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Testing of Ablation Material
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Final Report

Permeability Measurements of Two
Low-Density Phenolic-Nylon Chars

Authors: P. J. Lare and H. Hahn

Submitted to

National Aeronautics and Space Administration
Langley Research Center
Langley Station
Hampton, Virginia

Submitted by

Melpar, Inc.
7700 Arlington Boulevard
Falls Church, Virginia 22046

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FOREWORD

This report presents NASA with the permeability measurements on two (2) submitted specimens of each of two (2) low-density phenolic-nylon chars. Due to the extremely fragile state of these chars, the specimens were prepared and tested as described in this report. The measurements were made at low pressures (ΔP) slightly above atmospheric, at room temperature, and with both nitrogen and helium as the permeating gases.

1. INTRODUCTION

The following information was provided to Melpar by NASA concerning identification, composition, density, and thermal degradation procedures of the char samples.

"The lowest-density char (marked 'material A') was formed by thermal degradation of a low-density phenolic-nylon of 19 lbs/ft^3 bulk density. The thermal degradation was accomplished by exposing 3-inch-diameter discs of the phenolic-nylon to an electric-arc-heated subsonic stream of nitrogen for 90 seconds - the time required to produce a char layer of approximately $\frac{1}{4}$-inch thickness.

The highest-density char (marked 'material B') was formed by thermal degradation of a low-density phenolic-nylon of 42 lbs/ft^3 density. This material was exposed to the arc-jet stream for about 150 seconds in order to produce a char of about $\frac{1}{4}$-inch thickness.

For both materials the arc-jet was operated with a 4-inch nozzle located 2 inches from the material. The stream enthalpy was about 3250 Btu/lb and the thermal flux at the charring surface was about 120 Btu/ft^2 sec. The composition of both materials was 25% by weight of Union Carbide 'Bakelite' BRP-5549 phenolic resin, 35% by weight of Union Carbide Phenolic Microballons (BJO-0930), and 40% by weight of DuPont 'Zytel' 103 nylon powder."

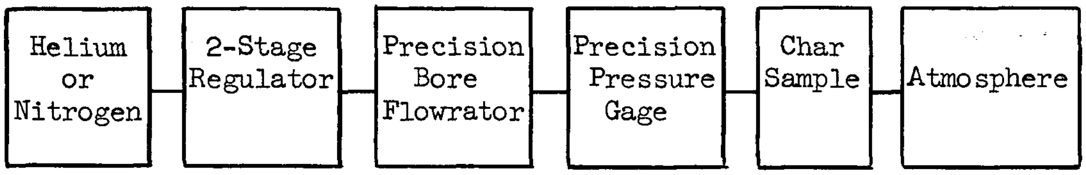
2. SAMPLE PREPARATION

The phenolic-nylon samples received for permeability testing measured approximately 3 inches in diameter by 3/4 inches thick having a char layer 1/4" on the front face and the sides of the discs. On all samples, the char layer was separated from the phenolic-nylon material but could not be removed from it without damaging the char. In order to handle and test these specimens properly, the char was anchored to the phenolic body by impregnating the char with a room-temperature curing epoxy adhesive (Hysol PC12-007A). The epoxy adhesive was applied to the sides and extended approximately 1/4" from the edge on the front surface. Several coatings were required to completely fill these surfaces and to bond the char to the phenolic body. In order to prevent extraneous side flow of the permeating gases, as was found to occur in the original samples, the front surface of the char was coated with a viscous, room-temperature curing epoxy adhesive (Miracle), except for an area 1/4" in diameter, i.e., the permeating area. The epoxy was applied with a syringe to the sample which was secured to a rotating wheel. Curing occurred at room temperature while the sample was rotating.

Machining of the specimens involved drilling and tapping (1/4" pipe thread size) a blind hole in the phenolic-nylon material, then cutting into the char using a 1/4" end mill. A Swagelck fitting (400-1-4) was then threaded into the tapped hole and sealed using Torr Seal (Varian).

3. TESTING

The apparatus, shown schematically below, was used to determine the permeation of the char samples to gaseous helium and nitrogen.



The precision Bore Flowrator (Fischer and Porter Co., No. 2-F$\frac{1}{4}$-20-5) was calibrated for helium and nitrogen using a "Precision" Wet Test Meter prior to testing the samples.

4. RESULTS

The following data was recorded during the permeability testing of the phenolic-nylon chars. Char #4 was improperly machined to a diameter of 1.20 cm on the high pressure side of the char. As such, the results of char #4 can only be considered as an approximation. The permeability for all char samples were calculated for a 1 psi differential across the char.

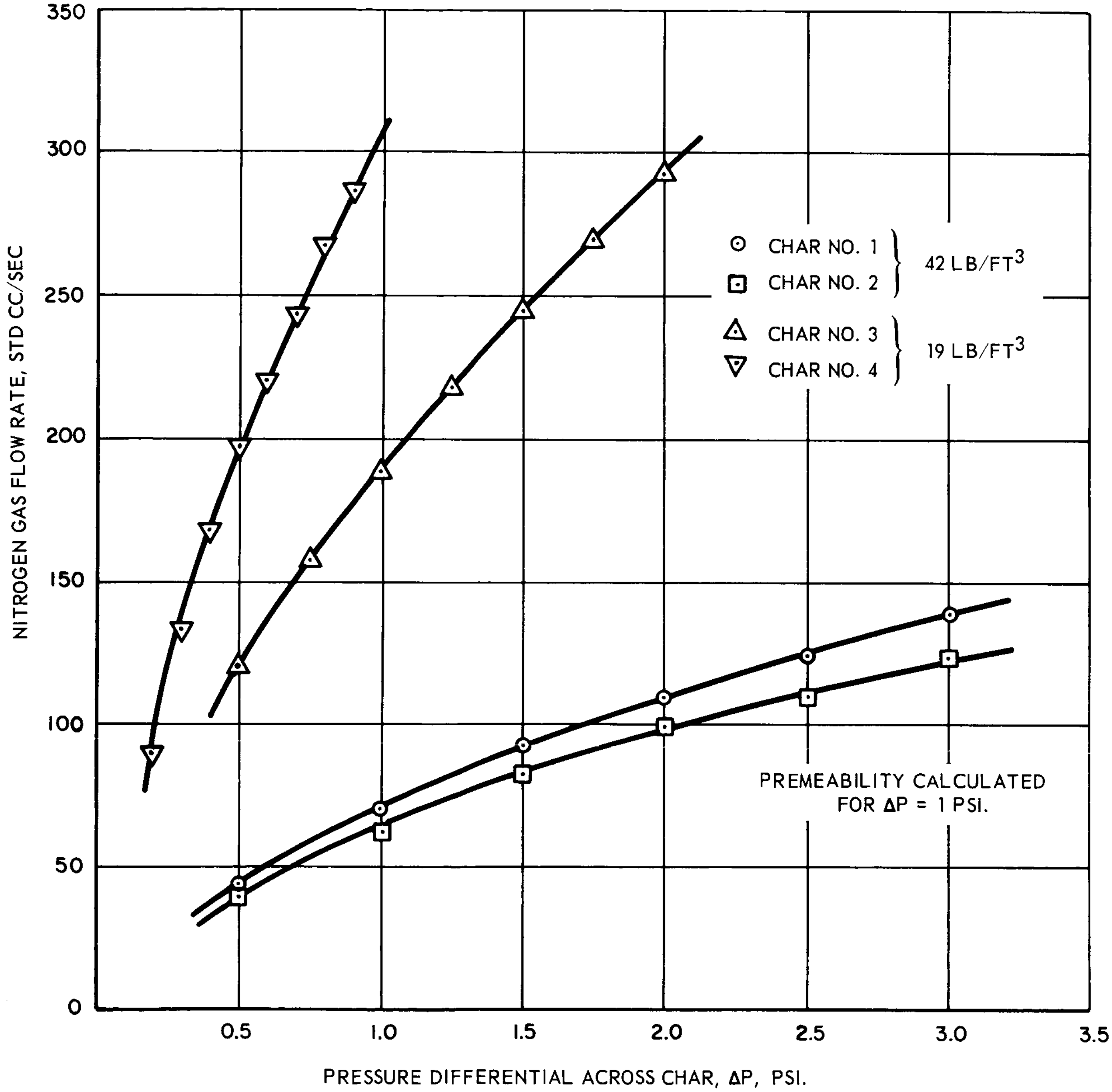


Figure 1. Permeation of Nitrogen Gas Through Chars

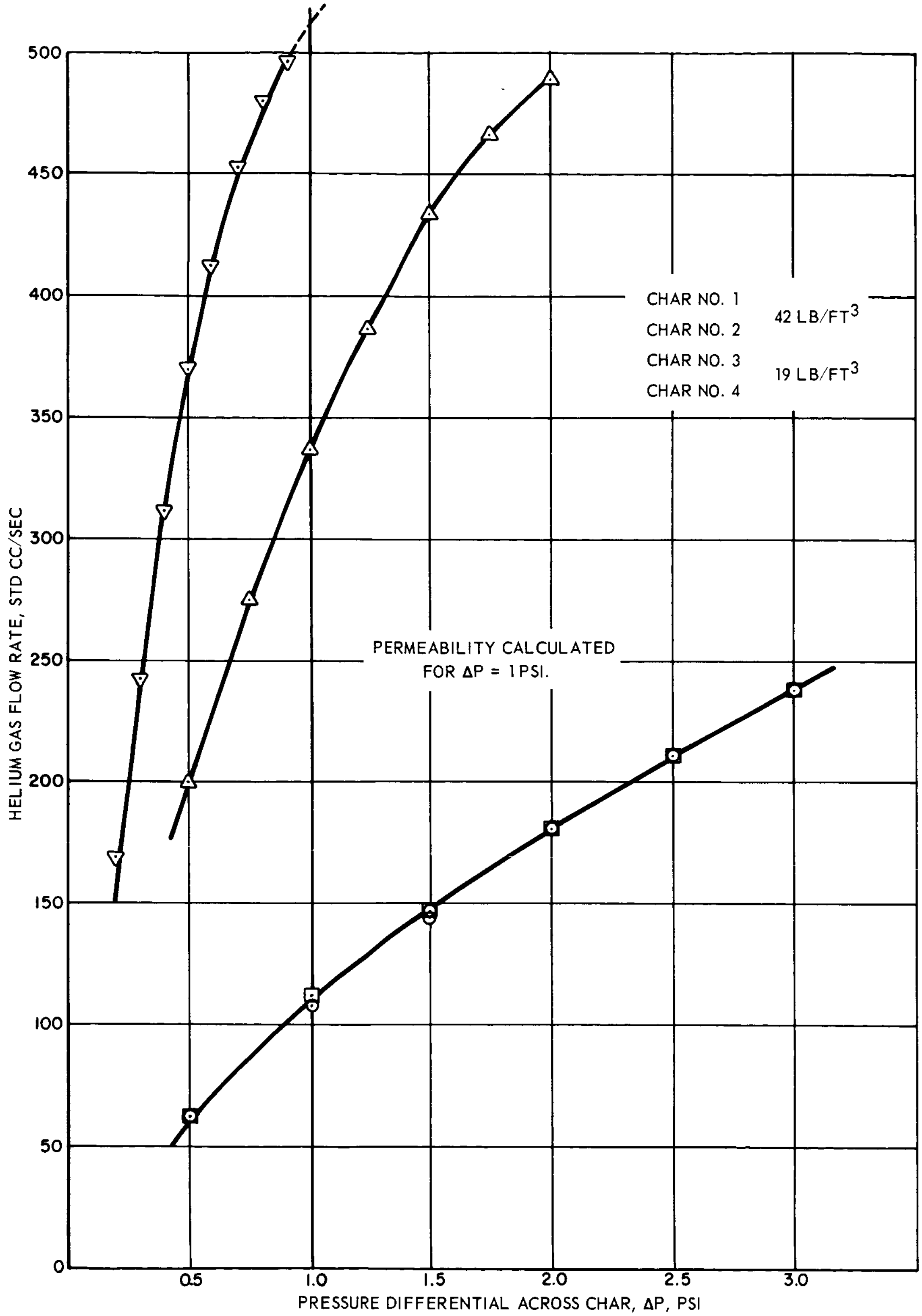


Figure 2. Permeation of Helium Gas Through Chars

Table 1. Observed Permeation of Phenolic-Nylon Material "B," 42 lb/ft^3

Char No.	Nitrogen Gas			Helium Gas		
	ΔP,* psi	Flow Rate, $\frac{STDCC}{SEC}$	Flowrator	ΔP,* psi	Flow Rate, $\frac{STDCC}{SEC}$	Flowrator
1	0.5	45	4.3	0.5	62	4.1
	1.0	71	5.9	1.0	108	5.3
	1.5	93	7.2	1.5	144	6.2
	2.0	110	8.2	2.0	181	7.2
	2.5	125	9.1	2.5	211	7.9
	3.0	140	9.9	3.0	238	8.6
2	0.5	40	4.0	0.5	62	4.1
	1.0	63	5.4	1.0	112	5.4
	1.5	83	6.6	1.5	147	6.3
	2.0	100	7.6	2.0	181	7.2
	2.5	111	8.3	2.5	211	7.9
	3.0	124	9.0	3.0	238	8.6

*Pressure Differential Across Char.

Table 2. Observed Permeation of Phenolic-Nylon Material "A," 19 lb/ft^3

Char No.	Nitrogen Gas ΔP,* psi	Nitrogen Gas Flow Rate, $\frac{STDCC}{SEC}$	Nitrogen Gas Flowrator	Helium Gas ΔP,* psi	Helium Gas Flow Rate, $\frac{STDCC}{SEC}$	Helium Gas Flowrator
3	0.50	121	8.8	0.50	200	7.6
	0.75	158	10.9	0.75	275	9.5
	1.00	189	12.6	1.00	337	11.1
	1.25	219	14.2	1.25	387	12.4
	1.50	246	15.6	1.50	434	13.6
	1.75	271	16.9	1.75	467	14.8
	2.00	293	18.0	2.00	489	16.1
4	0.1	-	-	0.1	-	-
	0.2	90	7.0	0.2	168	6.8
	0.3	133	9.5	0.3	242	8.7
	0.4	168	11.5	0.4	311	10.4
	0.5	198	13.1	0.5	370	11.9
	0.6	221	14.3	0.6	412	13.0
	0.7	244	15.5	0.7	452	14.2
	0.8	268	16.7	0.8	479	15.4
	0.9	287	17.7	0.9	497	16.5

*Pressure Differential Across Char.

Table 3. Calculated Permeability of Low-Density Phenolic-Nylon Chars

Char No.	Mat'l	Bulk Density lb/ft^3	Thickness cm	Dia. (Inside) cm	Dia. (Outside) cm	Area (Ave.) cm^2	Permeability @ 1 psi $\frac{std\ cc.cm}{cm^2.sec.cm\ of\ Hg}$	
1	B	42	.77	.63	.67	.33	32.0 (N_2)	48.6 (He)
2	B	42	.85	.63	.57	.28	37.0 (N_2)	65.8 (He)
3	A	19	.77	.64	.66	.33	85.2 (N_2)	152 (He)
4	A	19	.58	1.20	.66	.68	50.4 (N_2)	84.2 (He)