An Investigation of Some Mechanical and Thermal Properties of Lunar Simulant Materials Heated at 2.45 GHz

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During the time period from September 1, 1988 to February 28, 1989, work has progressed in the following areas. Lunar simulant material has been fabricated to simulate Apollo 11, Apollo 15, and Apollo 16 soils. Table 2.1 shows the approximate compositions which these soils simulate. Samples of each soil simulate were fabricated into right circular cylinders of approximately 1.27 cm diameter by 1.27 cm length. Each sample was then placed into a microwave reaction cavity and heated using 2.45 GHz radiation to a particular processing temperature at which it was held for a prescribed length of time. Figures 2.1 and 2.2 show examples of two microwave heating programs for these simulant samples. Upon completion of thermal processing, each sample had its top and bottom surfaces polished to a surface roughness of approximately 4 μ inches RMS.

Table 2.1. Simulated compositions (weight percent).

	A11 (10089, 4)	A15 (15999, 126)	A16 (69999, 75)
SiO_2	42.03	46.52	45.26
TiO_2	7.48	1.40	0.58
Al_2O_3	13.59	17.10	26.22
FeO	15.74	12.05	5.82
MnO	0.20	0.17	0.07
MgO	7.86	10.42	6.39
CaO	11.98	11.17	14.76
Na_2O	0.44	0.43	0.45
K_2O	0.14	0.20	0.13
Cr_2O_3	0.30	0.27	0.12
P_2O_5	0.11	0.20	0.13
S	0.13	0.07	0.07

Samples were then thermally shocked using an apparatus consisting of a tube furnace vertically oriented so that a sample could be suspended in it while being heated and then be allowed to drop, after some prescribed amount of time, through the furnace into a water quench.

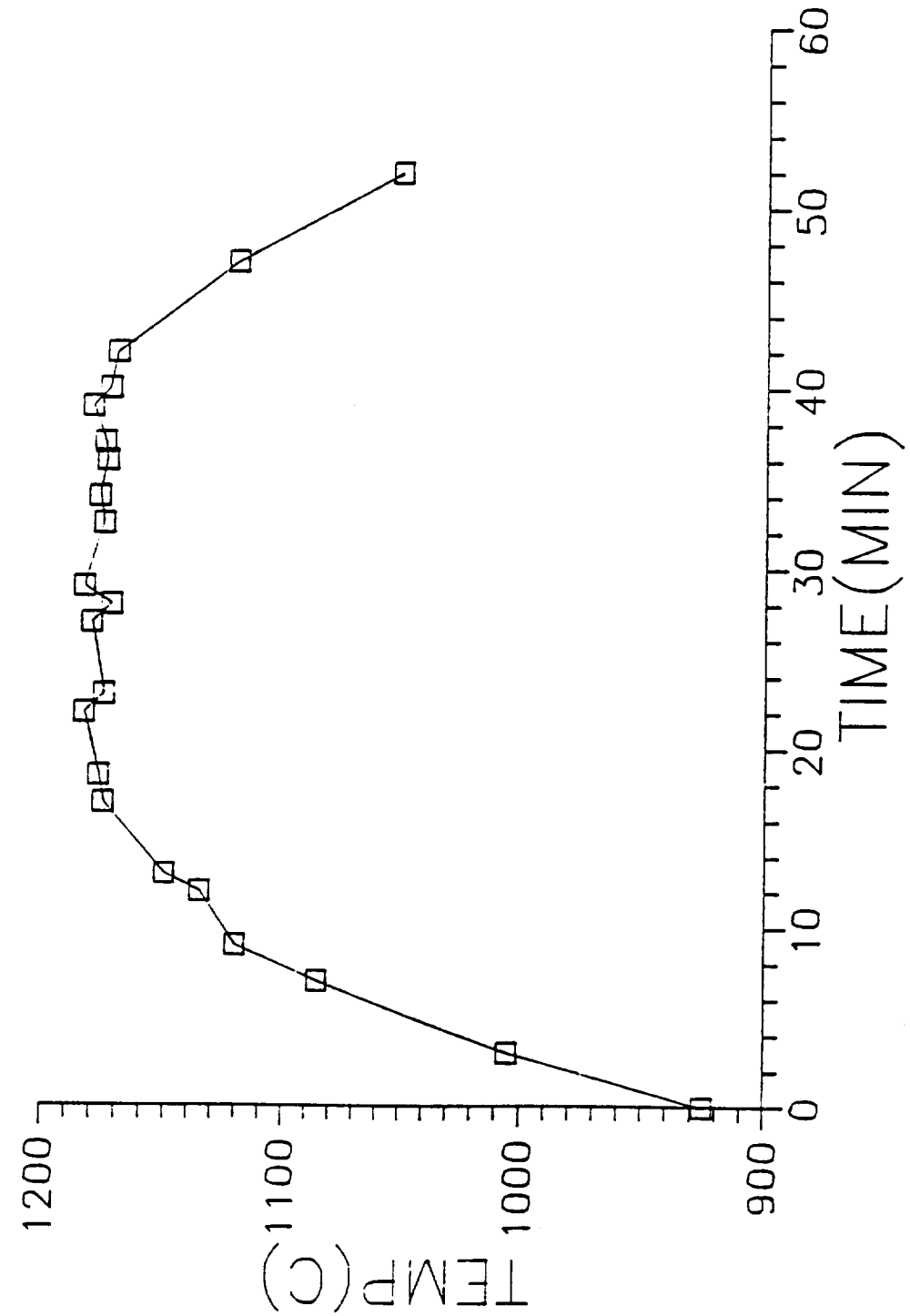

Figure 2.1. Time versus temperature for samples 2D and 4D.

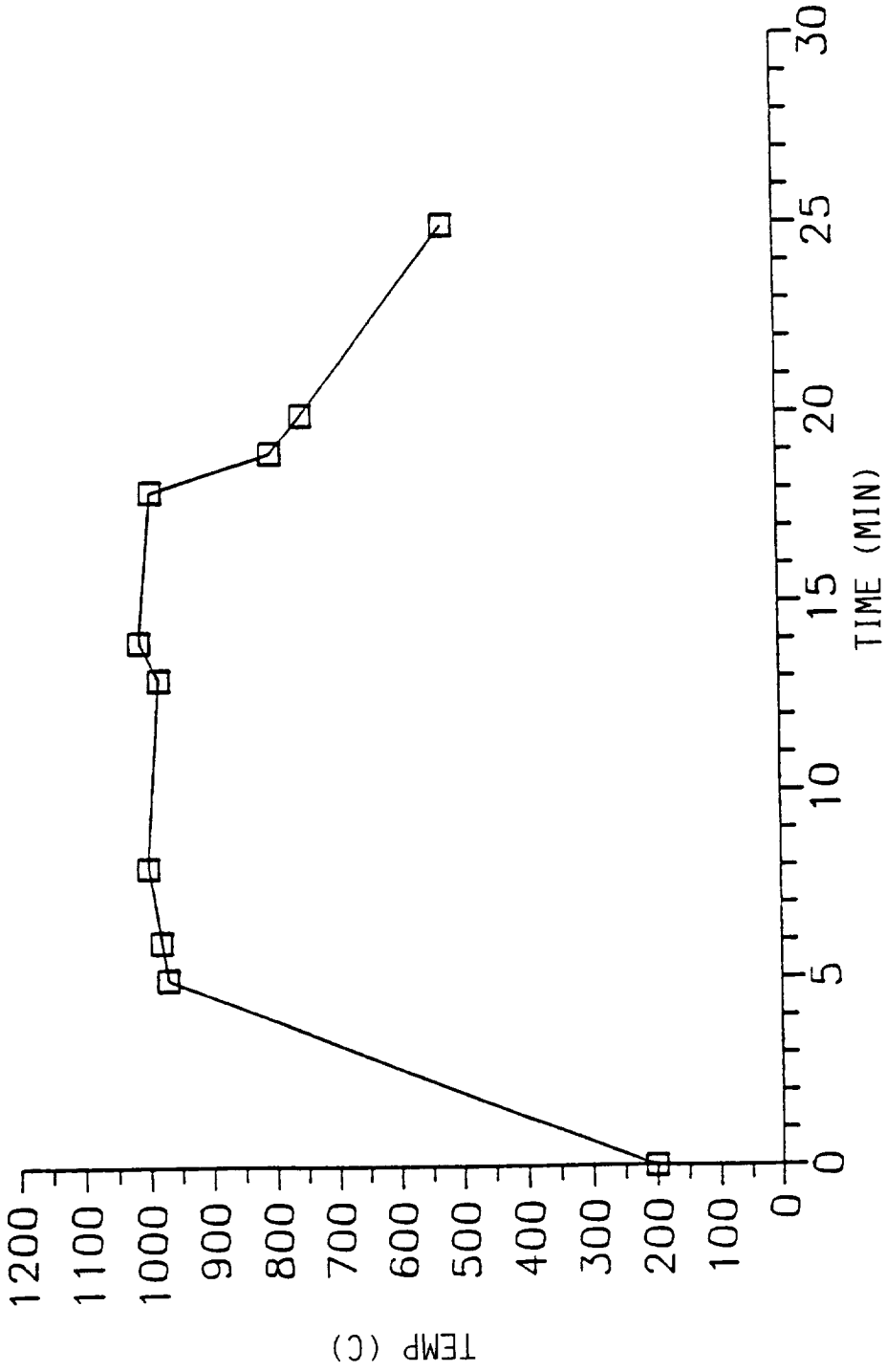

Figure 2.2. Time versus temperture for samples 9E-1 and 9E-2.

Initial work has been reported by Meek et al. (1988) on thermal shock properties of microwave sintered lunar simulant materials. The mechanical testing of these samples was carried out using conventional ASTM (American Society for Testing Materials) techniques. There is some question, however, about the procedure, so it was decided to look again at samples using a different technique, one which employs hardness data to determine the fracture toughness of a material and then relates this to thermal shock resistance. Some advantages of this technique are its low cost for analysis, a sample can be tested in many locations, and thermal shock resistance as a function of initial sample orientation in the microwave field can be determined.

Currently, we have prepared samples for testing at the Y-12 facility of Oak Ridge (operated by Martin Marietta) and are awaiting results. At the same time, other samples are currently being investigated using scanning electron microscopy to determine their microstructures.

An abstract for a paper on this work has been submitted for presentation at the 9th Princeton Conference on Space Manufacturing. The only uncertainty concerning this paper is whether we will receive data from the Y-12 facility in time to present it in this paper. If we do not, the paper will focus mainly on microstructural analysis of the samples as a function of processing technique.

For the next 16-month period, we propose to continue the work on lunar simulants, begin work on actual lunar sample material (Apollo 11, 15, 16), and begin work on carbonaceous chondrite material. Samples will be prepared in the same manner as the simulants. They will be thermally processed by conventional means and by using 2.45 GHz radiation. Their mechanical properties and thermal shock properties will be determined and then related to their observed microstructure.

The proposed budget for March 1, 1989 through June 31, 1990 is as follows:

I.	Salaries		
	A. Graduate Student	$15,872	
	B. Advisor	5,000	
	C. Shop	1,000	
	D. Secretarial	2,372	
	Benefits at 28%% of I.B-D	1,820	
	Subtotal	$24,192	
II.	Materials	1,000	
III.	Travel	800	
	Subtotal		25,992
IV.	Overhead at 38.5%% of I, II, and III		10,008
	TOTAL		$36,000

Reference

Meek, T. T., L. A. Fayerweather, M. J. Godbole, D. T. Vaniman, and R. B. E. Honnell, "Sintering Lunar Simulants Using 2.45 GHz Radiation," *Engineering Construction and Operations in Space, Proceedings of Space 88*, ASCE, 1988, p. 102-110.