Metal Foam Technology in Rocket Engine Design

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- In the early nineties, NASA initiated the "National Launch System Effort".
- The goals are to develop reliable, low-cost, liquid hydrogen/oxygen Rocket engines.
- Testing at Pratt & Whitney and at Rocketdyne
- A new initiative is funded through SBIR to utilize metal foams.
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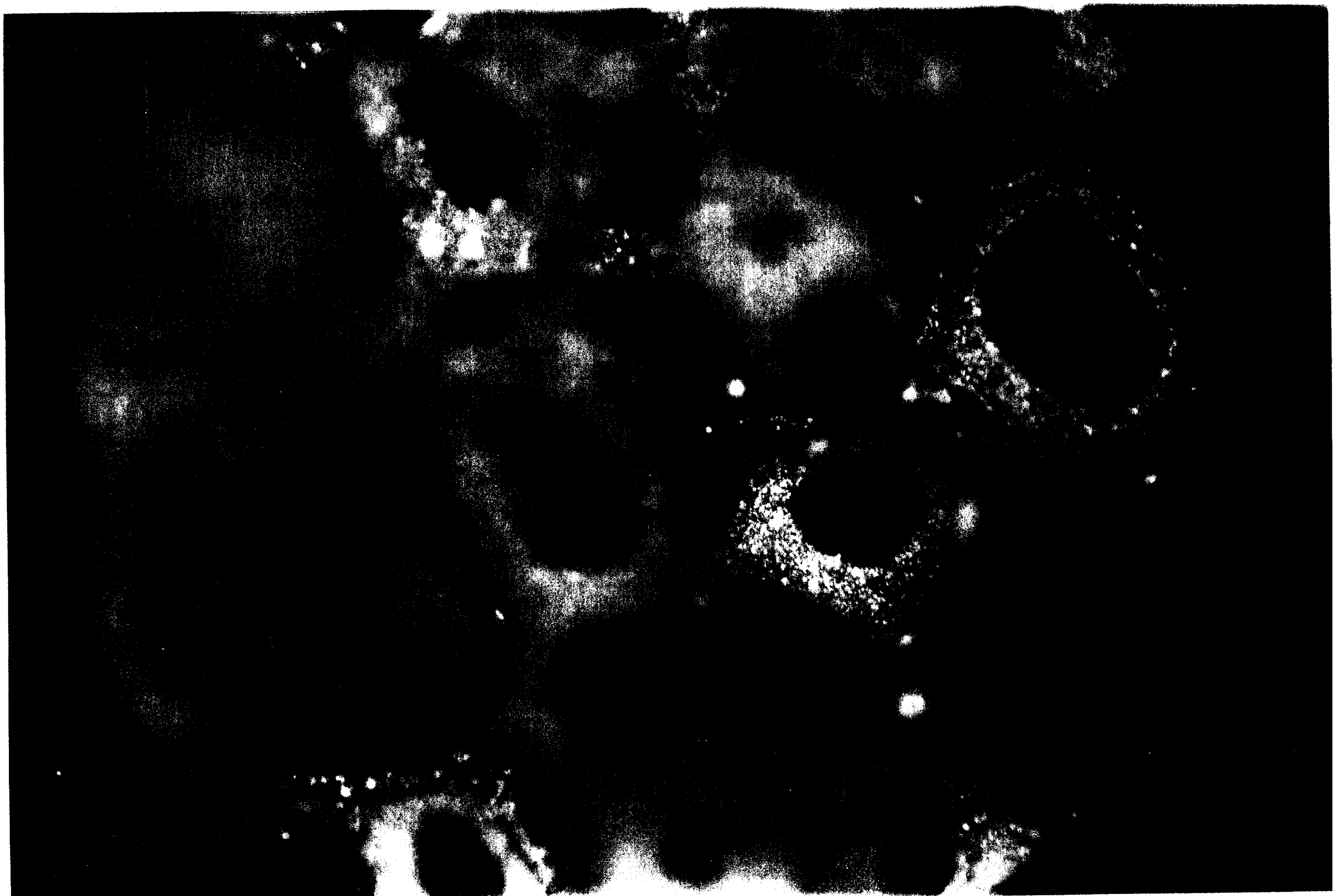
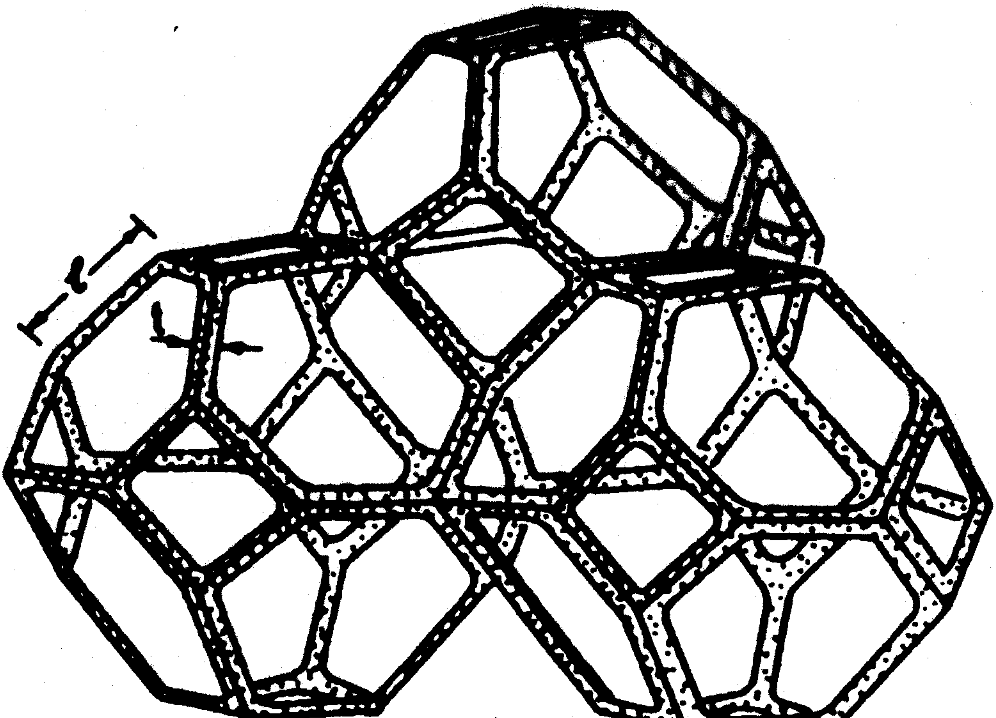
⇒ Foams are manufactured by a CVD process.

⇒ Polyerythane is used as a starting skeleton, and the structure is built up from the gas phase by thickening the ligaments.



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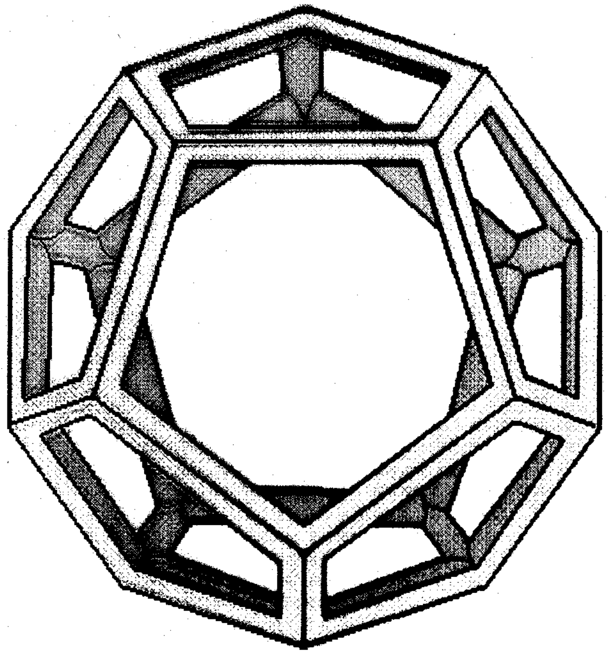
Foam Cellular Structure



Single Cell Dodecahedron

Strut Parameters		
Foam	Radius, r	Length, l
100 ppi	0.02 mm	0.19 mm
65 ppi	0.03 mm	0.32 mm
20 ppi	0.05 mm	0.65 mm

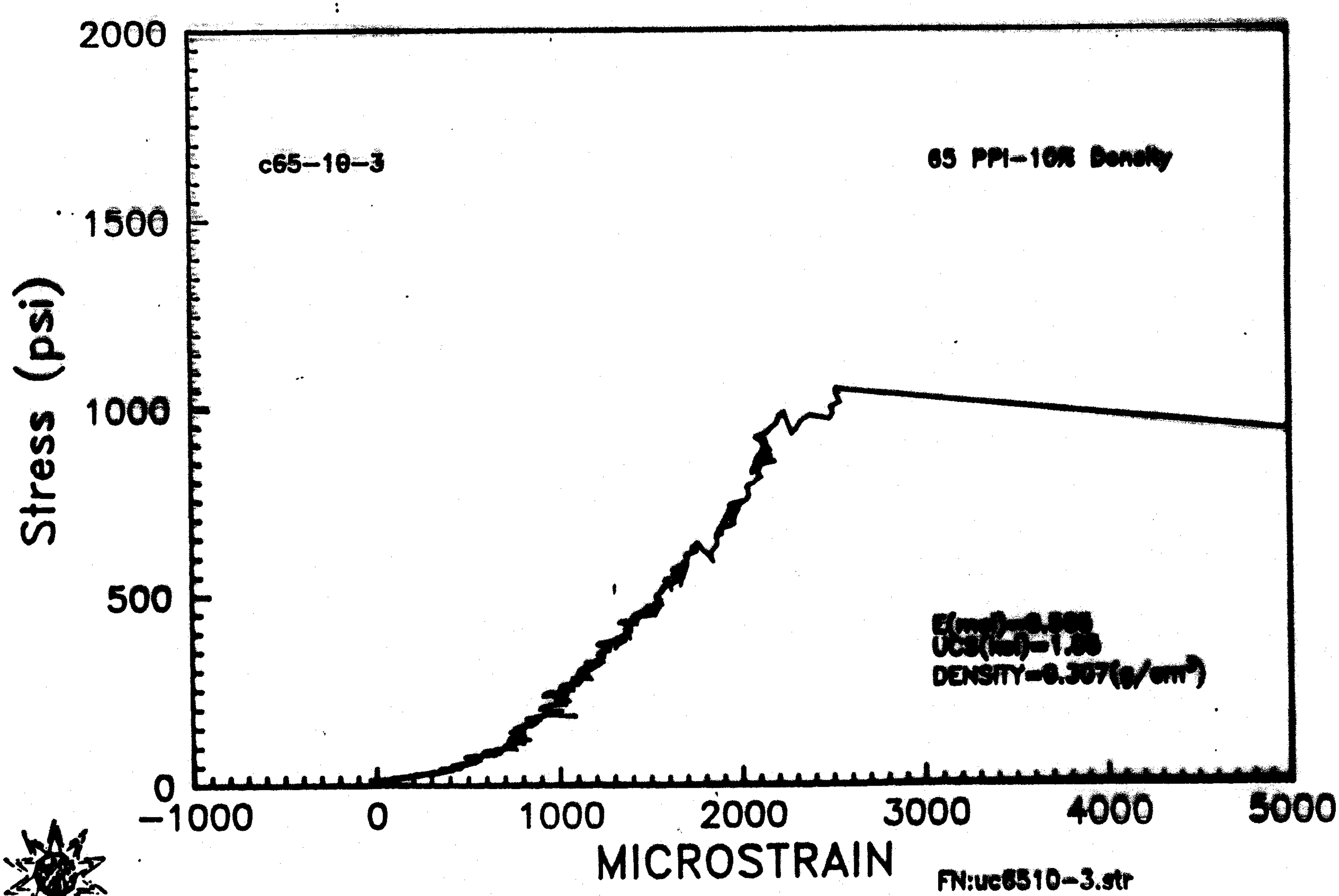
n - sided faces	%
n = 6	10
n = 5	71
n = 4	19

Geometrical Parameters of Interest

- Permeability, κ
- Effective hydraulic diameter, d_h
- Specific surface area, S_w
- Volumetric porosity, ϵ
- Surface porosity, ϵ_s

Desired Characteristic Length $L_c = \dfrac{4\epsilon}{S_w}$

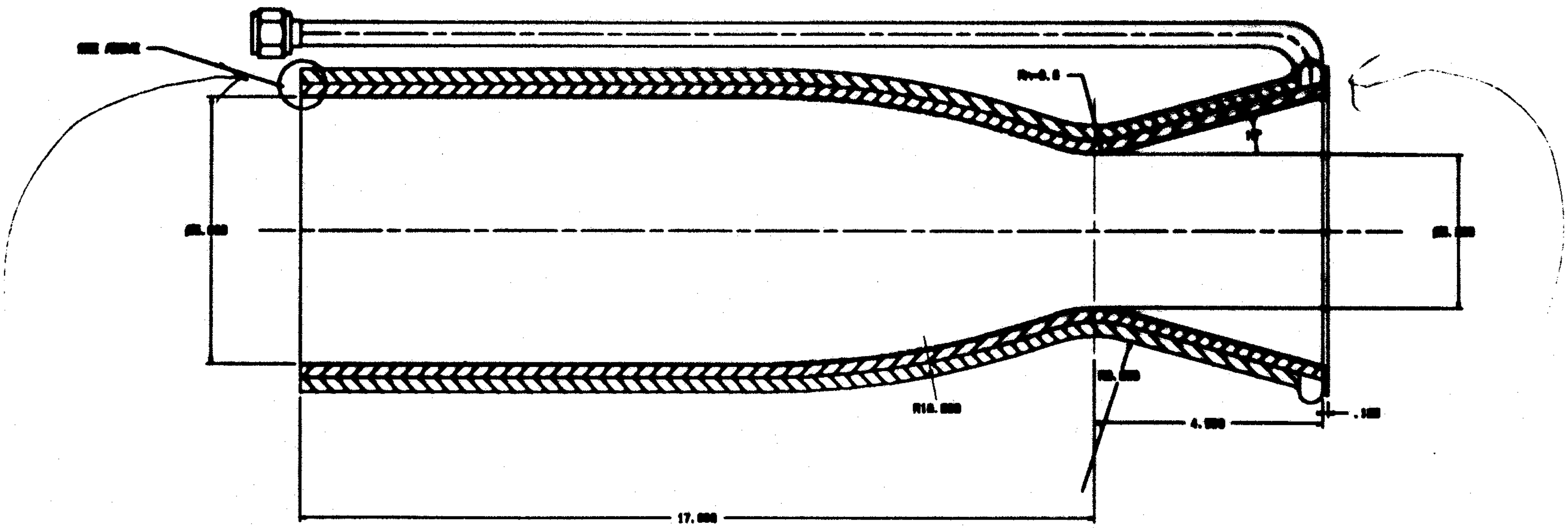
ULTRAMET Silicon Carbide Foams
Compressions @ 1000°C
WA 4200



Energy Materials

CHAMBER DESCRIPTION

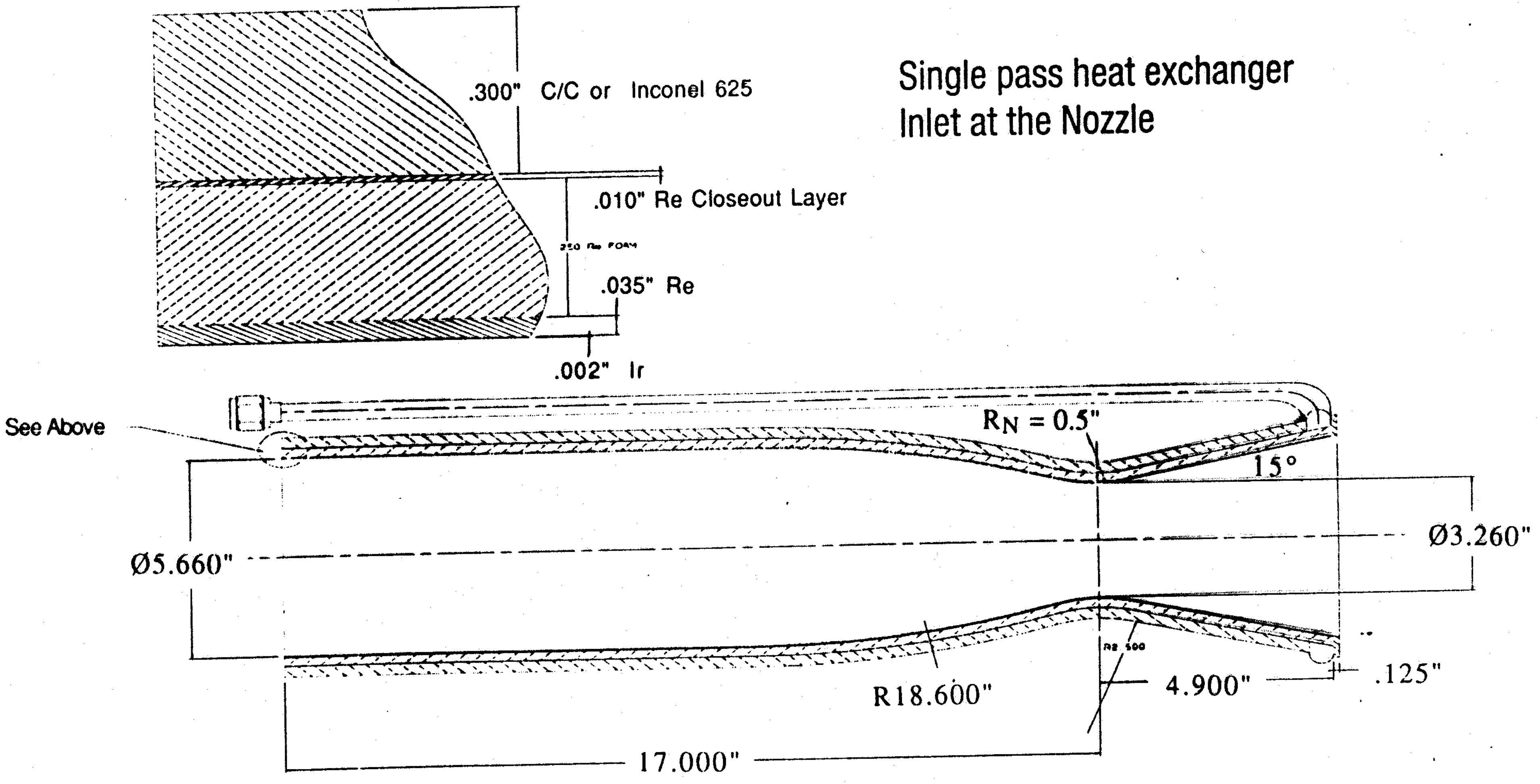
Single pass heat exchanger
Inlet at the Nozzle



working on manifold design now

Boeing North American
Rocketdyne Division

Chamber Description



Single pass heat exchanger
Inlet at the Nozzle

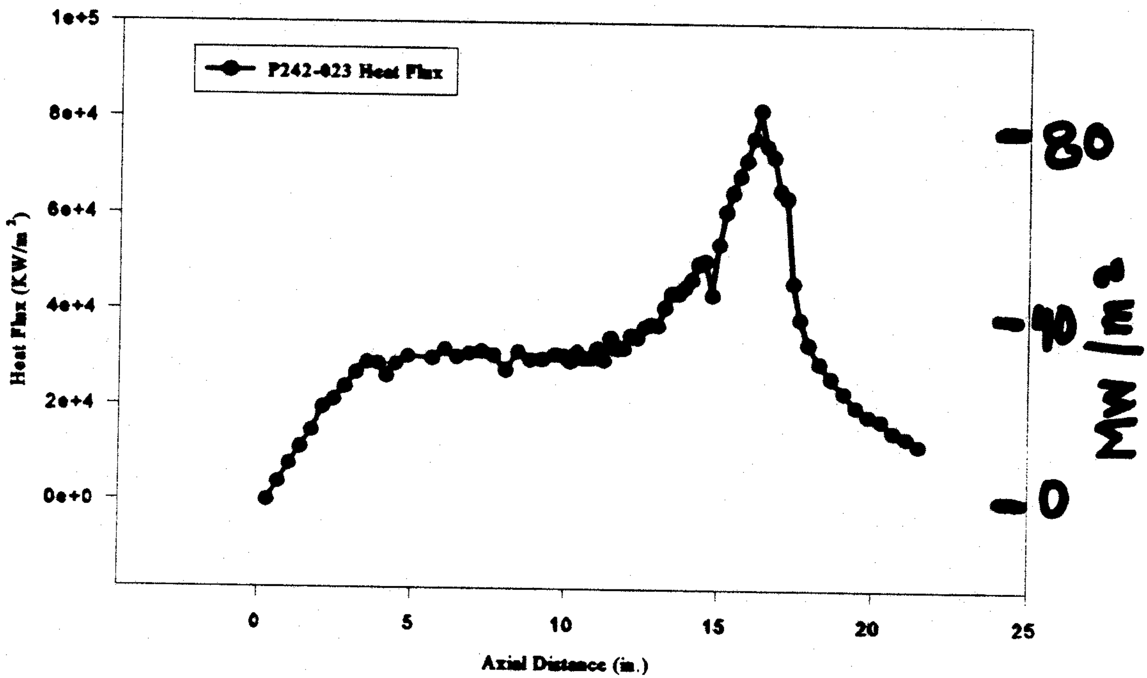
Operating Parameters

Parameter	Nominal
Chamber Pressure:	600 psia
Chamber Diameter:	5.66 in
Throat Diameter:	3.26 in
Area Ratio:	7.0
L':	17.0 in
MR	6.0
Wdot F:	3.0 lbm/s
Wdot Ox:	18.0 lbm/s
Coolant Flow of F:	3.0 lbm/s

2.4 Thermal and Mechanical Loading

In addition to the high heat flux loading, an internal stress of 700 psi is applied to the inner surface Re-Ir layer. The distribution of the internal heat flux on the inner-most Ir layer is shown in the figure below.

P242-023 Heat Flux Along The Chamber Axial



SBIR Engine Heat Load

Section	Area (in**2)	Heat Flux (Btu/in**2-sec-°R)	Heat Load (Btu/sec)
Chamber (barrel)	258.0	10.5	2700.
Throat (conv.)	52.0	18.8	980.
Nozzle (div.)	95.0	6.0	570.

			4250 Btu/sec.

$$dT(max) = Q/(\dot{w}*Cp) = \frac{(4250 \text{ Btu/sec})}{(3.0 \text{ lbm/sec})*(3.8 \text{ Btu/lbm-°R})}$$

Maximum Hydrogen Temperature Gain = 373°R = 207 K
(based on 1360 R wall temp. heat flux)

Maximum Hydrogen Temperature Gain = 292°R = 162 K
(based on calculated SBIR wall temps)

2.2 FEM Mesh Details

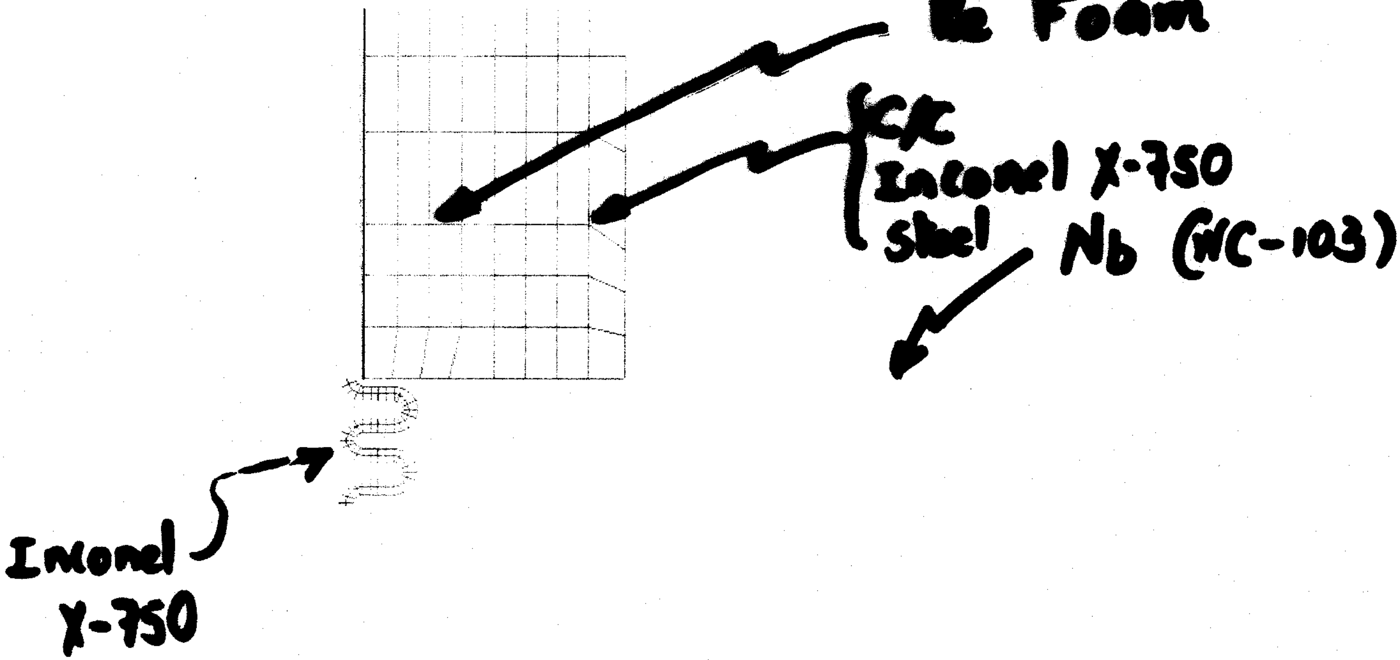


Figure 4 Flange Support Region Meshing Details.

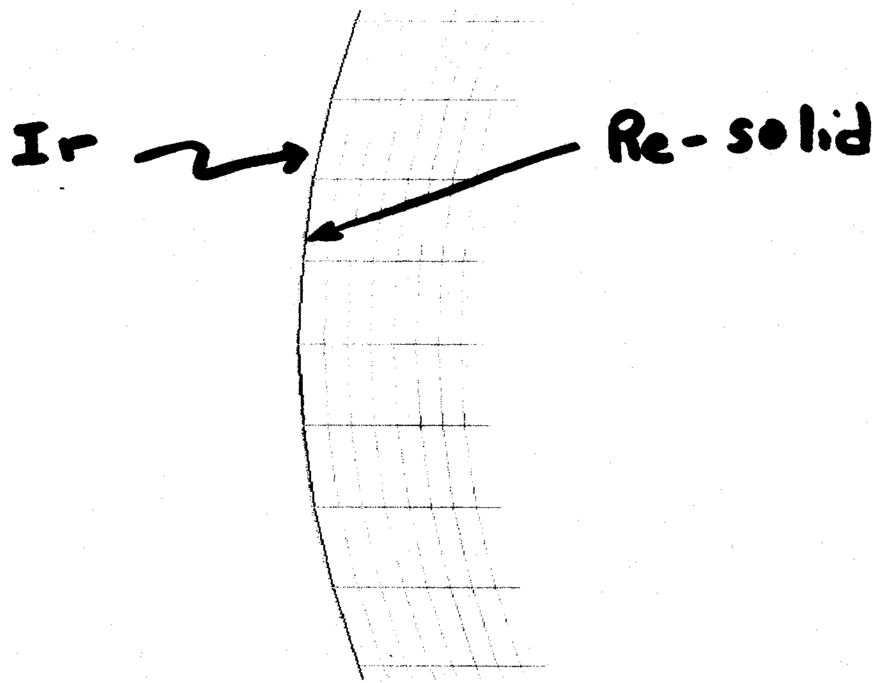
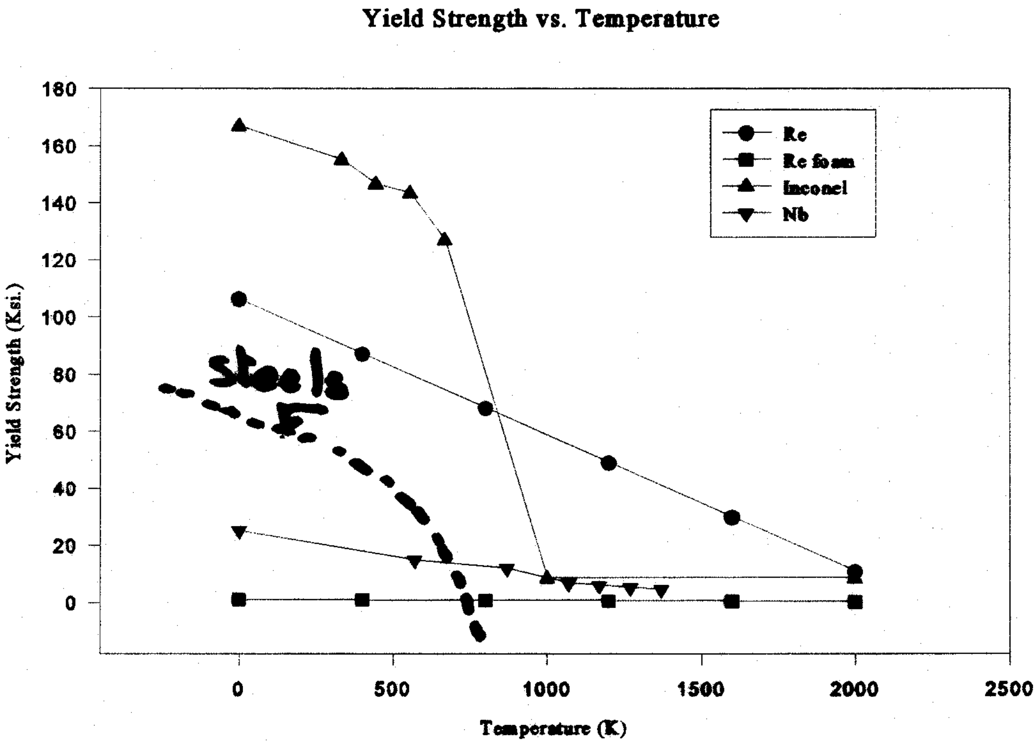


Figure 5 Throat Region Meshing Details.

A plot of the temperature-dependent mechanical properties used in the ALGOR FEM analysis is also shown in the figure below.



4.2 Von-Mises Stress Nodal Plots

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4.2.2 ... sec. After Firing ¬¿á¬●Ç¬¬α¬Ç¬á

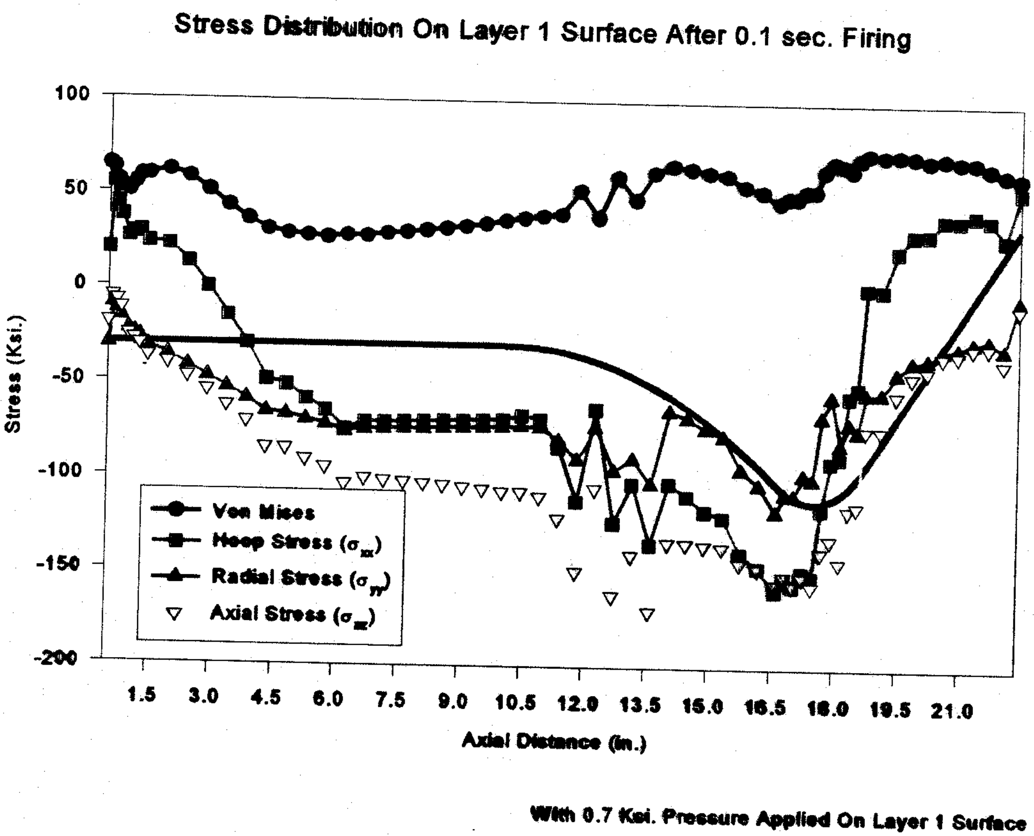

Figure 25