

UNCLASSIFIED

AD 273 774

*Reproduced
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA**



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

CATALOGED BY ASTIA 273774

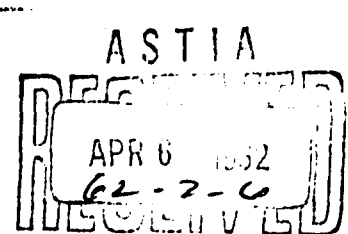
#



IMPROVEMENT OF THE USEFULNESS
OF PYROLYTIC GRAPHITE
IN ROCKET MOTOR
APPLICATIONS (U)

Contract No. DA-36-034-ORD-3279 RD
Project No. TB4-004

Quarterly Progress Report
December 1961 through February 1962



TISIA

A

90000

ATLANTIC RESEARCH
CORPORATION

ATLANTIC RESEARCH CORPORATION
ALEXANDRIA, VIRGINIA

IMPROVEMENT OF THE USEFULNESS
OF PYROLYTIC GRAPHITE
IN ROCKET MOTOR
APPLICATIONS (U)

Quarterly Progress Report
December 1961 through February 1962

Contract No. DA-36-034-ORD-3279 RD
Project No. TB4-004

Contributors:

J. D. Batchelor
E. F. Ford
S. W. McCormick
E. L. Olcott
R. K. White

March 20, 1962

ATLANTIC RESEARCH CORPORATION
Alexandria, Virginia

ATLANTIC RESEARCH CORPORATION

HENRY G. SHIRLEY MEMORIAL HIGHWAY AT EDSALL ROAD
ALEXANDRIA, VIRGINIA FLEETWOOD 4-3400 TWX ALEX VA. 1089



CHEMISTRY
PHYSICS
ELECTRONICS
ENGINEERING
RESEARCH
DEVELOPMENT
MANUFACTURING
CONSULTING

March 15, 1962

Commanding General
Army Ordnance Missile Command
Redstone Arsenal, Alabama

Attention: ORDXM-RKX

Gentlemen:

Attached you will find a Quarterly Progress Report on Contract No. DA-36-034-ORD-3279RD, entitled "Improvement of the Usefulness of Pyrolytic Graphite in Rocket Motor Applications." This report covers the period from December 1, 1962 through February 28, 1962.

Very truly yours,

ATLANTIC RESEARCH CORPORATION

James D. Batchelor
Project Director

JDB:clr

Encl.

CONTENTS

	<u>Page</u>
I. INTRODUCTION AND SUMMARY	1
II. DEPOSITION-PROCESS STUDIES	2
III. MECHANICAL DESIGN STUDIES	7
IV. MOTOR-FIRING TESTS	8

LIST OF TABLES

<u>Table No.</u>	<u>Title</u>	<u>Page</u>
I.	Deposition-Process Run Conditions	3
II.	Nozzle Test-Piece Fabrication Runs	10
III.	Motor Test Firings with 6500°F Propellant	11

LIST OF FIGURES

<u>Figure No.</u>	<u>Title</u>	<u>Page</u>
1	Microstructure of Deposits on Different Substrates at 1340°C	4
2	Effect of Steam Pretreatment on Microstructure of Pyrolytic Graphite	6
3	Segmented Test Nozzle Before Assembly for Test with 6500°F Propellant	9
4	Effect of Motor Pressure on Nozzle Erosion Rate for 2000°C Pyrolytic Graphite	13

I. INTRODUCTION AND SUMMARY

This report covers the work performed during the quarter starting December 1, 1961 and ending February 28, 1962. Research and evaluation on deposition process conditions and the evaluation of pyrolytic graphite coatings in sub-scale rocket motor nozzle tests continued. The deposition studies emphasized means of improving the fabrication of pyrolytic coatings of useful quality. The motor tests of coated nozzles were designed to measure the inherent serviceability of pyrolytic graphite under severe conditions using an advanced propellant of 6500°F flame temperature. In line with the interest of the sponsor (Ordnance Material Research Office) the principal goal of this program continues to be the definition, in detail, of the serviceability of good quality pyrolytic graphite coatings under a variety of severe nozzle environmental conditions selected to cover the range found in missile development programs.

Deposition runs, in which pyrolytic graphite was formed at a low temperature (1340°C) on tubular substrates of three different grades, showed significant differences in the microstructure of the coating. The deposit on a relatively non-graphitic substrate had a finer microstructure than that on the standard graphite substrate. The coating on a high-purity, coarse-grained graphite had a coarser structure. Steam pretreatment of the substrate produced an increase in the cone size in pyrolytic graphite which was probably caused by increased activity of local sites on the substrate surface.

Pyrolytic graphite nozzles were tested in three rocket motor firings to define the effect of motor pressure on the erosion rate of the standard (2000°C) coating. A fourth motor test indicated that a lower temperature coating (1700°C) was not serviceable with the 6500°F propellant. Further motor tests are planned to determine the serviceability of pyrolytic graphite under various motor operating conditions.

II. DEPOSITION-PROCESS STUDIES

The relationship of the deposition-process variables to the quality of the pyrolytic graphite coating is not being approached as an optimization program but rather as a search for methods to simplify conditions or use less expensive equipment. A good grade of pyrolytic graphite currently produced at 2000°C permits evaluation in rocket nozzle tests to proceed independent of the deposition studies.

As outlined in the last quarterly report, the effect of surface condition of the substrate on the microstructure of the coating is being studied. Lower deposition temperatures are also being evaluated. Accordingly, two series of deposition tests were made. In the first, the effect of the graphitic nature of the substrate and its purity were observed. Pyrolytic graphite was deposited on three different substrates at 1340°C. Deposition conditions are given in Table I. Photomicrographs of the polished cross-section of each coating are shown in Figure 1. The substrate in Run 42 was grade AGOT (National Carbon Co.) which is a high-purity graphite produced for nuclear applications. In Run 43, the substrate was the standard grade of graphite pipe used in most of the studies to date. The substrate for Run 44, taken from another lot of the graphite pipe, was chosen because of the markedly less graphitization of this batch (as measured by X-ray diffraction patterns) compared to the normal graphite pipe.

The coating formed on each of these substrates was rather coarse, which is characteristic of the low-temperature (1340°C) deposit. However, the deposit on the less-graphitic substrate was somewhat finer-grained and was of a more uniform microstructure than that formed on the standard graphite substrate. The pyrolytic deposit on the AGOT graphite was coarser and rougher than that on the standard substrate, but this coarseness was probably caused, at least in part, by the coarse surface of the AGOT material.

To obtain further data on the effect of surface condition on the coating microstructure, a second series of tests was carried out with a steam activation pretreatment of the substrate. For Run 45, a graphite substrate was exposed to argon saturated with

TABLE I. Deposition Conditions

Run No. ^a	Substrate Temperature (°C)	Substrate Material	Substrate Pretreatment	Carbon-Source Gas	Source Gas Concentration (per cent)
42	1340	AGOT Graphite	None	Propane	2.5
43	1340	Graphite ^b Pipe, Lot 1	None	Propane	2.5
44	1340	Graphite ^b Pipe, Lot 2	None	Propane	2.5
45	2000	Graphite ^b Pipe, Lot 1	Water-saturated Argon, 15 min. at 2000°C	Methane	5.0
46	2000	Graphite ^b Pipe, Lot 1	None	Methane	5.0

^a Conditions common to each run

1. Ten per cent of gas flow entered outside of injector
2. Total gas flow of 20 SCFH
3. Substrate surface finish, 80 grit

^b Of the two graphite pipe lots, Lot 1 showed a much more graphitic X-ray diffraction pattern than did Lot 2 which resembled baked carbon.



Run 42 X150



Run 43 X150



Run 44 X150

Figure 1. Microstructure of Deposits on Different Substrates at 1340°C

water vapor at room temperature for 15 minutes immediately prior to deposition. The pretreatment and the deposition were both carried out at 2000°C. Run 46 was a control test in which all conditions were the same as Run 45 except that the steam pretreatment was eliminated. The deposit on the steam-pretreated substrate had an increased cone size, especially near the surface. Typical areas are shown in Figure 2. This increased cone size was probably caused by an increased activity of a number of reactive sites at which rapid nucleation and growth occurred. This is consistent with the activation process which would occur through steam treatment.

The results from both of these series of tests suggest that a uniform microstructure of reduced cone size requires a surface on the substrate which is moderately smooth and as uniformly inactive (chemically) as possible. Further trials are planned to test this postulate. During the coming quarter, a special effort will be made to determine the improvement which can be achieved through substrate surface preparation. In this way, the final six months of the program can be used to test nozzles prepared by the most promising deposition techniques. This amount of lead time will allow definitive nozzle tests of any special grades of pyrolytic graphite.



Run 45 X150



Run 46 X150

Figure 2. Effect of Steam Pretreatment on Microstructure of Pyrolytic Graphite

III. MECHANICAL DESIGN STUDIES

Analytical studies of the stress-strain relationships for pyrolytic graphite coatings on graphite substrates have been summarized in previous reports on this contract. Difficulties were encountered in completely defining the shear stresses which exist at or near the edge of a coated section of a normal nozzle contour. Consideration of this problem during the current quarter indicated that the gain to be realized in pursuing this mathematical analysis further is no longer consistent with the program goals requested by the sponsoring agency. Thus, no further detailed analysis was carried out during the current period.

The advantages of a nozzle made of several individual coated segments stacked together appear worthwhile based on a qualitative study of the stress relation. It appears that segments of relatively short length will prove more serviceable than longer nozzle sections. Short segments reduce the curvature of each section and may reduce the magnitude of the stresses at the edges. Nozzle test results from other programs may allow a check to be made of this proposition. The nozzles tested in this program use a segmented design principally because of the ease of fabrication and characterization of such test pieces. However, the success of these pieces may be the result of improved stress distribution in the segmented design.

IV. MOTOR FIRING TESTS

As discussed in the previous quarterly report, pyrolytic graphite withstands the 5600°F flame temperature of an aluminized Arcite propellant so well that little differentiation between test nozzles is possible. Thus, the motor firings this quarter were all made using an aluminized Arcocel propellant with a 6500°F flame temperature. Some further tests with the 5600°F propellant, especially of pyrolytic graphite coatings formed at lower temperatures, will be necessary as the program progresses.

Two motor tests were made this quarter using one-piece, fully coated nozzles because an early test indicated the three-piece, segmented test nozzle might be unsuitable. The indication was that erosion of the best molded graphite entrance section of the segmented nozzle was quite noticeable in every test with the 6500°F propellant. It has been concluded, however, that this problem is not critical and that the segmented nozzle can be used satisfactorily for our test program. Since the segmented nozzle is easier to fabricate and easier to examine, before and after a firing, the two other motor tests completed this quarter used the segmented nozzle design. Figure 3 shows a three-piece, segmented nozzle before final assembly.

Six furnace runs were made for nozzle preparation. In four of these, pyrolytic graphite was deposited on contoured sections of segmented nozzle pieces. One-piece nozzles were coated in the other two runs. All of the runs except one were made at 2000°C to produce the standard grade pyrolytic graphite coating. In the remaining run, a contoured section was coated at a substrate temperature of 1700°C. Complete data are shown in Table II.

Four nozzle test pieces were tested with Arcocel 163 (6500°F) propellant. A summary of the data is shown in Table III. The first three firings used the standard 2000°C pyrolytic graphite coating. In the first test, FYB-3, a segmented nozzle performed extremely well at low motor pressure (350 psi). Erosion was negligible. Comparison of the behavior

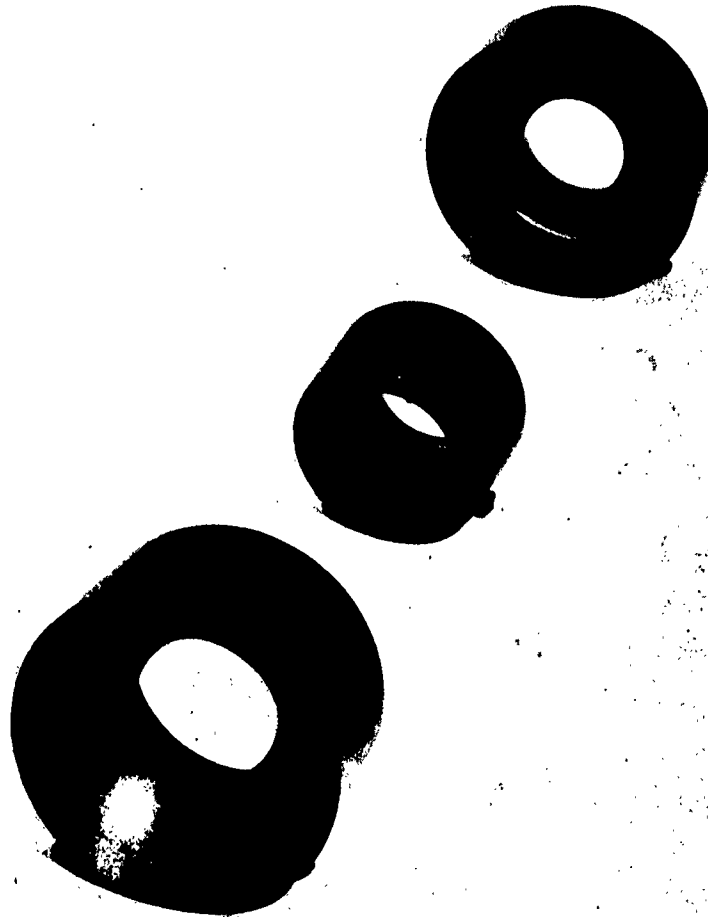


Figure 3. Segmented Test Nozzle Before Assembly
for Test with 6500°F Propellant.

TABLE II. Nozzle Fabrication Runs

Run No.	Substrate Temperature (°C)	Total Gas Flow (SCFH)	Run Duration (hr)	Substrate Geometry	Substrate Throat Diameter (inch)	Coated Throat Diameter (inch)
N-7	2000	10	2.5	Full nozzle	0.590	0.519/.523
N-8	2000	10	2.2	Full nozzle	0.590	0.527/.530
N-9	2000	8	2.0	Contoured throat section	0.580	0.552
N-10	1700	10	2.0	Contoured throat section	0.580	0.517 (finished to 0.520)
N-11	2000	8	2.25	Contoured throat section	0.580	0.552
N-12	2000	8	3.66	Contoured throat section	0.580	0.539

^aGas flow consisted of 5 per cent methane in argon.
Ten per cent of argon introduced outside of injector.

TABLE III. Motor Test Firings with Arcocecel 163 (6500°F) Propellant

Firing No.	Fabrication Run	Average		Firing Duration (sec)	Nozzle Diameter (inch)		Average Erosion Rate (mil/sec)
		Motor Pressure (psi)	Pressure (psi)		Before	After	
PYB-3	N-6	350	350	35.5	0.558	0.556/.559	0.0
PYB-4	N-7	468	468	66.2	0.519/.523	0.594/.620	0.65
PYB-5	N-8	600-750 (est.) ^a	46 (est.) ^a	46 (est.) ^a	0.527/.530	0.561/.648	0.52 (based on coating) 0.36 (at min. dia. point) ^b
PYB-6	N-10	322	322	68.3	0.520	0.670/.712	Coating removed completely

^a Estimated from ballistic properties because of instrumentation failure.

^b Calculated away from gouge in nozzle produced by back-up failure.

of this nozzle at low motor pressure with that reported last quarter for PYB-2 fired at high motor pressure (830 psi) indicated clearly the extreme importance of motor pressure in defining the serviceability of pyrolytic graphite coatings. Figure 4 graphically represents this effect of motor pressure on erosion rate.

The other two tests of the standard 2000°C coating with Arcocel 163 (6500°F) propellant, also included on Figure 4, require some further discussion because of difficulties encountered with these nozzles. Both of these tests, PYB-4 and PYB-5, were made with fully coated, one-piece nozzles. These one-piece nozzles were prepared as a hedge against the problem of failure in the molded graphite entrance section of the segmented nozzles. In test PYB-4, the pyrolytic graphite coating was eroded through in the 66.2 second firing duration. The average erosion rate of 0.65 mil/sec was naturally greater than that to be expected from the coating alone because of the rapid erosion of the unprotected substrate toward the end of firing. However, even the erosion rate of 0.52 mil/sec based on removing just the coating appears higher than anticipated for the moderate average pressure in the motor chamber during this test (468 psi). Thus, the quality of this coating remains suspect with the probability that some spalling, rather than uniform erosion, of the coating occurred during firing. The erosion rate for this test thus lies above the line in Figure 4 which represents coatings of good performance. During firing PYB-5, the backing material failed locally and produced a gouge in the nozzle which introduced considerable uncertainty in the calculated erosion rate. Assuming that the minor diameter of the fired nozzle (approximately 90° from the gouged area) represents the basic erosion pattern for this test, an erosion rate of 0.36 mil/sec was calculated. The average chamber pressure during test also is uncertain because of an instrumentation failure. The average was calculated from ballistic considerations with the uncertainty shown in Figure 4 by the horizontal line through this data point. The uncertainty in the results from these two full-nozzle tests is unfortunate and further tests are planned to better define the effect of motor pressure on erosion rate.

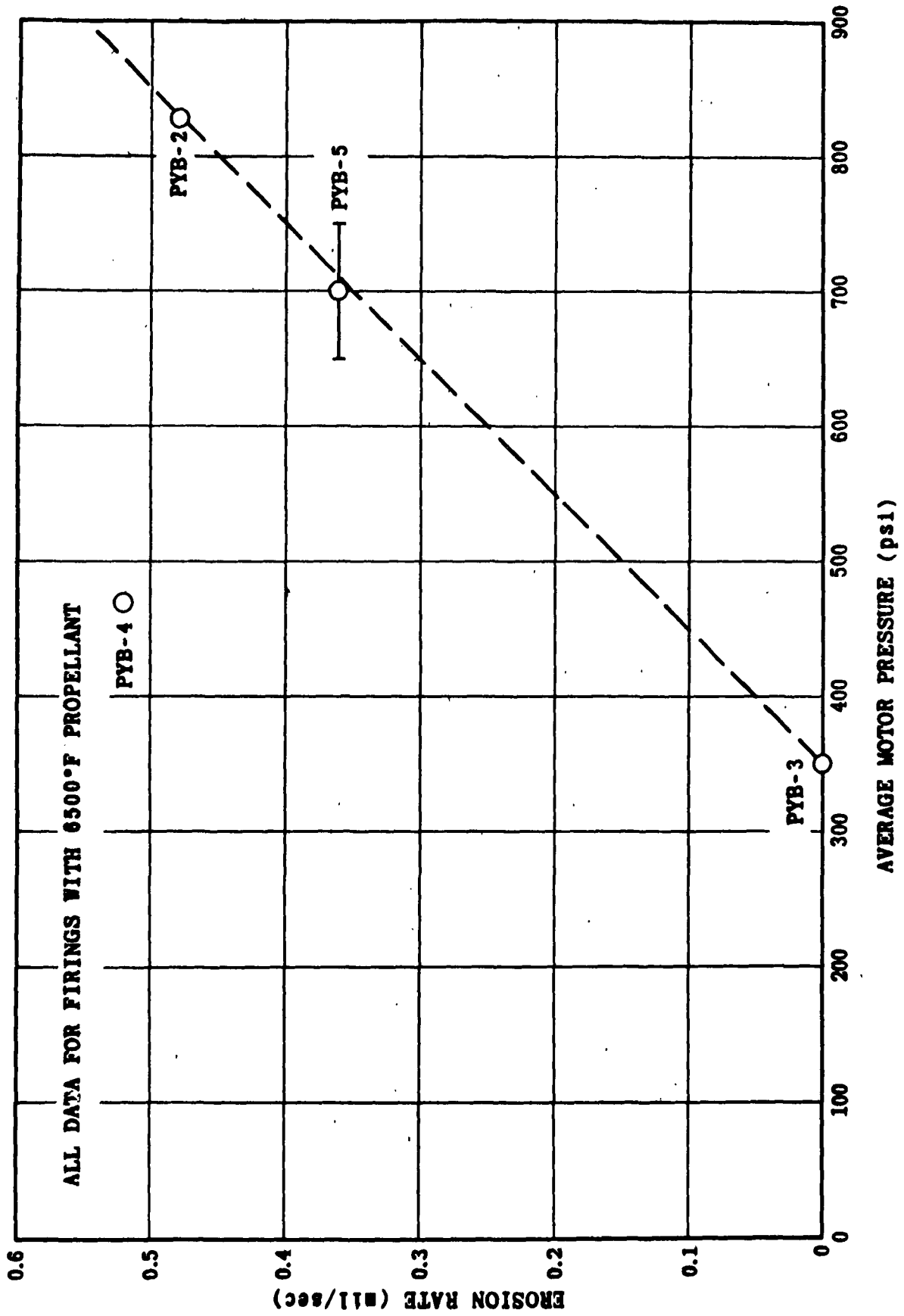


Figure 4. EFFECT OF MOTOR PRESSURE ON NOZZLE EROSION RATE FOR 2000°C PYROLYTIC GRAPHITE.

ATLANTIC RESEARCH CORPORATION
ALEXANDRIA, VIRGINIA

The final motor test of this period used the segmented nozzle prepared with a 1700°C-pyrolytic graphite coating. This coating was completely eroded away during the 68-second firing. Although the surface of this coating was coarse, as deposited, and was polished smooth before the test, the indication is that coatings made at lower deposition temperatures may not be serviceable with 6500°F propellant. Some motor tests will be scheduled with coatings produced at lower temperatures using Arcite 373 (5600°F) propellant for screening purposes before further tests are made with such coatings in the hotter propellant.

8 pages
118 copies

INITIAL DISTRIBUTION LIST

PYROLYTIC GRAPHITE

	<u>No. of Copies</u>
Office of the Director of Defense Research and Engineering ATTN: Mr. J. C. Barrett Room 3D 1067, The Pentagon Washington 25, D. C.	1
Advanced Research Project Agency ATTN: Dr. G. Mock The Pentagon Washington 25, D. C.	1
Defense Metals Information Center Battelle Memorial Institute Columbus, Ohio	1
Solid Propellant Information Agency Applied Physics Laboratory The Johns Hopkins University Silver Spring, Maryland	3
Office Chief of Ordnance ATTN: ORDTB-Materials Department of the Army Washington 25, D. C.	1
Commanding General Aberdeen Proving Ground ATTN: Dr. C. Pickett, C&CL Aberdeen Proving Ground, Maryland	1
Commanding General Ordnance Tank-Automotive Command ATTN: Mr. S. Sobak, ORDMC-IF-2 Detroit 9, Michigan	1

INITIAL DISTRIBUTION LIST

PYROLYTIC GRAPHITE

	<u>No. of Copies</u>
Commanding General Ordnance Weapons Command ATTN: Mr. B. Gerke, ORDOW-IA Rock Island, Illinois	1
Commanding General Army Ordnance Missile Command ATTN: Dr. G. H. Reisig Mr. W. B. Thomas, ORDAB-RPEM Documentation & Technical Information Branch ORDAB-IEE Redstone Arsenal, Alabama	1 1 2 1
Commanding General Army Ordnance Missile Command ATTN: Mr. Robert Fink, ORDXM-RKX Mr. W. K. Thomas, ORDXM-IQMT Mr. A. L. Price, ORDXM-IXDA Mr. N. M. Shapiro, ORDXM-RR Technical Library Mr. Fohrell, ORDXM-RFE Redstone Arsenal, Alabama	3 1 1 2 4 1
Commanding Officer Frankford Arsenal ATTN: Dr. H. Gisser, ORDBA-1330 Mr. H. Markus, ORDBA-1320 Philadelphia 37, Pa.	1 1
Commanding Officer Ordnance Materials Research Office Watertown Arsenal ATTN: RPD Watertown 72, Mass.	1
Commanding Officer Picatinny Arsenal ATTN: Mr. J. J. Scavuzzo, Plastics and Packaging Lab Mr. D. Stein, ORDBB-DE3 Dover, N. J.	3 1
Commanding Officer PLASTECH Picatinny Arsenal Dover, N. J.	1

Initial Distribution List, Pyrolytic Graphite (continued)

	<u>No. of Copies</u>
Commanding General Watertown Arsenal Watertown 72, Massachusetts ATTN: Mr. S. V. Arnold Watertown Arsenal Laboratories	1
Commanding Officer Rock Island Arsenal ATTN: Materials Section, Laboratory Rock Island, Illinois	1
Commanding Officer Springfield Armory ATTN: Mr. R. Korytoski, Research Materials Lab Springfield 1, Mass.	1
Commanding Officer Watertown Arsenal ATTN: ORDBE-LX Watertown 72, Mass.	3
Commanding Officer Watervliet Arsenal ATTN: Mr. F. Bashnaw, ORDBF-RR Watervliet, New York	1
Headquarters U. S. Army Signal R & D Laboratory ATTN: Mr. H. H. Kedesky, SIGRA/SL-XE Fort Monmouth, N. J.	1
Commander Army Research Office Arlington Hall Station Arlington 12, Virginia	1
Chief of Research and Development U. S. Army Research and Development Liason Group ATTN: Dr. B. Stein APO 757, New York, N.Y.	1
Chief, Bureau of Naval Weapons Department of the Navy ATTN: RMMP Room 2225, Munitions Building Washington 25, D. C.	1

8 pages
118 copies

Initial Distribution List, Pyrolytic Graphite (continued)

	<u>No. of copies</u>
Department of the Navy Office of Naval Research ATTN: Code 423 Washington 25, D. C.	1
Department of the Navy Special Projects Office ATTN: SP 271 Washington 25, D. C.	1
Commander U. S. Naval Ordnance Laboratory ATTN: Code WM White Oak, Silver Spring, Maryland	1
Commander U. S. Naval Ordnance Test Station ATTN: Technical Library Branch China Lake, California	1
Commander U. S. Naval Research Laboratory ATTN: Mr. J. E. Srawley Anacostia Station Washington 25, D. C.	1
U. S. Air Force Directorate of Research and Development ATTN: Lt. Col. J. B. Shipp, Jr. Room 4D 313, The Pentagon Washington 25, D. C.	1
Wright Air Development Division ATTN: H. Zoeller, ASRCEE-1 Wright-Patterson Air Force Base, Ohio	2
ARDC Flight Test Center ATTN: Solid Systems Division, FTRSC Edwards Air Force Base, California	5
AMC Aeronautical Systems Center ATTN: Manufacturing and Materials Technology Div, LMBMO Wright Patterson Air Force Base, Ohio	2
Commander Armed Services Technical Information Agency ATTN: TIPDR Arlington Hall Station Arlington 12, Virginia	10

Initial Distribution List, Pyrolytic Graphite (continued)

	<u>No. of copies</u>
National Aeronautics and Space Administration	
ATTN: Mr. R. V. Rhode	1
Mr. G. C. Deutsch	1
Washington, D. C.	
Dr. W. Lucas	
George C. Marshall Space Flight Center	
National Aeronautics and Space Administration	
ATTN: M S&M-M	1
Huntsville, Alabama	
Dr. L. Jaffe	
Jet Propulsion Laboratory	
California Institute of Technology	
4800 Oak Grove Drive	1
Pasadena, California	
Mr. William A. Wilson	
George C. Marshall Space Flight Center	
ATTN: M-F&AE-M	1
Huntsville, Alabama	
Aerojet-General Corporation	
ATTN: Librarian	
Post Office Box 1168	1
Sacramento, California	
Aerojet General Corporation	
ATTN: Librarian	1
Mr. C. A. Fournier	1
Post Office Box 296	
Azusa, California	
Allison Division	
General Motors Corporation	
ATTN: Mr. D. K. Hanink	1
Indianapolis 6, Indiana	
ARDE Portland, Inc.	
ATTN: Mr. R. Alper	1
100 Century Road	
Paramus, N.J.	
Atlantic Research Corporation	
ATTN: Mr. E. L. Olcott	1
Shirley Highway and Edsall Road	
Alexandria, Virginia	
Curtiss-Wright Corporation	
Wright Aeronautical Division	
ATTN: Mr. R. S. Shuris	1
Mr. A. M. Kettle	1
Wood-Ridge, N. J.	

Initial Distribution List, Pyrolytic Graphite (continued)

	<u>No. of copies</u>
Hercules Powder Company Allegheny Ballistics Laboratory ATTN: Dr. R. Steinberger Post Office Box 210 Cumberland, Maryland	1
Hughes Aircraft Company ATTN: Librarian Culver City, California	1
Library, Rohm & Haas Company Redstone Research Division Redstone Arsenal, Alabama	1
Tapco Group ATTN: Mr. W. J. Piper 23555 Euclid Avenue Cleveland 17, Ohio	1
Library, Thiokol Chemical Corporation Redstone Division Redstone Arsenal, Alabama	1
National Carbon Company A Division of Union Carbide Corporation Post Office Box 6116 Cleveland 1, Ohio ATTN: Library (Miss M. S. Wright)	2
Chief, Bureau of Naval Weapons Department of the Navy ATTN: RRMA-22 Washington 25, D. C.	1
Wright Air Development Division ATTN: WWRNC-2 Wright-Patterson Air Force Base, Ohio	1
Armour Research Foundation ATTN: Dr. N. Parrikh 10 West 55th Street Chicago 16, Illinois	1
AVCO Manufacturing Corporation Research and Advanced Development Division 201 Lowell Street Wilmington, Massachusetts	1
Beryllium Corporation ATTN: Mr. W. H. Santachi Reading, Pennsylvania	1

Initial Distribution List, Pyrolytic Graphite (continued)

	<u>No. of copies</u>
Carborundum Company Research and Development Division ATTN: Mr. C. E. Schulze Niagara Falls, New York	1
Clevite Corporation Mechanical Research Division ATTN: Mr. G. Davis 540 East 105th Street Cleveland 8, Ohio	1
Fansteel Metallurgical Corporation ATTN: Mr. A. B. Michael North Chicago, Illinois	1
General Electric Company FPO Technical Information Center Post Office Box 196 Cincinnati 15, Ohio	1
General Electric Company ANP Department Cincinnati 15, Ohio ATTN: Mr. H. E. Santer	1
High Temperature Materials, Inc. Technical Library 31 Antwerp Street Brighton, Mass.	1
Hughes Tool Company Aircraft Division ATTN: Mr. H. Leggett Culver City, California	1
Arthur D. Little, Inc. ATTN: Dr. Flint Acorn Park Cambridge 40, Mass.	1
National Research Corporation ATTN: Mr. M. Torti 70 Memorial Drive Cambridge 42, Mass.	1
Nuclear Development Corporation of America ATTN: Dr. Oppenheimer White Plains, New York	1
Raytheon Manufacturing Company ATTN: Mr. S. D'Urso Waltham 54, Massachusetts	1

Initial Distribution List, Pyrolytic Graphite (continued)

	<u>No. of copies</u>
Solar Aircraft Company ATTN: Mr. N. B. Elsner San Diego 12, California	1
United Aircraft Corporation ATTN: M. Lubin Thoren Kress The Library 400 Main Street East Hartford 8, Connecticut	1
Value Engineering Company ATTN: Mr. J. Huminik Alexandria, Virginia	1
Westinghouse Electric Corporation Materials Manufacturing Department ATTN: Dr. F. L. Orrell Blairsville, Pennsylvania	1
Georgia Institute of Technology Engineering Experiment Station ATTN: Mr. J. D. Walton, Jr. Ceramics Branch Atlanta, Georgia	1
The Johns Hopkins University Applied Physics Laboratory ATTN: Dr. Avery Silver Spring, Maryland	1
Massachusetts Institute of Technology ATTN: Dr. J. Wulff Cambridge, Massachusetts	1
DATAC, Research Library, A-52 The Martin Company P. O. Box 179 Denver 1, Colorado	2
Aeronutronic Division of Ford Motor Co. P. O. Box 697 Newport Beach, California ATTN: Mr. Leon Green, Jr.	2