-1 can be linearly extrapolated to other flow rates for practical purposes.

Equation (1) $\Delta F = C_P\, q\, \Delta S \sin^2\alpha$ with $C_p = 2$

where is the angle between the flow direction and the surface normal n and q is the dynamic pressure of the air flow at the point of impingement.

Equation (2) $\rho\,(R, \theta) = \rho_R(R)\, f(\theta)$

where $\rho(R, \theta)$ is the fluid density and $\rho_R\,(R)$ depends on R only. The angle θ is measured from the centerline of the pipe exit and $f(\theta)$ depends on θ only.

Equation (3)

$$q(R,\theta) = A_0\left(\frac{2}{\gamma+1}\right)^{1/(\gamma-1)} \frac{\gamma}{\gamma-1} P_c \left(\frac{R_e}{R}\right)^2 \frac{A_*}{A_e} f(\theta)$$

where

$$A_0 = \frac{\left(\frac{1}{2}\right)\sqrt{\frac{\gamma-1}{\gamma+1}}}{\int_0^{\theta_L} d\theta\, f(\theta)\, \sin\theta}$$

$$f(\theta) = \left[\cos\left(\frac{\pi}{2}\frac{\theta}{\theta_L}\right)\right]^{(\gamma+0.41)/(\gamma-1)} \qquad \text{for } \theta < \theta_L \qquad f(\theta) = 0 \qquad \text{for } \theta \geq \theta_L$$

where

$$\theta_L = \frac{\pi}{2}\left(\sqrt{\frac{\gamma+1}{\gamma-1}} - 1.0\right)$$

and γ is the specific heat ratio of air. A_e and A_* are the tube exit and throat (minimum cross section) areas, respectively. R is the distance of the impingement point that is measured from the pipe exit centerline and R_e is the pipe exit radius.

The parameter A_0 was derived by the conservation of energy. The angular distribution function $f(\theta)$ is based on cold flow test data correlation and the aforementioned conservative assumptions.

Constant value contours of (q/P_c) are shown in Figure 10.0.2.1.3-1, where R_* is the pipe throat (minimum) radius

10.0.2.1.4 Dynamic Pressure for the Diffuser Nozzle Flow

The flow model for the diffuser nozzle, as shown in Figure 10.0.2.1.4-1, is to simulate the air flowing out from an annular gap with the area that is equivalent to the total area of the small holes. Consequently, the air flow expands in both the r and x directions. The flow field was calculated by using Computational Fluid Dynamics (CFD) that was based on the Euler formulation.

The dynamic pressure distributions at various distances are shown in Figure 10.0.2.1.4-1. It should be noted that the dynamic pressure increases near the pipe centerline (Ttheta=90 deg.). This is because the flow converges in that region with shock formation.

Unlike the pipe flow in the previous section, results of the diffuser nozzle are only applicable for this specfic configuration.

10.0.3 (Reserved)

10.0.4 (Reserved)

TABLE 10.0.2.1.1-1 VENT CONFIGURATIONS AND FLOW CHARACTERISTICS

Vent	R*	Xo	Yo	Zo	Direction
ISS External Airlock located in					
bay 3 (down)	0.397	714.35	-35.29	329.4	-Z
(up)	0.397	714.35	-35.29	329.4	+Z
Depress valve in position 0					
ISS Docking Base in bay 3					
(system 1)	Note 1	768.34	0	435.59	YZ
(system 2)	Note 1	768.34	0	441.19	YZ

Note:

All dimensions are in inches.
R* = choke radius
Pc = 14.7 psia nominal

1. Exit vent through a 1.88 inches diameter diffuser with 360 X 0.062 inches diameter holes located around perimeter. Exit vent is in radial direction and in YZ plane.

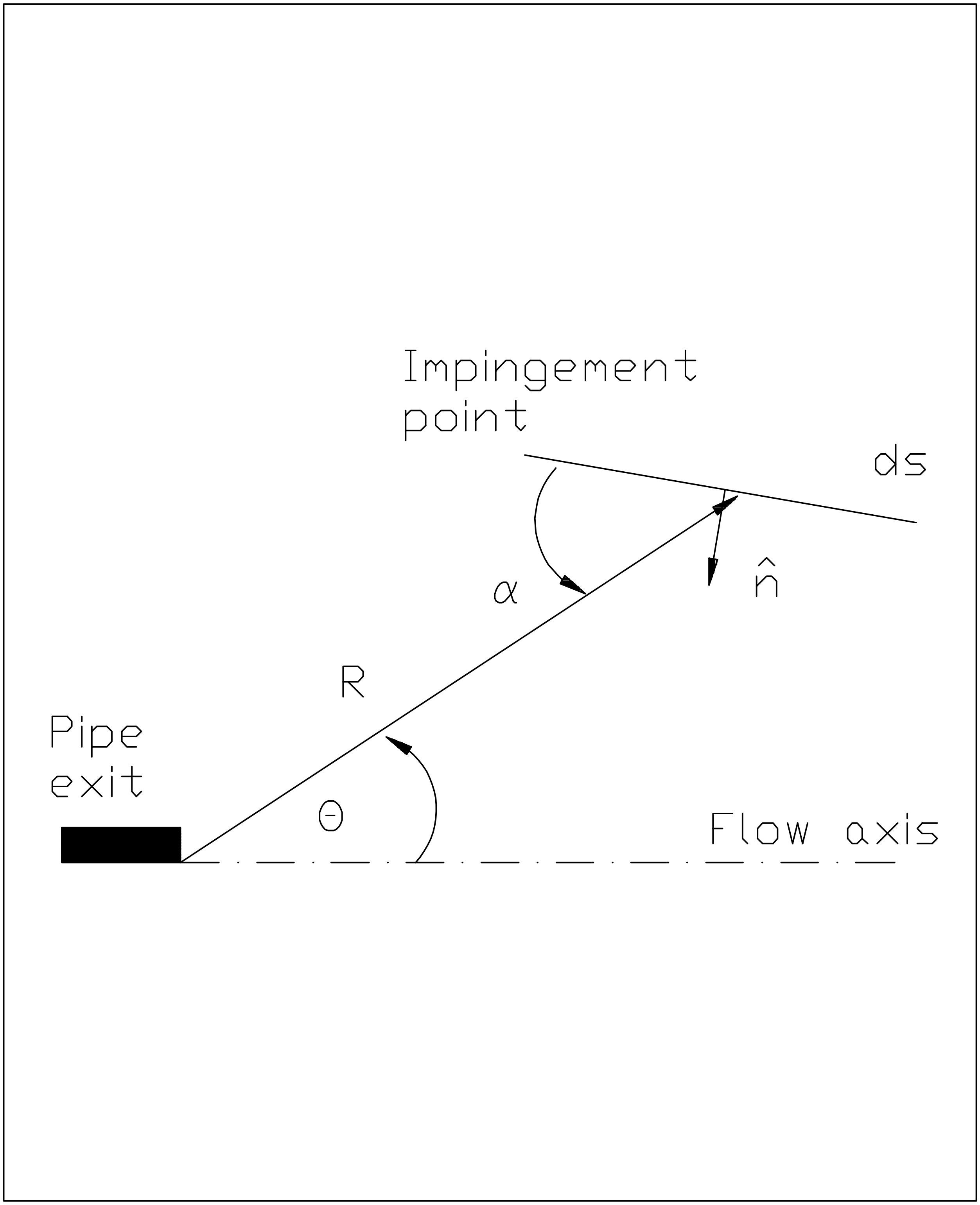

FIGURE 10.0.2.1.2-1 Source Flow Jet Model

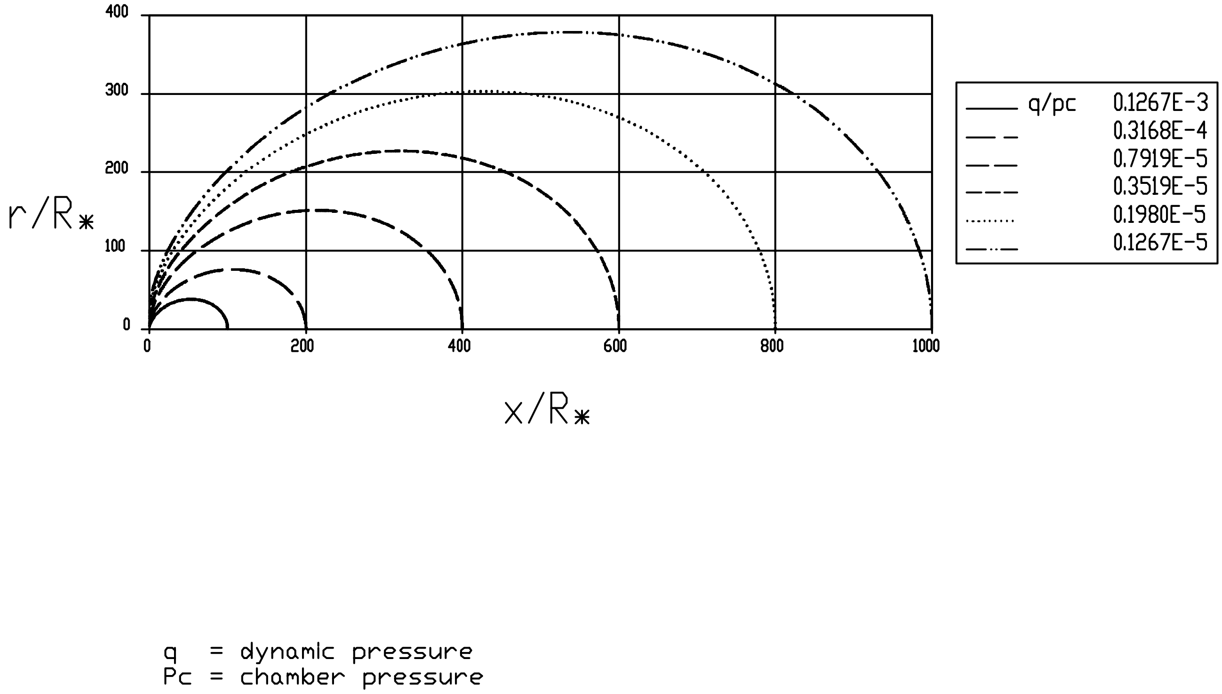

FIGURE 10.0.2.1.3-1 Dynamic Pressure Distribution of Pipe Flow

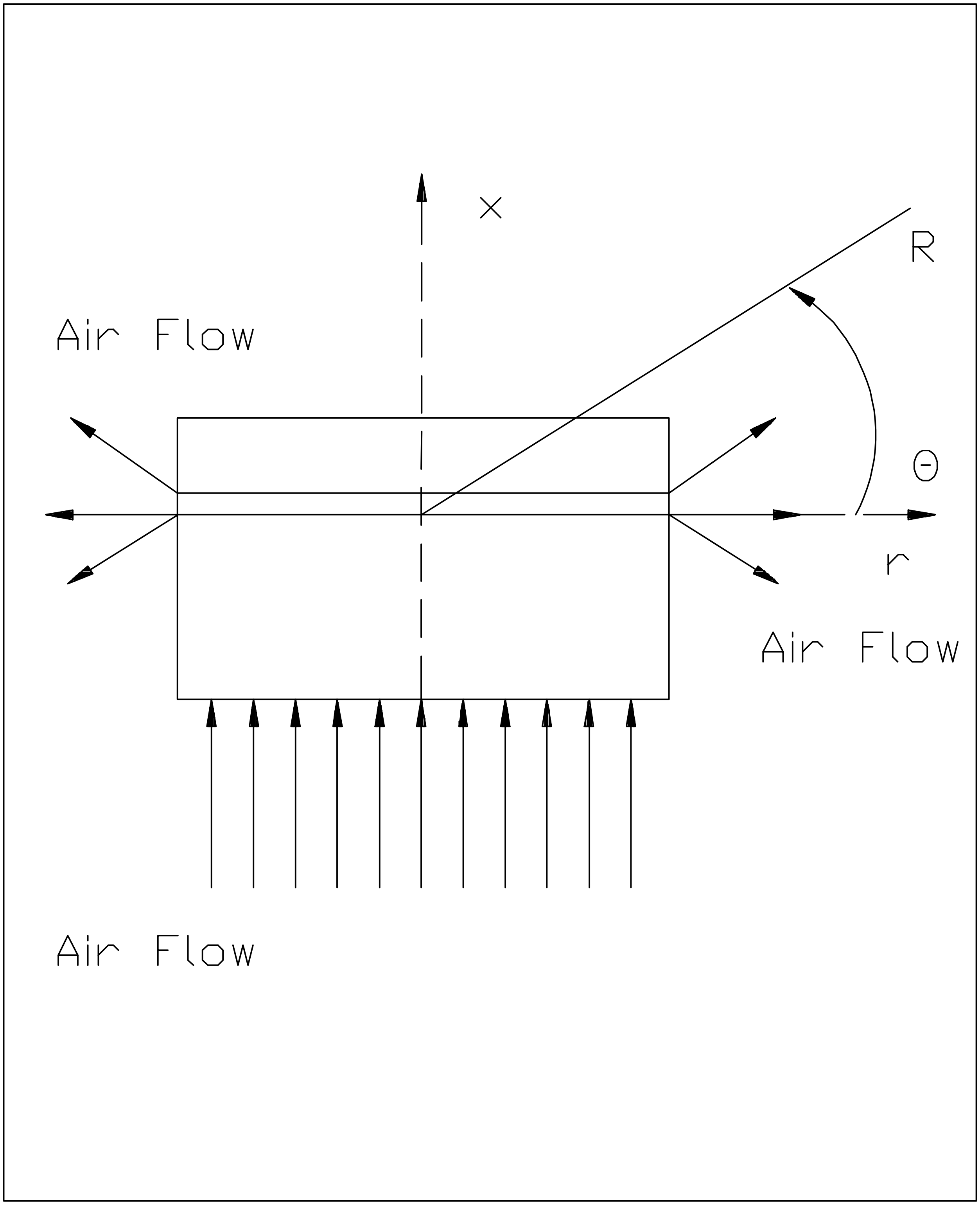

FIGURE 10.0.2.1.4-1 Flow model for Diffuser Nozzle

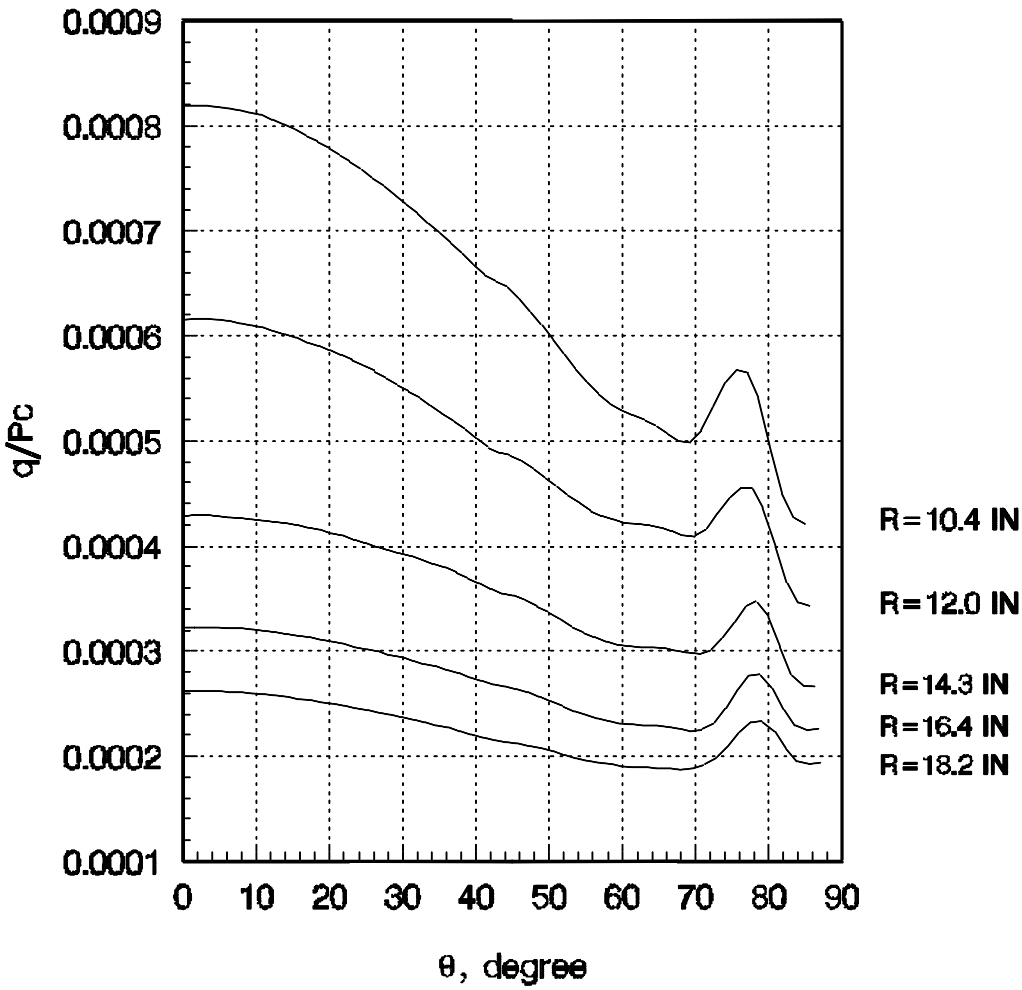

FIGURE 10.0.2.1.4-2 Dynamic Pressure Distribution for Diffuser Nozzle
(SHEET 1 OF 5)

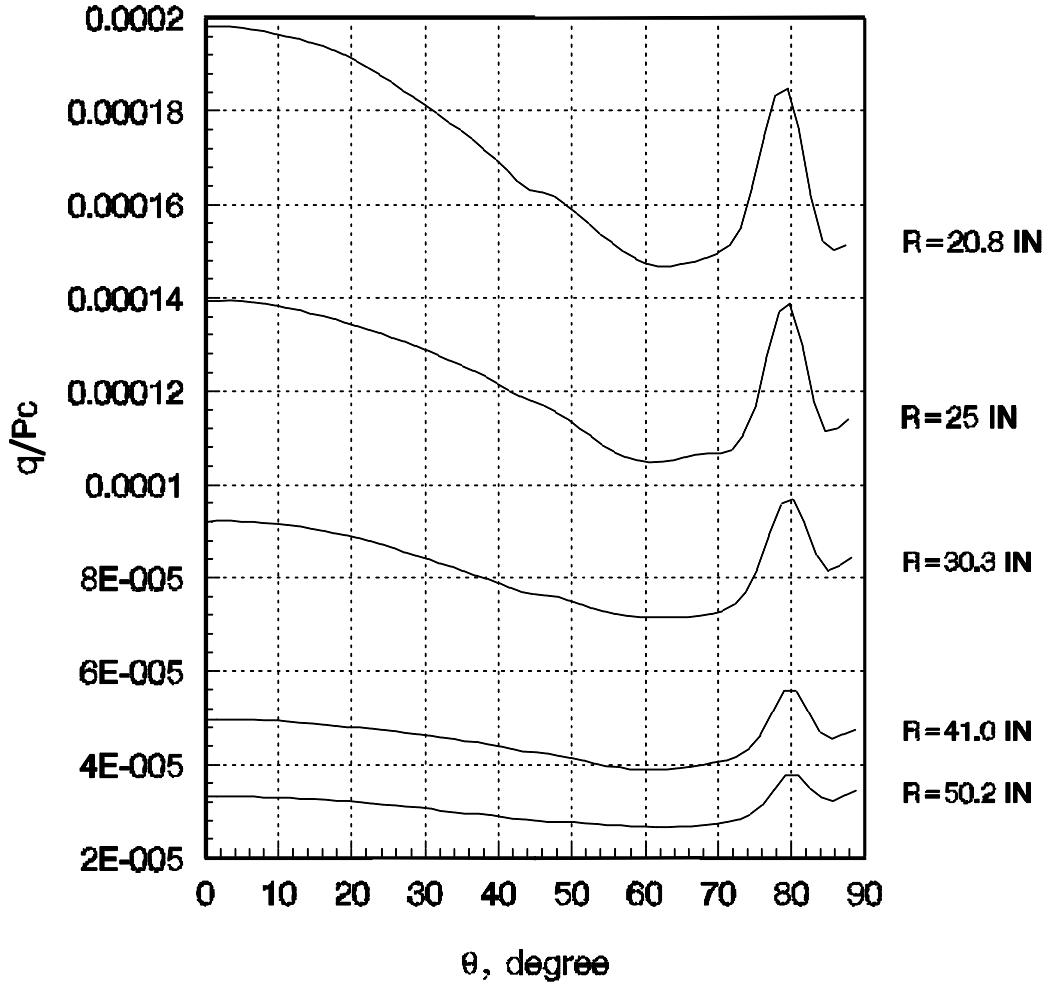

FIGURE 10.0.2.1.4-2 Dynamic Pressure Distribution for Diffuser Nozzle
(SHEET 2 OF 5)

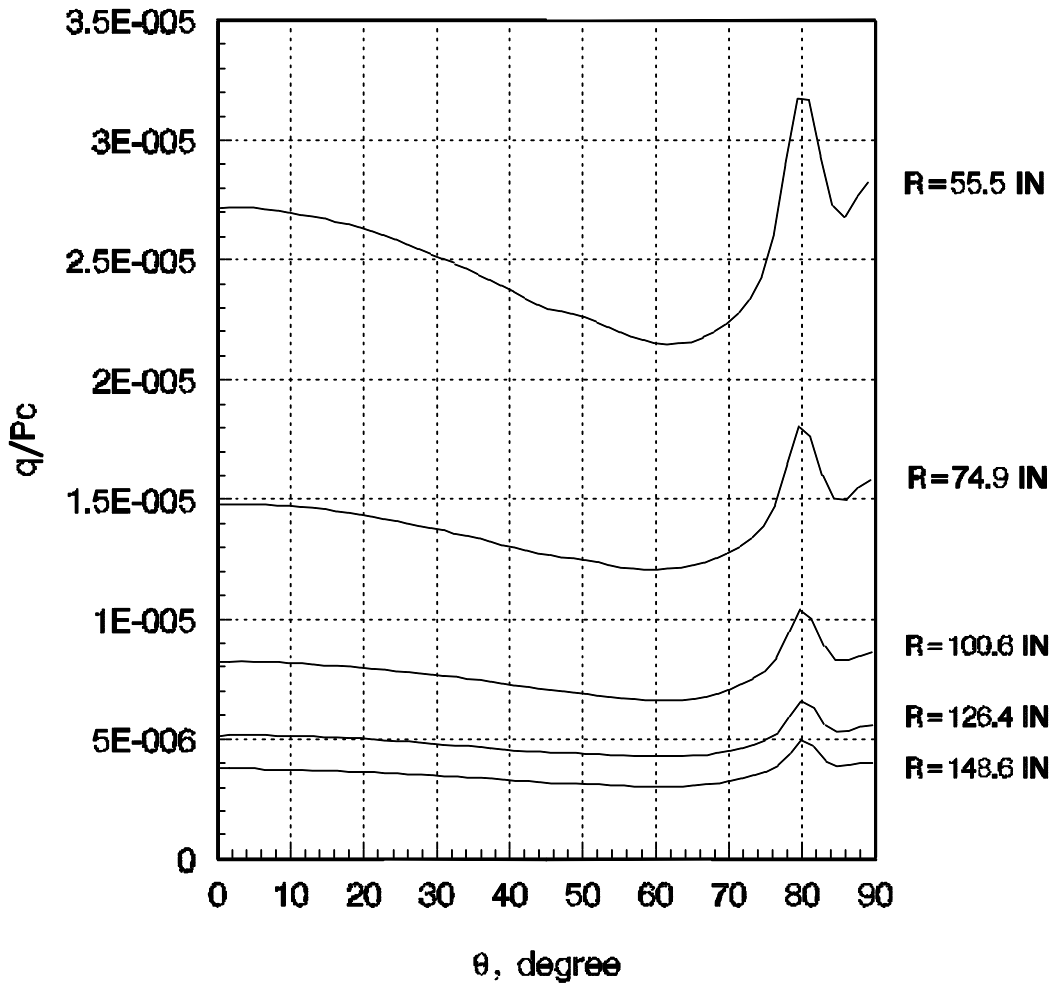

FIGURE 10.0.2.1.4-2 Dynamic Pressure Distribution for Diffuser Nozzle
(SHEET 3 OF 5)

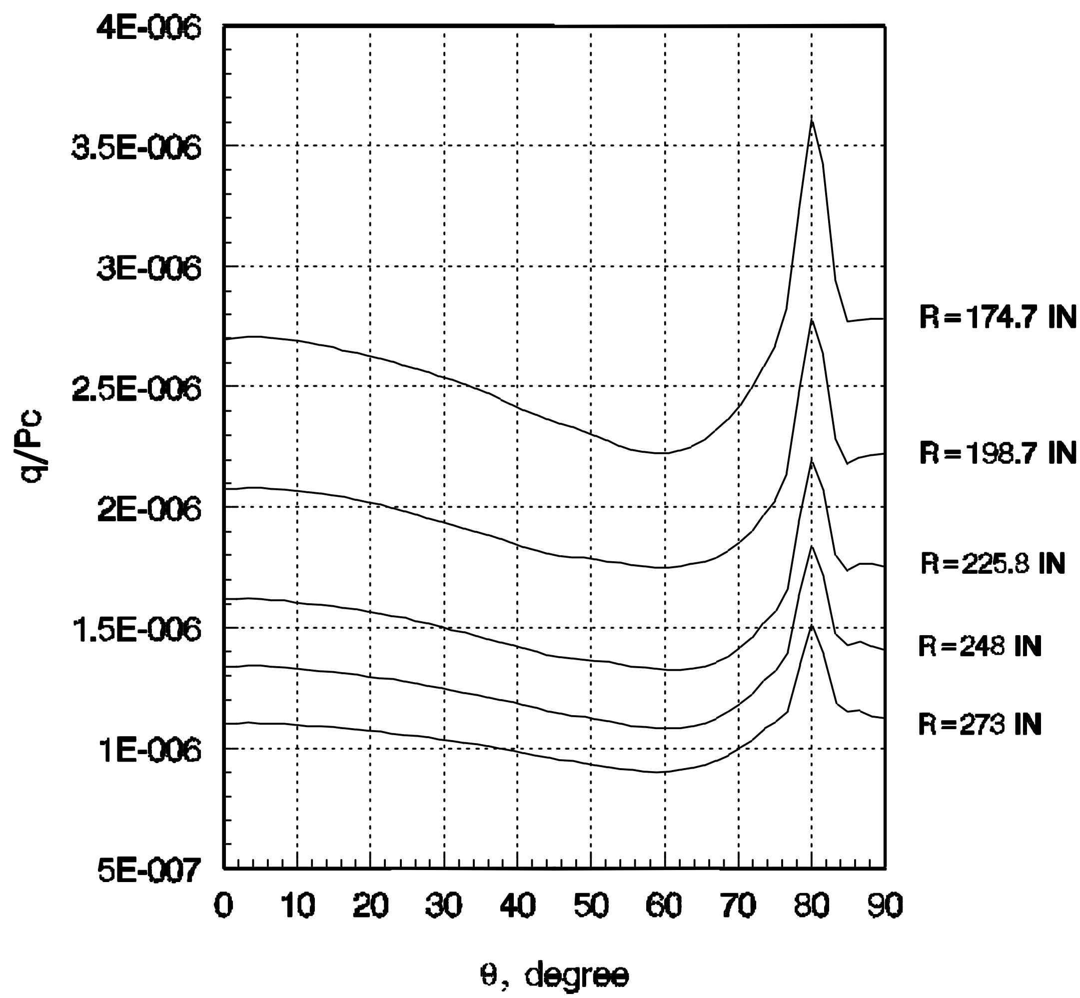

FIGURE 10.0.2.1.4-2 Dynamic Pressure Distribution for Diffuser Nozzle
(SHEET 4 OF 5)

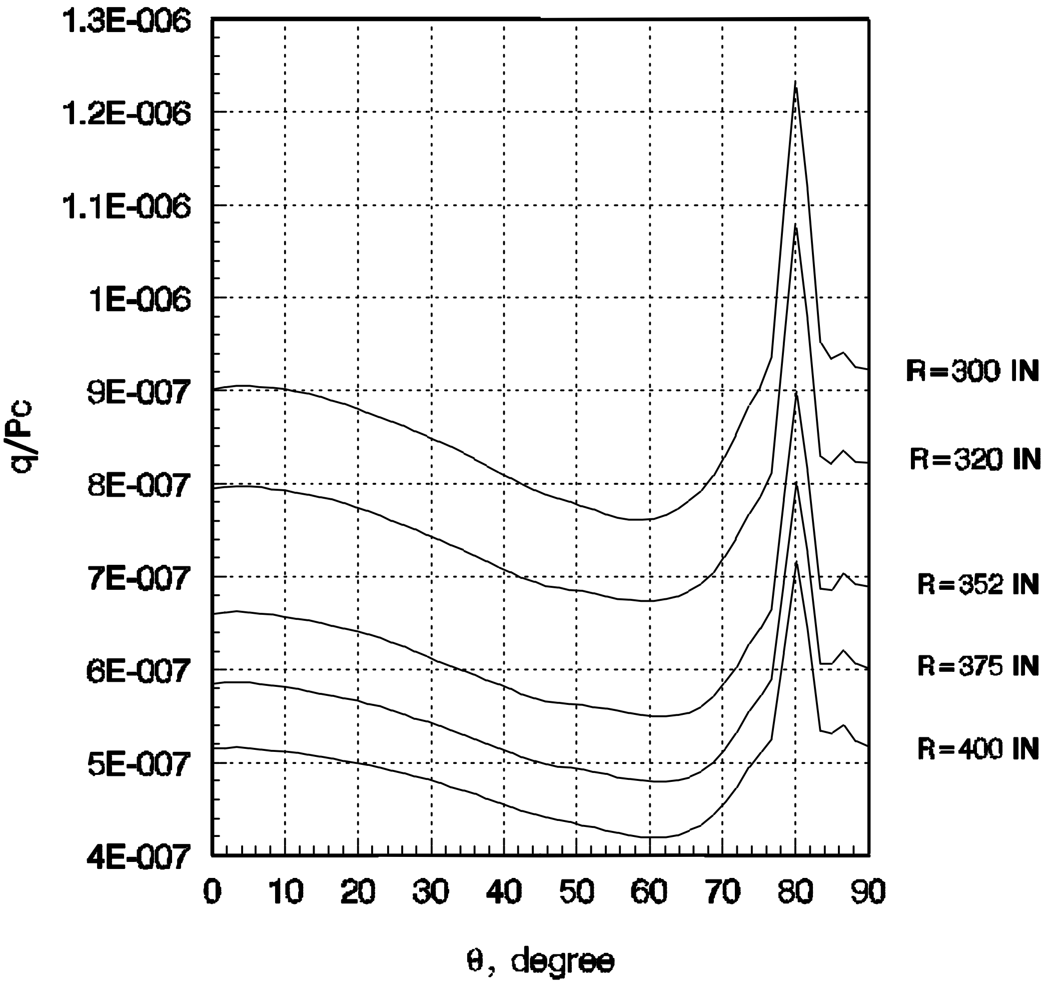

FIGURE 10.0.2.1.4-2 Dynamic Pressure Distribution for Diffuser Nozzle
(SHEET 5 OF 5)

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