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**PRELIMINARY MEASUREMENT OF LOSS COEFFICIENT
FOR THE BERYLLIUM REFLECTOR ASSEMBLY FLOW TESTS**

by

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INTRODUCTION

Cooling of the beryllium reflector is effected by hydrogen flowing through a series of passages covering the entire length of the reflector. The hydrogen is introduced through holes in the lower support ring, flows through the reflector and is exhausted through holes in the upper support ring.

The purpose of this memo is to summarize the results of tests on a segment of the beryllium reflector assembly.

The areas which were investigated were:

1. The effect of the hole size and geometry on pressure loss coefficients for the dome end and nozzle end support rings.
2. The effect of inlet and exhaust configuration on the pressure drop across the reflector.
3. The pressure distribution and flow patterns in the thin plenum between the support ring and the reflector.

Tests were conducted using air at ambient temperature and 90 to 120 psig inlet pressure.

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TEST APPARATUS AND INSTRUMENTATION

The test fixture, shown on Figures 1 and 2 was connected to a variable flow air supply capable of 600 scfm at 125 psig. Air was introduced in the inlet plenum through two (2) stainless steel tubes. From the inlet plenum the flow passes through holes in the support ring, Figure 3A into the thin space between the inlet support ring and the reflector before entering the reflector cooling holes. At the exhaust end of the reflector all cooling holes exhaust into a thin space between the reflector and the outlet support ring before passing through the holes in the outlet support ring, Figure 3B and then to the outlet plenum. This test fixture simulates a 2.5 degree segment of the entire reflector.

The lower plenum, where pressure P_1 is maintained, is assembled to a simulated inlet support ring which has fifteen (15) holes through which complete flow passes. The thin inlet space between the inlet support ring and the reflector is simulated by different thickness plates used between the simulated support ring and the main body of the fixture. Two thicknesses were used: namely, 1/8" and 3/16". The effect of shim rods was also investigated by using the above plates with and without simulated shim rods, Figure 4. The plenum, the simulated support ring and plate are properly orientated and fastened to the main body of the fixture which has four (4) tubes simulating the cooling holes in the reflector segment. Similar components are also assembled at the outlet of the fixture, with the exception of the shim rods.

Fourteen (14) pressure taps were placed at different locations as indicated and were connected to pressure gauges and manometers. Both pressures and differential pressures could be read at all points and between all points respectively through two (2) banks of manifold valves.

The inlet pressure was read at P_1 in the inlet plenum. The pressure in the support ring space was averaged between taps P_2 and P_{2A} and pressure differential read between them and P_1 . Four (4) P_3 readings were taken, namely P_{3A} , P_{3B} , P_{3C} , and P_{3D} near the inlet end of the four tubes simulating the holes in reflector segments. These four readings were alternately taken with their respective differential pressures relative to P_2 and P_4 . A duplicate arrangement was used for the outlet end, namely P_{4A} , P_{4B} , P_{4C} , and P_{4D} at the outlet end of the four tubes. Their respective pressures were read and their differential pressures taken with respect to the pressures P_5 and P_{5A} in the outlet space of the support ring.

P_6 indicated the pressure in the outlet plenum. Flow through the model was measured by an ASME calibrated orifice. For various tests, in addition to changing the configuration of the inlet and outlet of the tubes from sharp edge to 1/8 radius and 1/4 radius, Figure 5 the size of the 15 holes in the segment of the inlet support ring was changed from .125" to 0.085" in diameter. The space between this support ring and the reflector was varied

from 1/8" to 3/16" in thickness. Size of the 42 holes in the segment of the outlet support rings were also changed from .081" to .0625" diameter while the space between the reflector and this support ring was varied from 1/16" to 1/8" to 3/16" in height.

These various tests were run with the following parameters:

Inlet Pressure	120 and 90 psig
Inlet Temperature	530°R
Mass Flow	.025 to .165 pps
Outlet Pressure	65 to 115 for 120 psig inlet
Outlet Pressure	45 to 85 for 90 psig inlet

ANALYSIS

From the above pressure readings, the following calculations were made:

Mass Flow

$$w = .1125 \sqrt{\rho P_7}$$

where

w	= mass flow (lb/sec)
P_7	= flow pressure at inlet of orifice above atmosphere (inches of water)
ρ	= density (lb/cu. ft)

when

$$\rho = 2.6997 \frac{(P_7 \times .03613) + (P_{\text{atmos}} \times .4912)}{1}$$

where P_{atmos} = barometric reading (inches of mercury)
 T = air temperature ($^{\circ}$ Rankine)

Loss Coefficient

$$C = 2.7565 \frac{\Delta P_{\text{avg}} \rho D^4}{w^2}$$

where ΔP_{avg} = pressure drop (psi)
C = loss coefficient
D = hole diameter (inches)

Reynolds Number

$$Re = \frac{4 w 12}{N \pi D \mu g}$$

where Re = Reynolds number
N = number of holes
 μ = viscosity (lb-sec/ft²)

Friction Factor

$$f = \frac{D}{L} C$$

where L = length of tube (inches)

DISCUSSION

Figure 6 presents loss coefficient for the holes in the inlet support ring (C_{1-2}) as a function of Reynolds Number based on hole diameter. By comparing tests 16, 17 and 18 with tests 13 and 14, the effect of the volume of the small space at the outlet of the holes on the loss coefficient can be determined. It can be seen that the loss

coefficient (C_{1-2}) was independent of this volume over the range of Reynolds Numbers tested. Since this plenum volume does not affect the coefficient, then the shims would not have an effect on the coefficient. Comparing tests 7, 8 and 9 and tests 13, 14, 16, 17 and 18 shown that loss coefficient is relatively independent of hole size for the sizes tested.

Figure 7 presents loss coefficient for the inlet to the reflector (C_{2-3}) as a function of Reynolds Number based on tube diameter for various inlet geometries. As would be expected, the loss coefficient for a sharp edged inlet is greater than that for the 1/8 or 1/4 radius. Figure 8 presents the loss coefficient for the inlet to the reflector (C_{2-3}) as a function of Reynolds Number based on tube diameter for a 1/8 radius inlet. Comparing tests with the same inlet plate hole size, (tests 13, 14 vs 16, 17, 18) one can see that plenum volume has no appreciable effect on the loss coefficient, and the same is true for the shims. Comparing tests having the same plenum volumes but supplied by different sizes of holes in the support plate (tests 7, 8, 9 vs 16, 17, 18) show that the hole size has a small effect.

Figure 9 presents friction factor (f_{3-4}) for the four tubes which simulate the reflector for typical tests. As Reynolds Number increases from 1×10^5 to 3×10^5 , the friction factor increases from .02 to .0235. This is in agreement with curves obtained by Nikuradse*.

Figure 10 presents loss coefficient for the outlet of the simulated reflector (C_{4-5}) versus Reynolds Number based on tube diameter for a sharp edged, 1/8 inch radius and 1/4 inch radius outlet. The 1/8 and 1/4 inch radius outlets have a pressure recovery and consequently the loss coefficient is negative. As would be expected, the loss coefficient

*Hunsacker, J. C. and Rightmire, B. G. - "Engineering Application of Fluid Mechanics", Pg. 126-127. McGraw Hill Book Company, Inc., 1947.

for the sharp edged exhaust is positive and greater than that for the rounded outlet. Contrary to what would be expected, the 1/4 inch radius has a poorer recovery than the 1/8 inch radius. It is possible that the volume of the plenum which is quite small has been affected and as outlet plenum increases, the coefficient (C_{4-5}) decreases (Figure 11).

Figure 12 presents loss coefficient (C_{5-6}) for the simulated outlet support ring as a function of Reynolds Number based on hole diameter. The effect of hole size can be obtained by comparing test 9 with test 13. Due to compressibility effect, the coefficient increases with Reynolds Number, and the coefficient appears to be independent of hole size. The effect of entrance plenum volume on loss coefficient can be determined from Figure 13 by comparing tests 13, 18 and 16. As plenum volume increases, the loss coefficient decreases due to a reduction in turning loss. Figure 14 shows the effect of the reflector outlet configuration on the loss coefficient (C_{5-6}). The sharp edged outlet causes the loss coefficient to be higher than that for the 1/8 and 1/4 inch radius. This effect is due to an increase in plenum volume caused by the radius.

CONCLUSIONS AND RECOMMENDATIONS

1. Loss coefficient for the inlet support ring is independent of hole size and spacer plate volume for the sizes tested, and varies from 1.15 to 1.30.
2. Loss coefficient for the inlet to the reflector is slightly dependent on the spacer plate volume, but varies from a nominal value of 1.85 to 1.475 to 1.375 as the radius changes from sharp to 1/8 inch and 1/4 inch respectively.
3. Loss coefficient for the outlet of the reflector changes from 0.58 to -0.25 and -0.20 as the configuration changes from a sharp edged to 1/8 inch radius and 1/4 inch radius respectively.
4. Loss coefficient for the outlet of the reflector is dependent on spacer plate volume.
5. Loss coefficient for the holes in the outlet support ring is dependent on the volume at the inlet to the holes.

Figure 1

Reflector Assembly

Figure 2

Reflector Assembly Showing Location of Pressure Taps

Figure 3B Simulated Outlet Support Ring

Figure 3A Simulated Inlet Support Ring

SHIM RODS OUT

SHIM RODS IN

Figure 4

Spacer Plate

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Figure 5 Reflector Inlet and Outlet Configuration (1/8" Radius)

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Figure 7
Loss Coefficient for Inlet to the Reflector vs Reynolds Number
(Based on Tube Diameter)
For Various Inlet Geometries

Figure 9
 Friction Factor for the Simulated Reflector vs Reynolds Number
 (Based on Tube Diameter)
 For Typical Tests

Figure 10
 Loss Coefficient for the Outlet of the Simulated Reflector vs Reynolds Number
 (Based on Tube Diameter)
 For Various Outlet Geometries

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Figure 13
 Loss Coefficient for the Simulated Outlet Support Ring vs Reynolds Number
 (Based on Hole Diameter)
 For Various Outlet Spacer Plate Thicknesses

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