N92-32265

TURBINE DISK CAVITY AERODYNAMICS AND HEAT TRANSFER

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Experiments were conducted to define the nature of the aerodynamics and heat transfer for the flow within the disk cavities and blade attachments of a large-scale model, simulating the SSME turbopump drive turbines. These experiments of the aerodynamic driving mechanisms explored the following: (1) flow between the main gas path and the disk cavities, (2) coolant flow injected into the disk cavities, (3) coolant density, (4) leakage flows through the seal between blades, and (5) the role that each of these various flows has in determining the adiabatic recovery temperature at all of the critical locations within the cavities. The model and the test apparatus provide close geometrical and aerodynamic simulation of all the two-stage cavity flow regions for the SSME High Pressure Fuel Turbopump and the ability to simulate the sources and sinks for each cavity flow.

Carbon dioxide was used as a trace gas for constant density experiments or as the simulated "heavy gas" coolant. Gas samples were withdrawn at selected locations on the rotating and stationary surfaces in the fore and aft cavity and the interstage seal regions of the two stage system. The gas samples were used to determine the fraction of gas at a location which originates from each of three coolant injection locations or four gas path locations. Samples were also withdrawn at selected locations in the blade shank regions.

A parametric series of experiments was conducted with constant density fluids and an exploratory series of experiments was conducted with CO_2 as the simulated coolant. Experimental results showed (1) the variation of coolant distribution on the cavity and disk surfaces as a function of coolant flow ratio, (2) the effects on the coolant distribution for changes in the coolant inlet distributions, and (3) increased mixing of coolant with the ingested gas when a heavy gas (density ratio equal 1.5) was used as the coolant.

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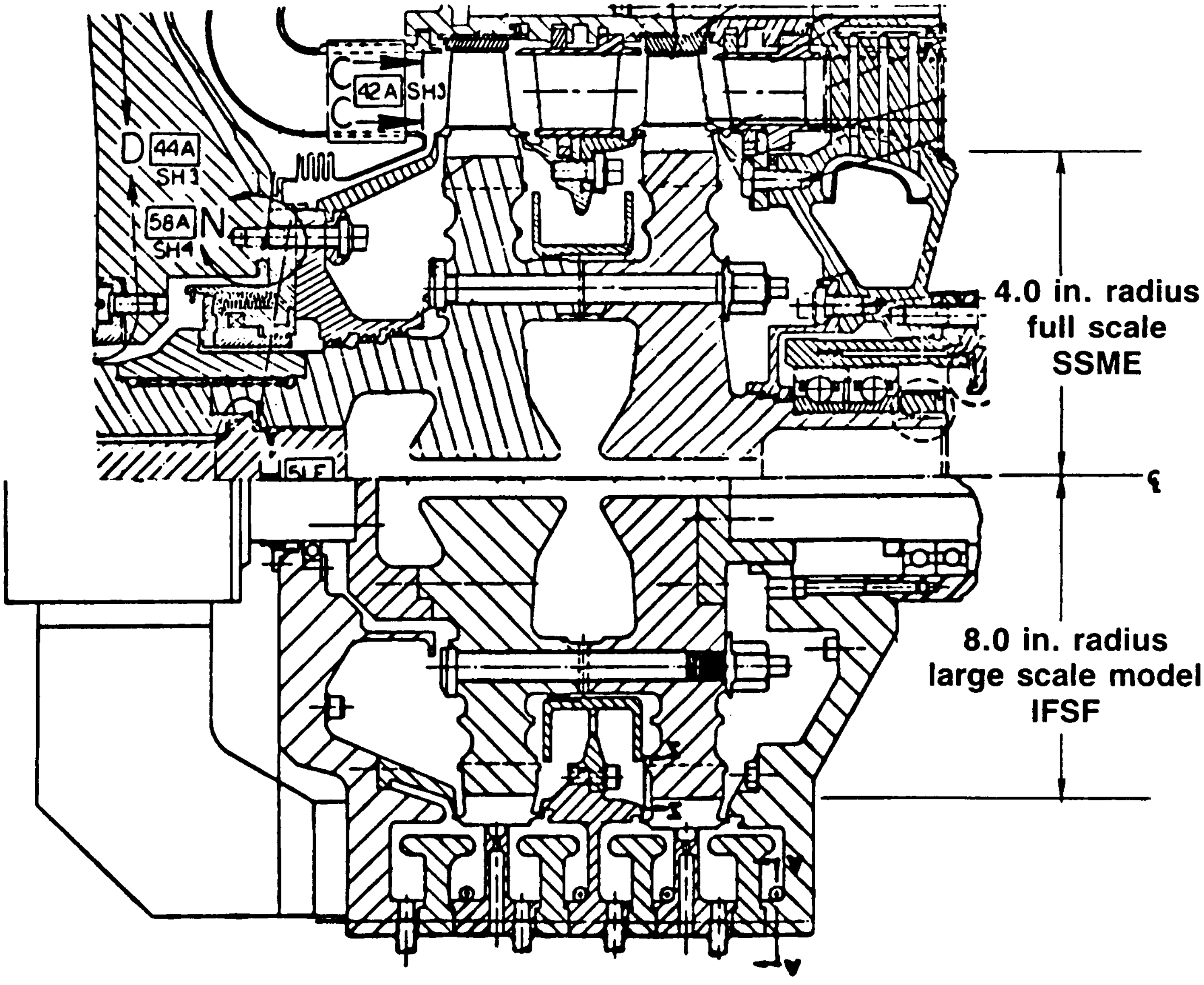
ACTUAL AND MODEL DISK/CAVITY SYSTEMS



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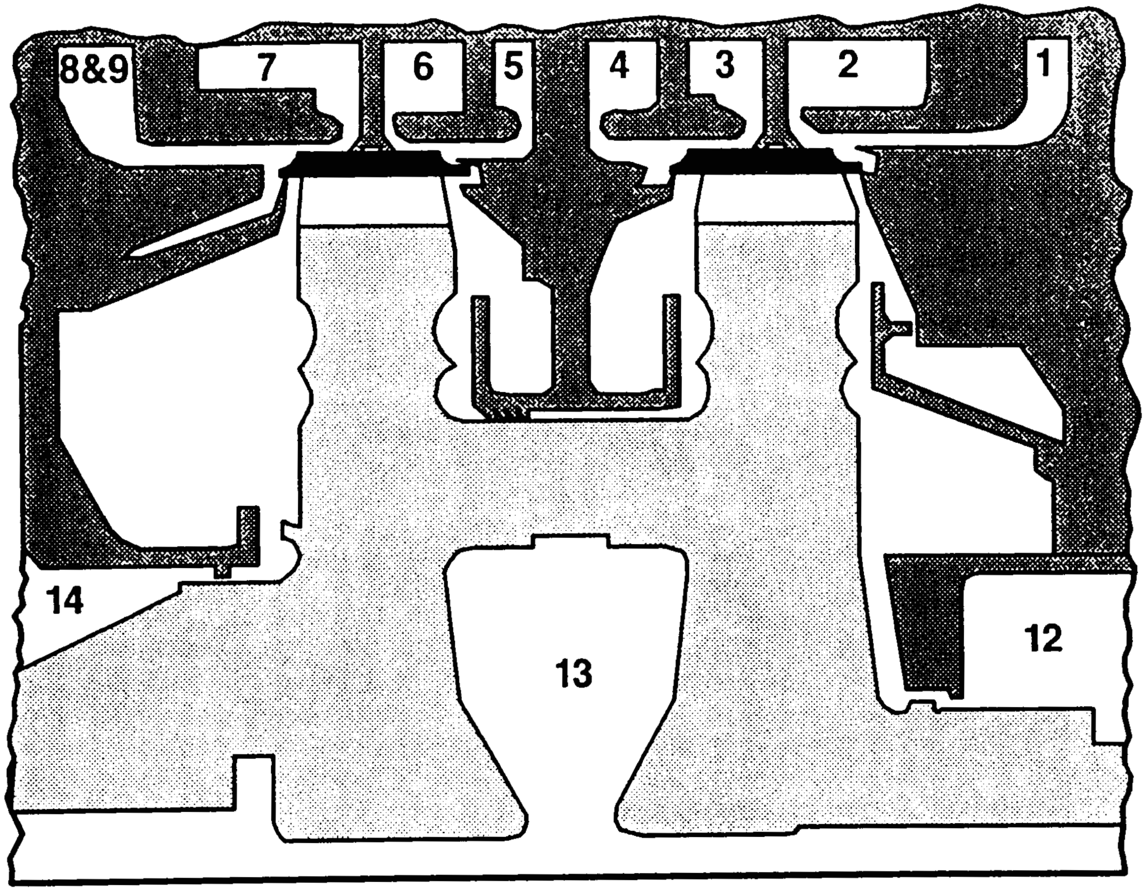
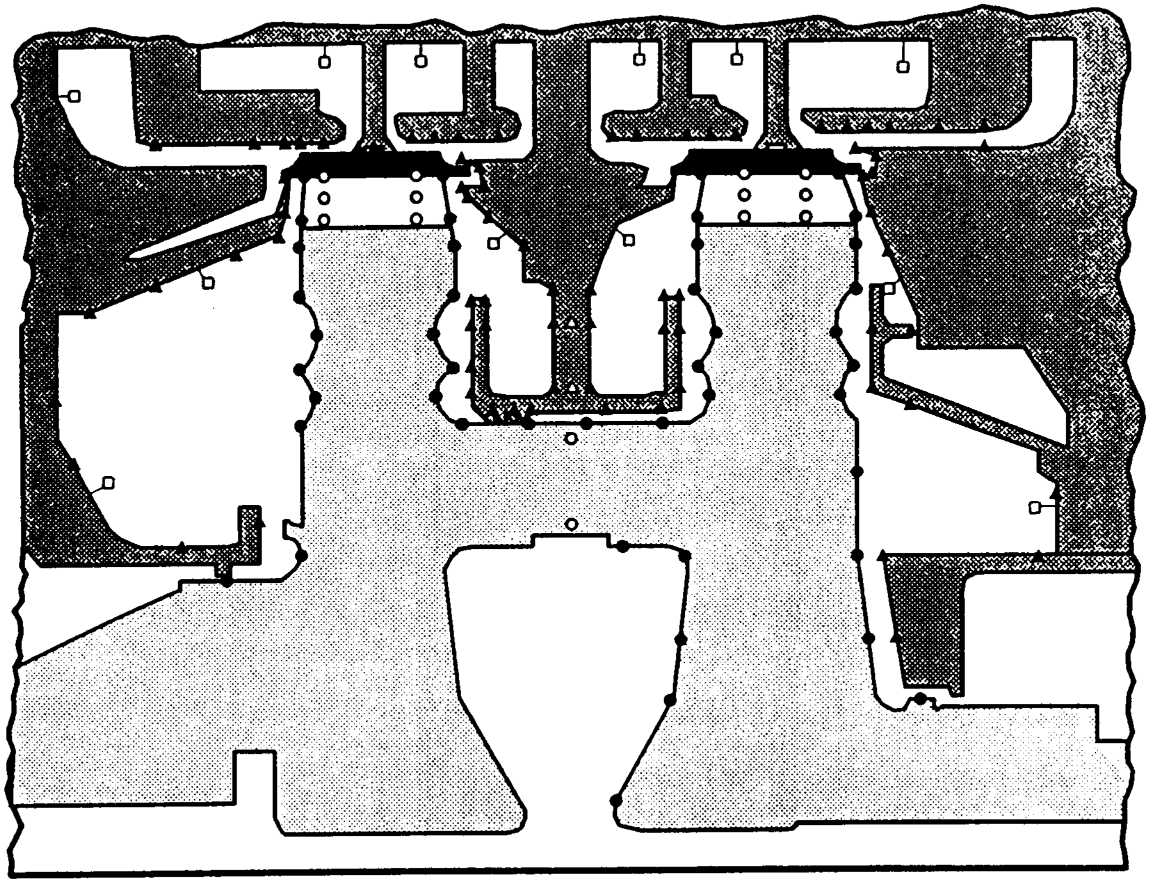
GAS SOURCES AND EXITS



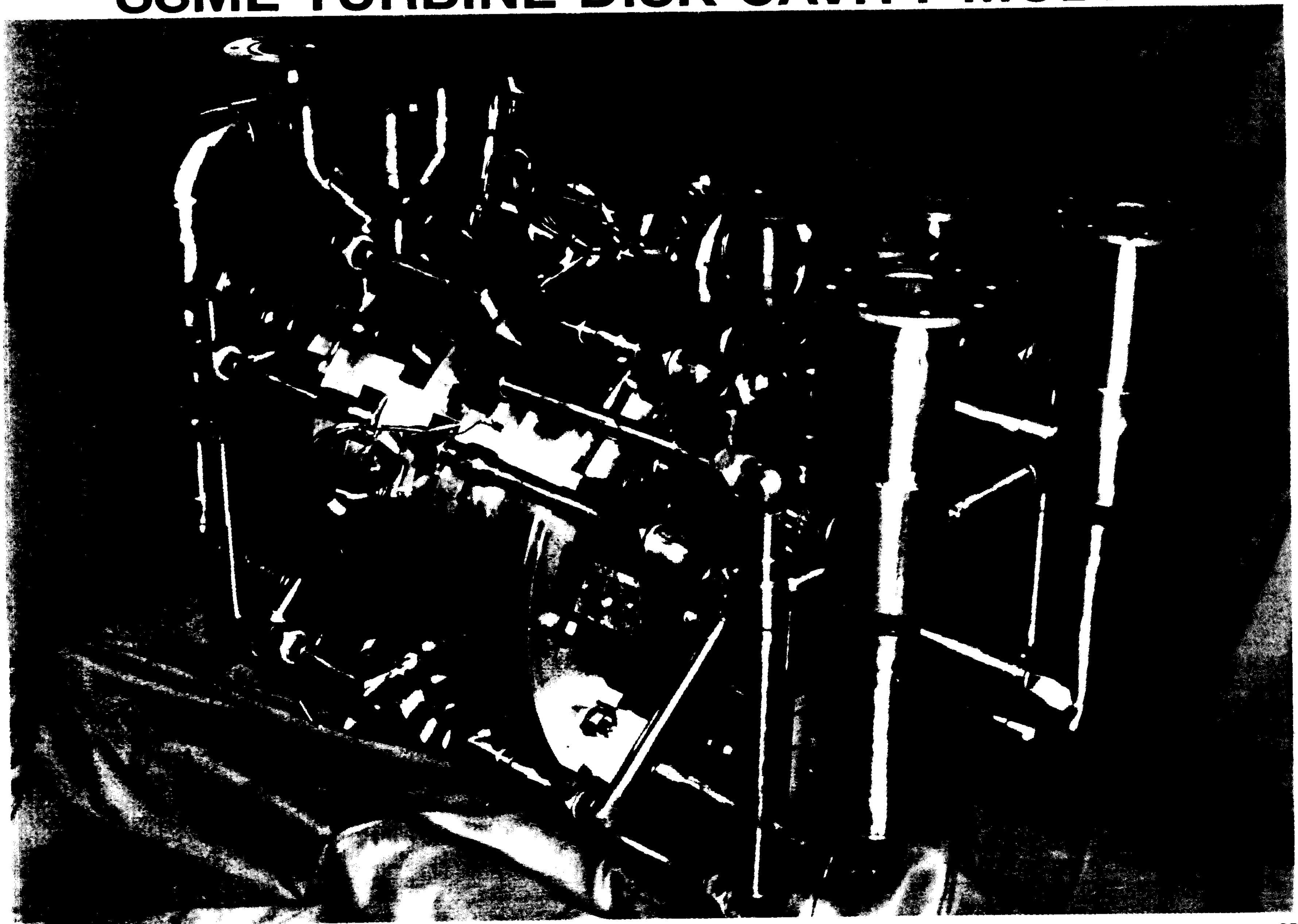
MODEL INSTRUMENTATION



□ Thermocouples
○ Pressure/CO_2 taps in passages
● Pressure/CO_2 taps on rotating components
▲ Pressure/CO_2 taps on stationary components

RB3278ETX.007

SSME TURBINE DISK CAVITY MODEL



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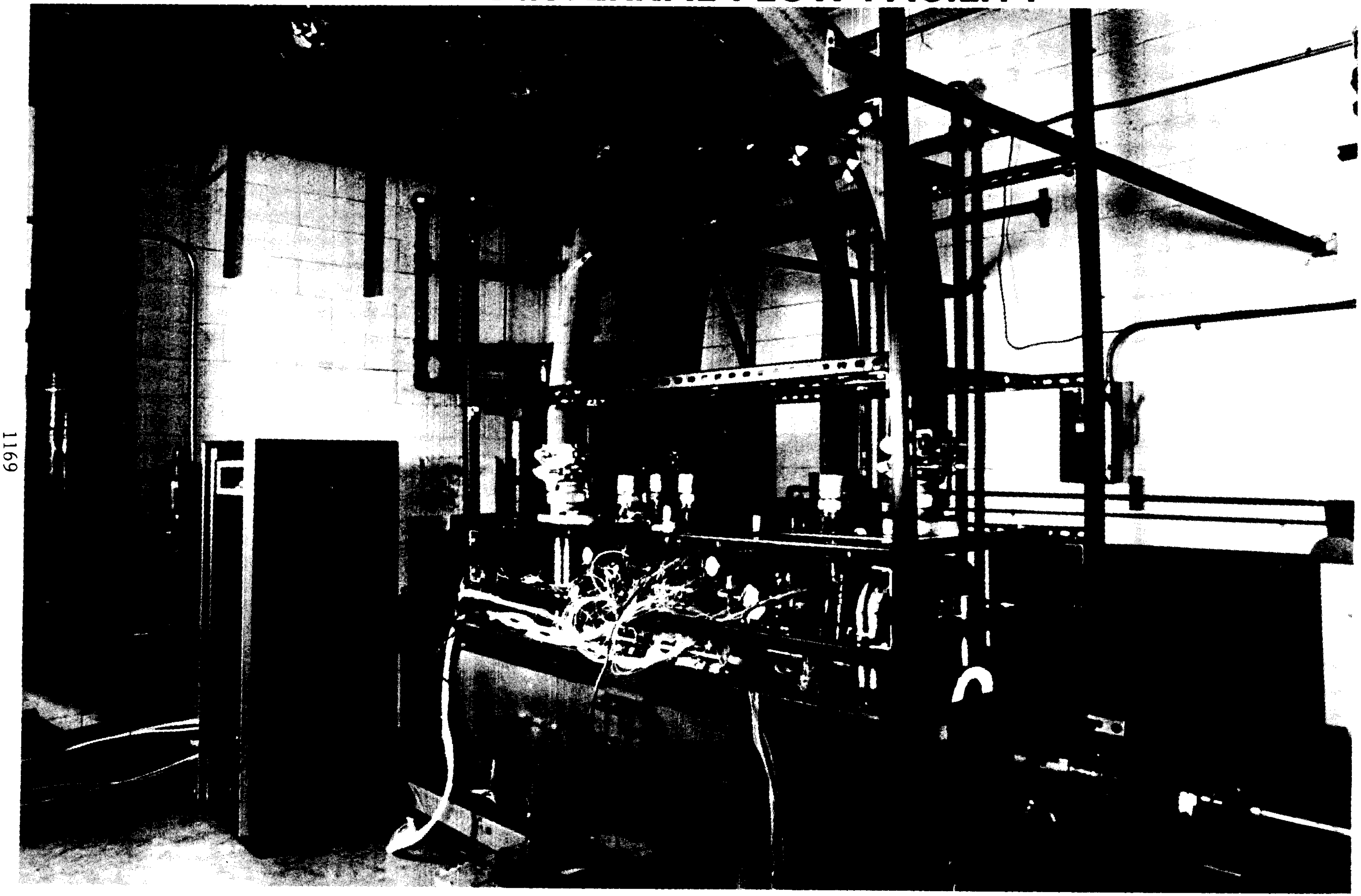
MODEL IN INTERNAL FLOW FACILITY



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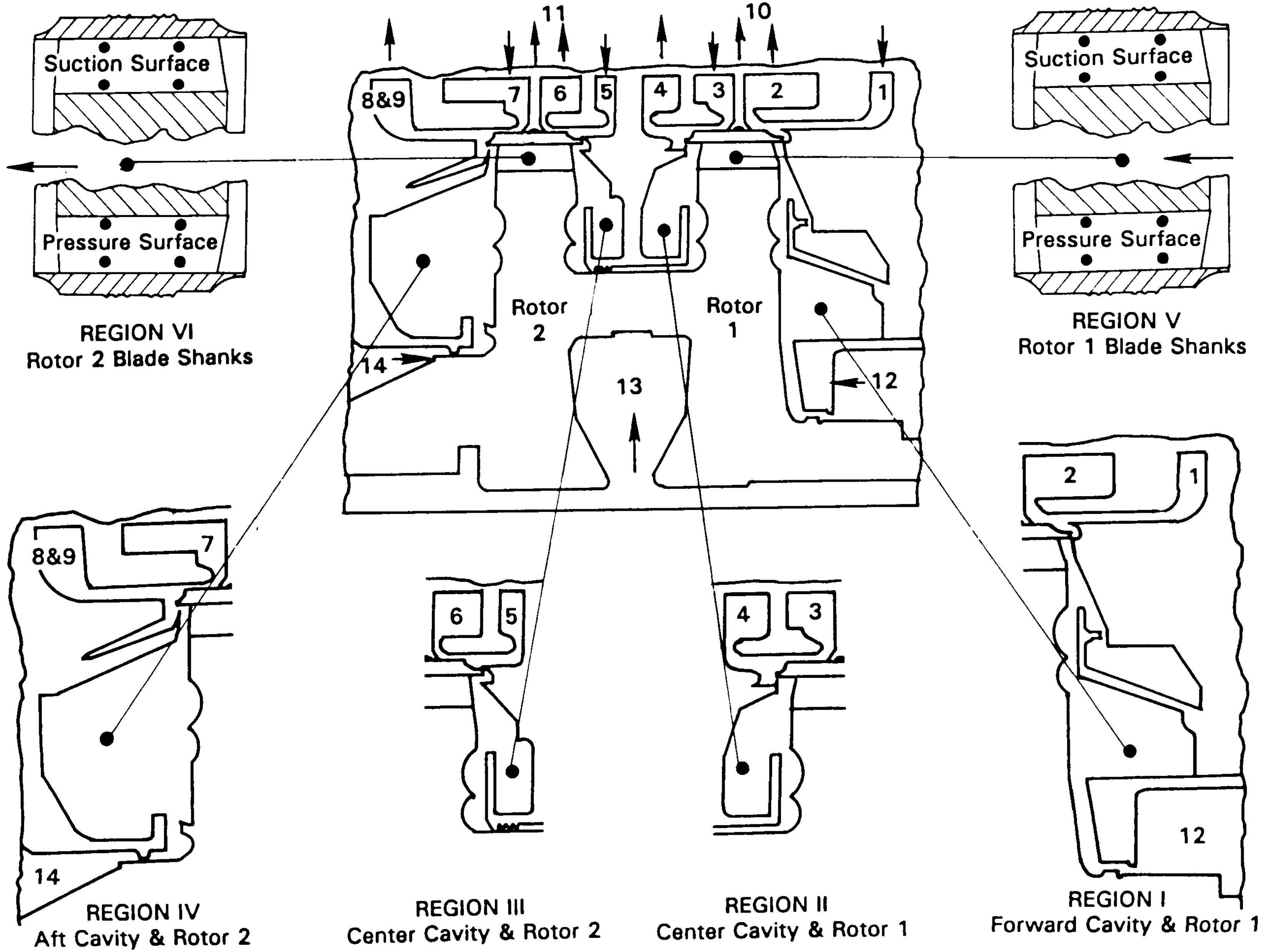
MODEL SEAL REGION AND GAS SOURCE/EXIT LOCATIONS



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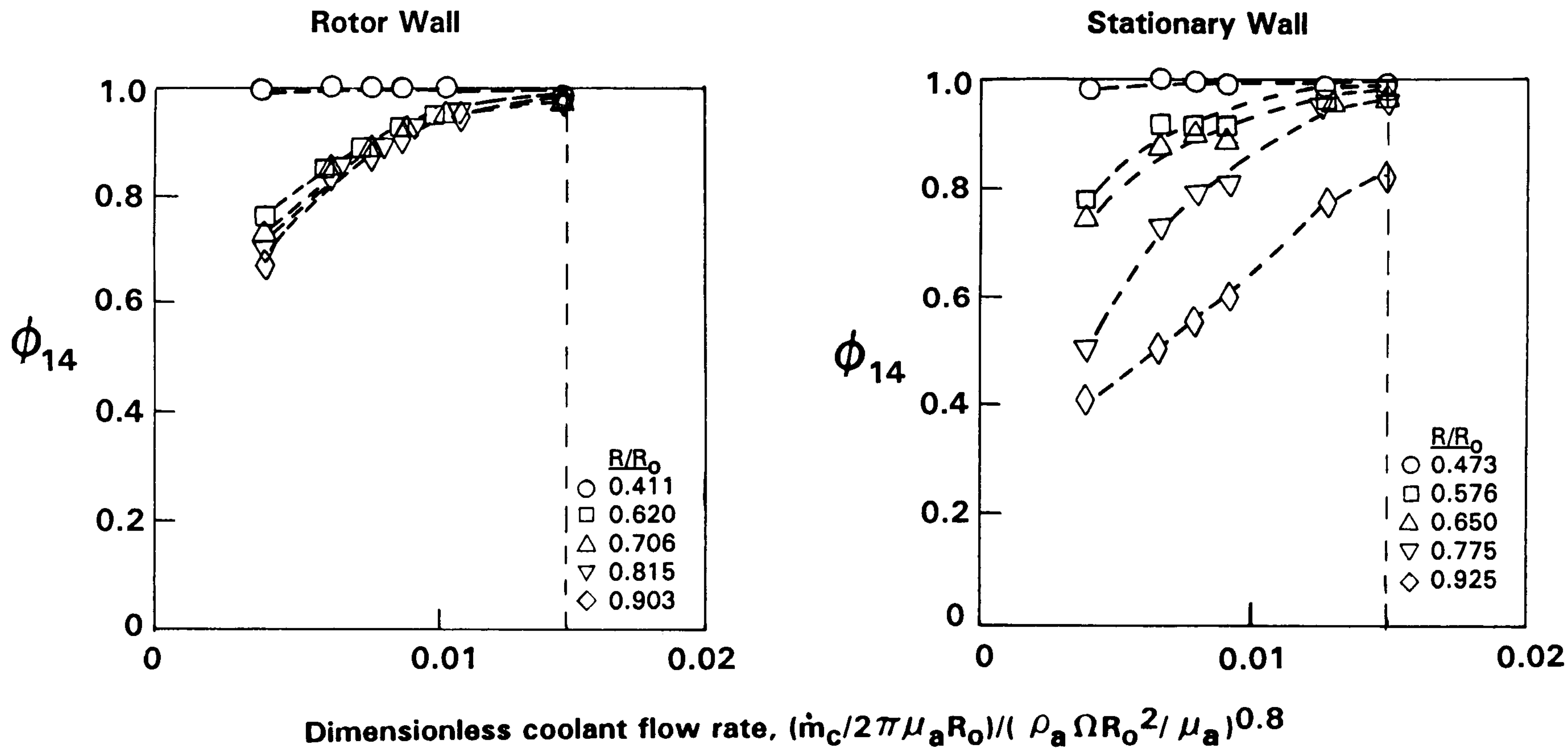
COOLANT CONCENTRATION ON ROTOR AND STATIONARY WALLS

Variables:
Radius
Coolant flow rate

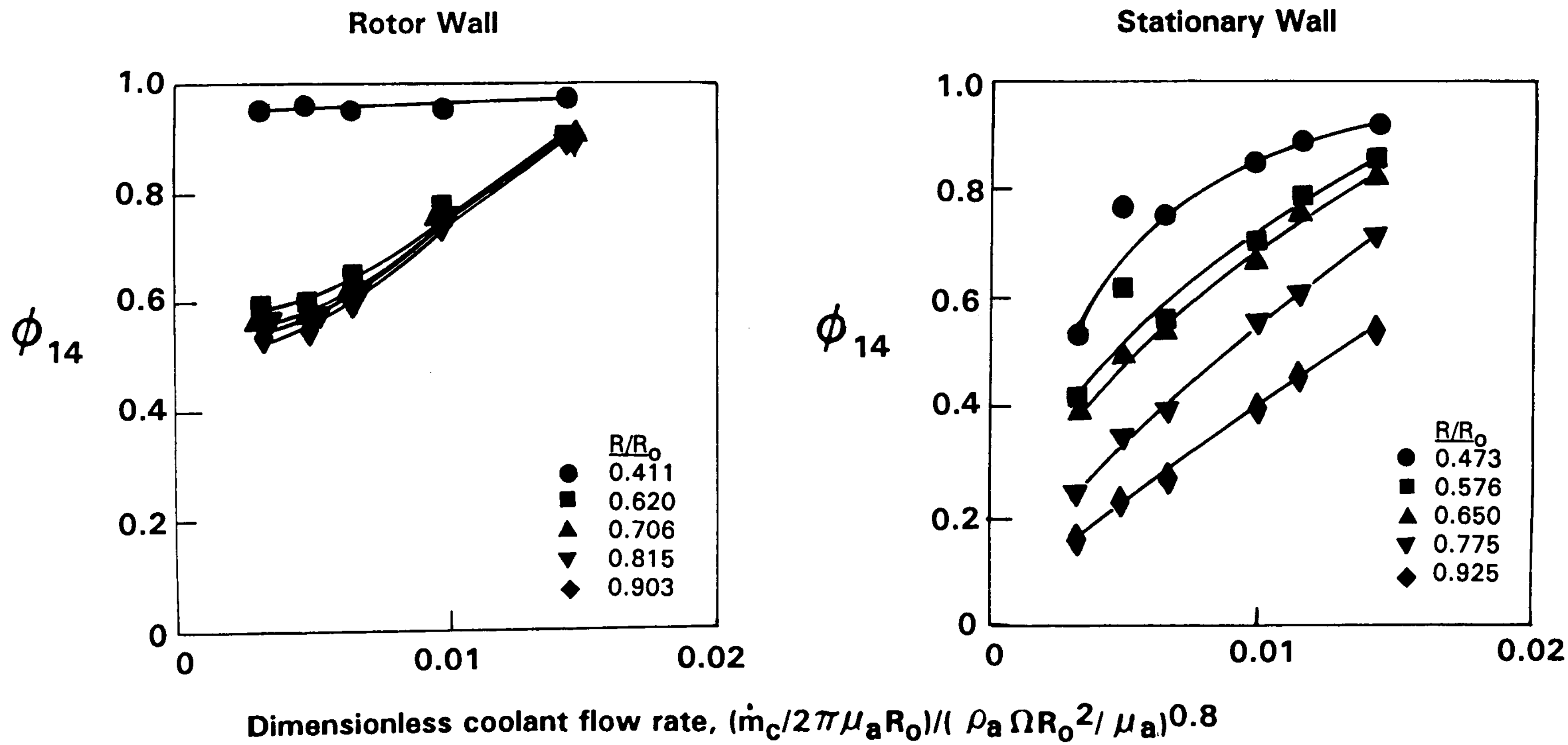
Region IV: Aft Cavity & Rotor 2
Coolant: Air



COOLANT CONCENTRATION ON ROTOR AND STATIONARY WALLS

Variables:
- Radius
- Coolant flow rate

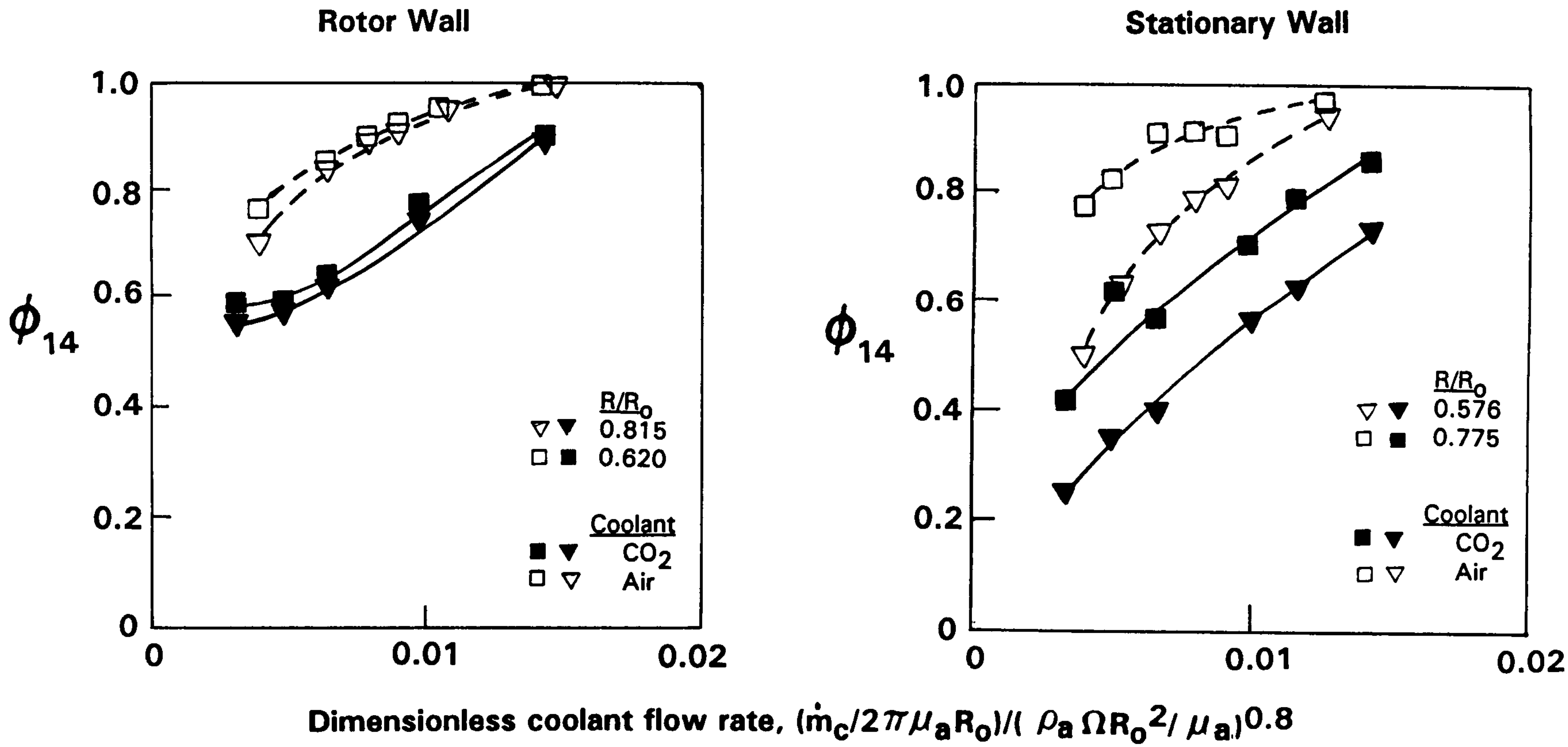
Region IV: Aft Cavity & Rotor 2
Coolant: CO_2



EFFECT OF COOLANT DENSITY ON DISTRIBUTION

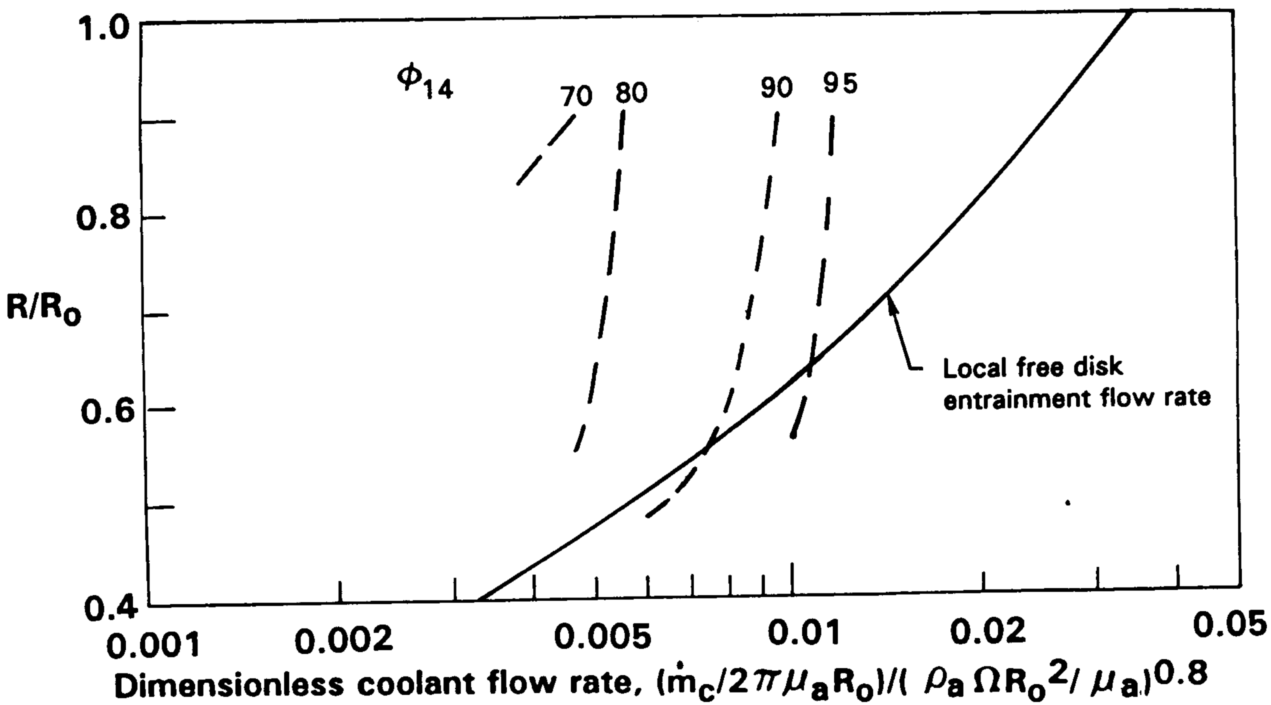
Variables:
- Radius
- Coolant flow rate
- Coolant density

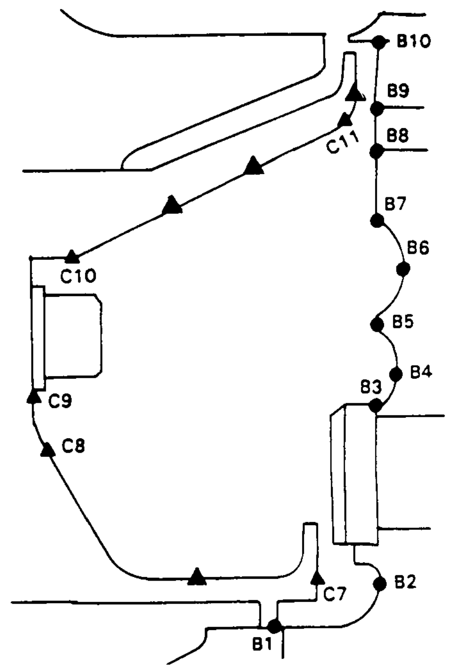
Region IV: Aft Cavity & Rotor 2



COOLANT DISTRIBUTION ON ROTOR

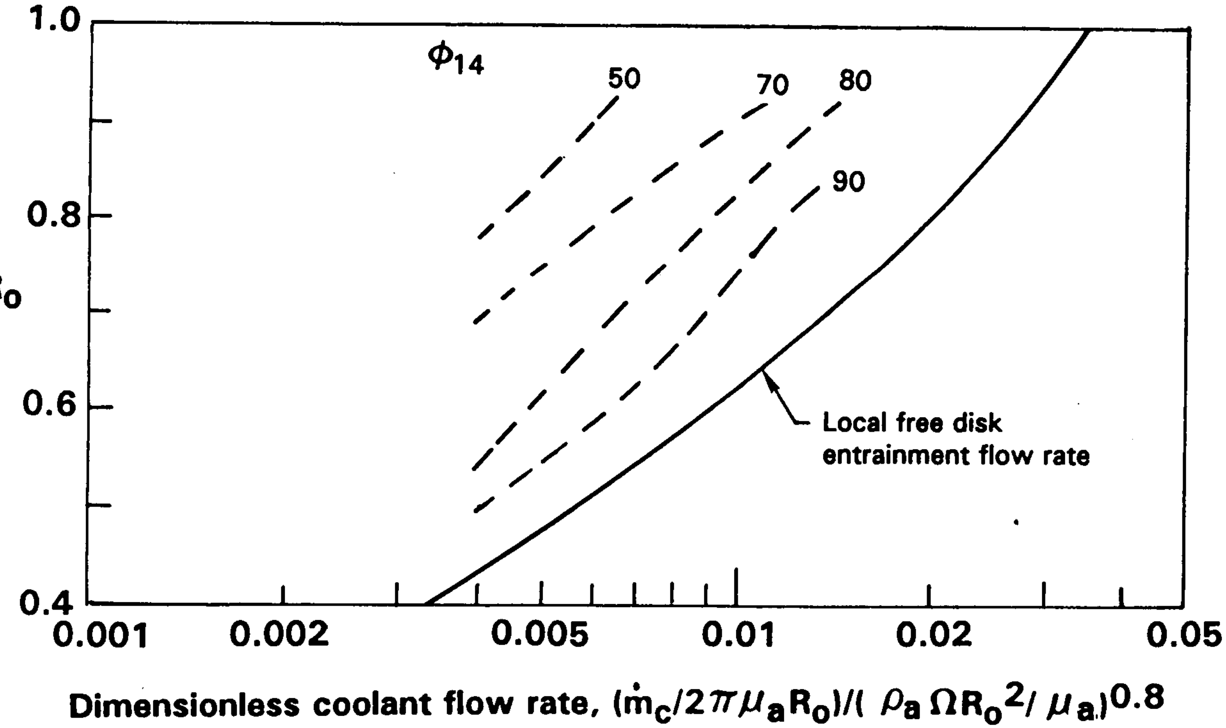
Region IV: Aft Cavity & Rotor 2
Coolant: Air

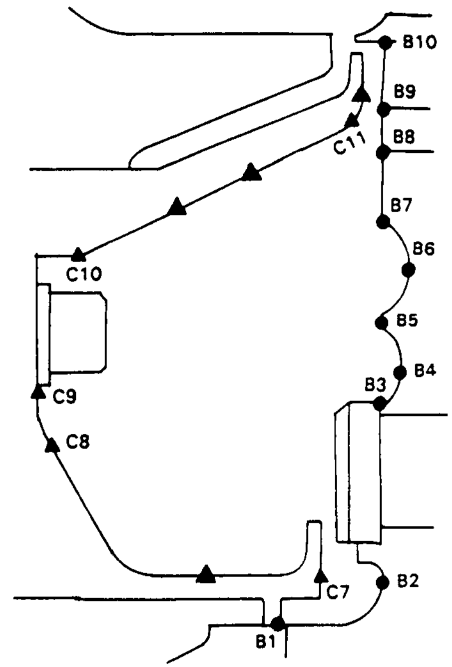




COOLANT DISTRIBUTION ON STATIONARY WALL

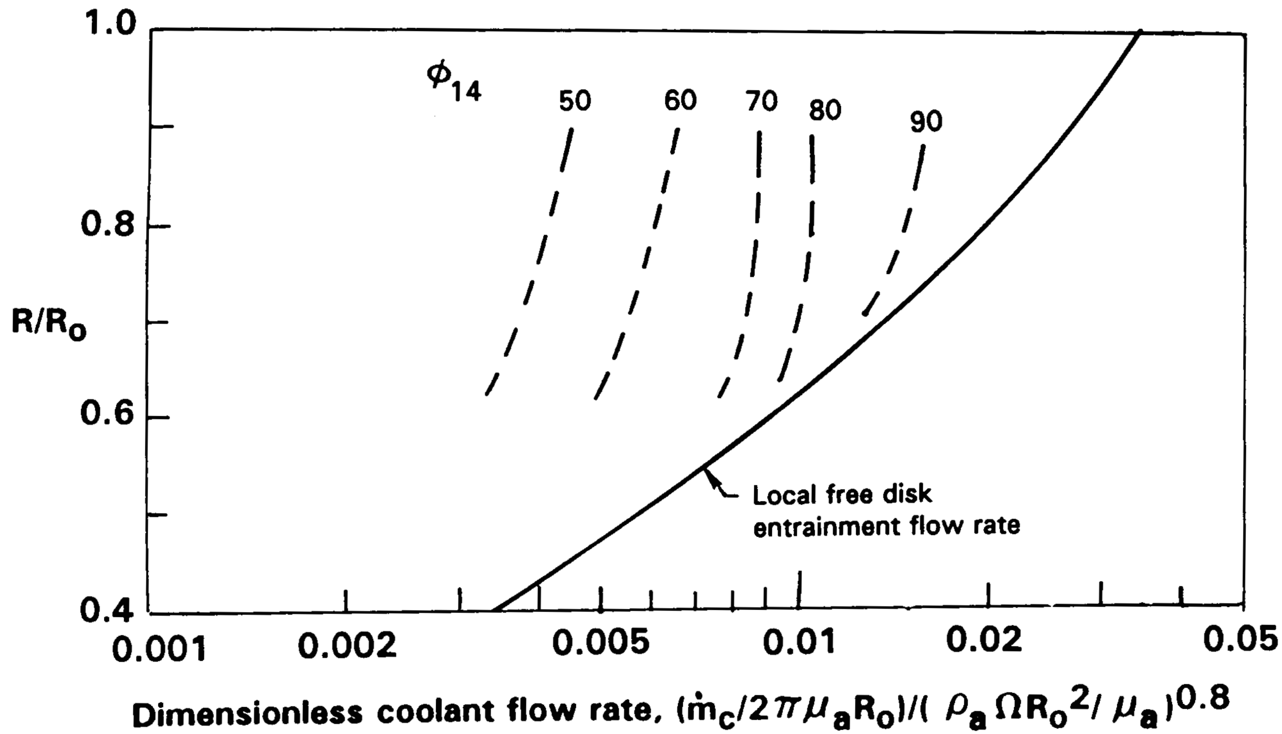
Region IV: Aft Cavity & Rotor 2
Coolant: Air

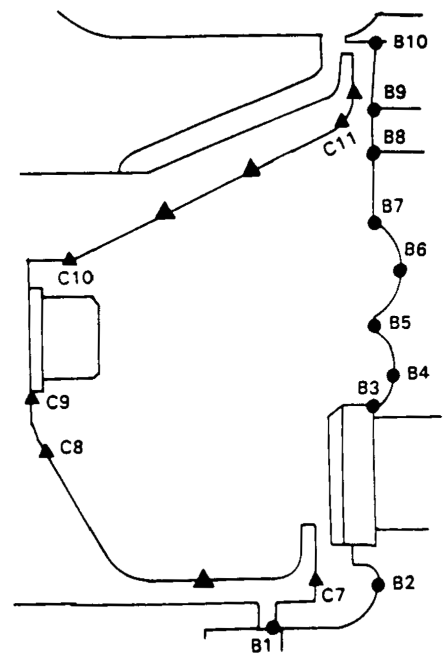




COOLANT DISTRIBUTION ON ROTOR

Region IV: Aft Cavity & Rotor 2
Coolant: CO_2





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COOLANT DISTRIBUTION ON STATIONARY WALL

Region IV: Aft Cavity & Rotor 2
Coolant: CO_2

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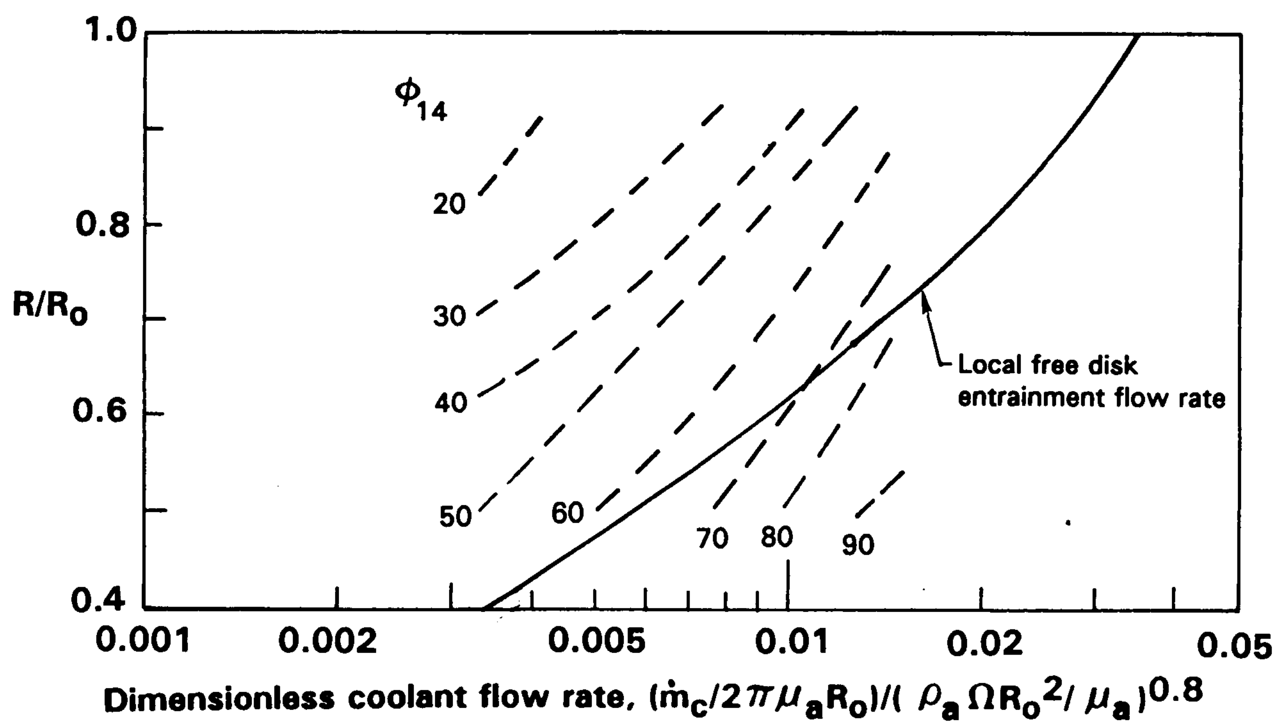

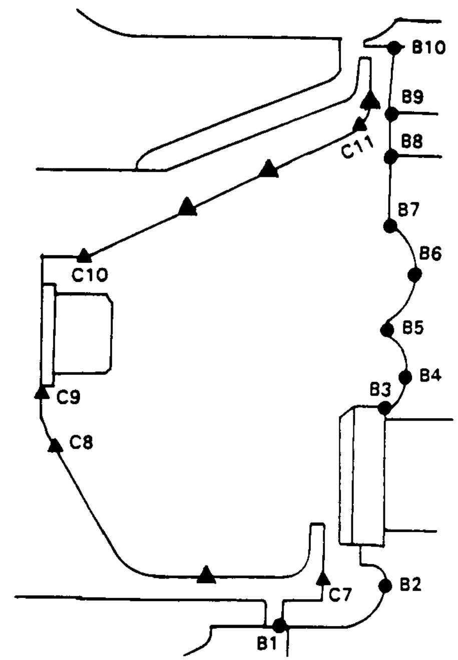

RESULTS/CONCLUSIONS

Constant Density

- Coolant flows approximately one-half free disk entrainment rate provide full purge of cavity ($\phi > 80\%$ below blade shanks)

- Coolant concentration on rotor surface high ($\phi > 90\%$) for coolant flows 1/4 design flow rate

- Cavity walls have largest variation of ϕ with coolant flow rate

RESULTS/SPECULATION

<u>Variable Density</u> (Exploratory Experiments with CO_2)

- Density ratio has strong effect
  - Coolant concentration on rotor decreased from constant density results at comparable weight flow or volume flow rates.
  - Coolant concentration on aft cavity wall decrease significantly from constant density results at comparable flow rates.

- Decreased coolant concentration attributed to increased mixing and probable instability of rotating flow with higher gas densities at low radii.