NAFEC TECHNICAL LETTER REPORT

NA- 79-58-LR

COMPARISON OF SMOKE DENSITIES
FROM THE OSU RATE OF HEAT AND SMOKE
RELEASE APPARATUS AND THE NBS SMOKE CHAMBER

by

Eldon B. Nicholas

FEDERAL AVIATION ADMINISTRATION
NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER
Atlantic City, New Jersey 08405

-FSS 000249R C3-

NOTICE

This document is disseminated to provide for quick reaction release of technical information to selected users. The contents may not conform to FAA formal publication standards and the technical information is subject to change and/or incorporation into a formal publication at a later date.

Approved by Thomas J. O'Brien

JOSEPH M. DEL BALZO
Director, National Aviation Facilities Experimental Center
Federal Aviation Administration
Department of Transportation

ABSTRACT

Smoke density tests were conducted on four aircraft cabin materials representing different usage categories. These tests were to determine if there was any relationship between results obtained from the OSU rate of heat and smoke release apparatus and the NBS smoke chamber.

A definitive statement on the relationship between the two test methods cannot be made based on the limited scope of this study. However, the OSU apparatus shows higher smoke density values for the solid-type materials (panels and thermoplastics) and lower values for the fibrous-type materials (fabrics and carpet).

TABLE OF CONTENTS

INTRODUCTION

PURPOSE.

The purpose of this study was to evaluate the smoke characteristics of four different aircraft materials measured with the smoke monitor used in the Ohio State Rate of Heat and Smoke Release Apparatus, and to compare these results with those obtained in the National Bureau of Standards (NBS) Smoke Chamber.

BACKGROUND.

The National Aviation Facilities Experimental Center (NAFEC) presently has two methods for measuring the smoke emitted from burning aircraft materials. These methods are (1) the NBS Smoke Chamber (reference 1) developed in late 1960 for measuring the smoke generation characteristics of solid materials; and (2) the Ohio State University (OSU) Rate of Heat and Smoke Release Apparatus (reference 2). This method is presently being evaluated by the American Society for Testing and Materials (ASTM) as a standard test method. Extensive work has recently been completed at NAFEC on smoke emissions at elevated heat flux exposures utilizing a modified version of the NBS smoke chamber (reference 3).

This report shows the relationships between results obtained from the two test methods.

DISCUSSION

TEST MATERIALS.

One material from each of four usage categories was selected for this study: (1) Fabric, PVC/cotton (Naugafoam^{R}), 0.044 inch thick, 32 oz./yd.^{2}; (2) Panel, polyvinyl flouride (PVF) film/fiberglas-phenolic front face/Nomex^{R} paper-phenolic honeycomb/fiberglas phenolic backface, 0.505 inch thick, 89.8 oz./yd.^{2}; (3) Flooring, wool carpet, 0.250 inch thick, 74 oz./yd.^{2}; and (4) Thermoformed parts, polycarbonate, 0.083 inch thick, 78.6 oz./yd.^{2}.

TEST METHODS.

A detailed description of the two methods utilized for this study can be found in references 1 through 3. The following is a brief description of the test methods.

OSU Rate of Heat and Smoke Release Apparatus.

The test specimen is injected into an environmental chamber through which a constant flow rate of air passes. The specimen exposure conditions are produced by a radiant panel which is adjusted to provide the desired radiant heat flux level incident upon the specimen surface. Either a vertical or horizontal specimen orientation may be tested. Ignition can be accomplished spontaneously or by the aid of a small pilot flame impinging on the surface of the specimen.

Smoke leaving the 5.25- by 2.75-inch rectangular stack interrupts a light beam passing across the stack which in turn causes a photoelectric cell to decrease its output voltage. This voltage is proportional to the light transmitted by the beam. For this study, the instantaneous total smoke release from this apparatus expressed as specific optical density (D_s) is calculated by integrating over time using the formula

$$D_s(t) = (AL)^{-1} \int_0^t V(t) \log \frac{100}{T(t)} \, dt \qquad (1)$$

where V(t) is the volumetric rate of airflow through the instrument (volume change was determined from the maximum stack temperature and was assumed to be constant), A is the specimen area, L is the length of the light beam, and T(t) is the percent light transmission.

Modified NBS Smoke Chamber.

The standard NBS smoke chamber (reference 1) was modified to provide the capability of exposing the test specimens to elevated heat flux levels up to 11.4 w/cm^2. This was accomplished by replacing the basic furnace with a special Mellen Model 10 furnace. A more detailed description of the modified smoke chamber is contained in NAFEC Final Report No. FAA-NA-79-26 (reference 3).

The NBS smoke chamber test data contained in this letter report was extracted from the 79-6 report.

Specific optical density (D_s) is computed from the formula

$$D_s = V(AL)^{-1} \log \frac{100}{T} \qquad (2)$$

where V is the chamber volume 0.509 m^3 (18 cubic feet), A is the specimen surface area, L is the length of the light beam, and T is the percent light transmission.

TEST RESULTS

The NBS smoke chamber and OSU apparatus smoke data for identical materials are compared in figures 2 through 20. Table 1 describes the materials evaluated and the test conditions.

FABRICS.

Figures 1 through 6 show D_s plots of the OSU and NBS tests for piloted and nonpiloted ignitions at 2.5, 5 (OSU) versus 5.7 (NBS), and 7.5 (OSU) versus 8.6 (NBS) W/cm^2 heat flux exposures.

A more rapid initial response is shown for the OSU apparatus because of the forced airflow rapidly passing the smoke through the light beam. In contrast, in the NBS smoke chamber, the movement of smoke toward the light beam is by convection.

All except the nonpiloted test at 2.5 W/cm^2 showed higher D_s values for the NBS chamber over the OSU apparatus.

PANELS.

Figures 7 through 11 are D_s time plots for the OSU and NBS tests at 5 (OSU) versus 5.7 (NBS) and 7.5 (OSU) versus 8.6 W/cm^2 for piloted and nonpiloted configurations and at 2.5 W/cm^2 for the piloted configuration. The nonpiloted test at 2.5 W/cm^2 heat flux exposure was not included because smoke was not measurable in the OSU apparatus due to very low emissions which are quickly exhausted through the stack.

As experienced with the fabrics, detection of smoke occurred earlier for the OSU apparatus than for the NBS chamber. However, unlike the fabrics, the panels displayed higher specific optical densities in the OSU apparatus than in the NBS chamber.

FLOORING.

Figures 12 through 17 are D_s time plots for a wool carpet in the OSU and NBS tests at 2.5 W/cm^2, 5 (OSU) versus 5.7 (NBS) and 7.5 (OSU) versus 8.6 (NBS) W/cm^2 for piloted and nonpiloted ignition.

Unlike the two previous usage categories, the initial indication of smoke for the carpet occurred earlier in the NBS chamber than in the OSU apparatus. The NBS chamber data showed higher maximum specific optical density values than the OSU apparatus in all of the tests. The smoke density profiles for the two test methods compared more favorably for the carpet than for the other three usage categories.

THERMOPLASTIC.

The D_s time plots for polycarbonates are shown in figures 18 through 20.

The OSU apparatus tests for this material were performed with the test specimen in the horizontal position. This was done because the plastic material could not be contained in the vertical specimen holder. Because the melted plastic was contained in the tray-like, horizontal specimen holder, probably accounts for the higher specific optical density values in the OSU apparatus. At nonpiloted, 2.5 W/cm^2 exposure conditions, smoke levels in the OSU apparatus were very low without ignition of the material. Therefore, only the piloted test results are shown at 2.5 W/cm^2.

The maximum heat flux level that could be obtained in the OSU apparatus at a horizontal test configuration was slightly over 6 W/cm^2, therefore, testing was not conducted at heat flux exposures above 5 W/cm^2. Results for piloted and nonpiloted tests at 5 (OSU) and 5.7 (NBS) W/cm^2 are shown in figures 19 and 20.

NINETY-SECOND RESULTS.

Figures 21 through 24 are bargraphs comparing smoke densities in the OSU apparatus to the NBS smoke chamber at 90 seconds for the different heat flux levels at piloted and nonpiloted conditions. Fibrous materials (fabric and wool carpet) show specific optical densities D_s at 90 seconds to be higher for the NBS chamber than for the OSU apparatus. Exceptions to this are the fabric at 2.5 W/cm^2 (nonpiloted) and the wool carpet at 7.5 W/cm^2 (piloted and nonpiloted).

The solid materials (panel and thermoplastic) indicate a higher specific optical density at 90 seconds for the OSU apparatus under all test conditions.

SUMMARY OF FINDINGS

The following is a summary of the significant findings based on the limited tests performed during this study:

1. Higher maximum specific optical densities were observed from the NBS chamber tests for the fibrous-type materials, Naugafoam fabric, and wool carpet.

2. The solid materials, panels and thermoformed plastics, showed higher maximum specific optical densities from the OSU apparatus.

3. In most cases, smoke was detected earlier in the OSU apparatus.

4. Under most test configurations, specific optical densities (D_s) at 90 seconds are higher from the NBS smoke chamber from fibrous materials and from the OSU apparatus for solid materials.

This study of the comparison of smoke densities obtained from the OSU rate of heat release apparatus to the NBS smoke chamber was undertaken under Project 181-521-100, "Cabin Crash Safety."

The NAFEC Program Manager is Constantine P. Sarkos. Further information can be obtained from Eldon B. Nicholas, ANA-350, (609) 641-8200, extension 3574.

REFERENCES

1. Standard Test Method for Smoke Generation of Solid Materials, National Fire Protection Association, NFPA 258, Boston, Massachusetts, 1976.

2. Smith, E. E., Test for Heat and Smoke Release Rates for Materials and Products, Ohio State University, Test Method Proposed for ASTM Standard.

3. Brown, L. J., Smoke Emissions from Aircraft Interior Materials at Elevated Heat Flux Levels, Federal Aviation Administration, NAFEC, Report No. FAA-RD-79-26.

TABLE 1 MATERIAL DESCRIPTION AND TEST CONDITIONS

Figure No.	Material Description	Test Conditions Ignition P/NP*	Heat Flux w/cm^2 OSU	NBS
1	Fabric, PVC/cotton (Naugafoam$^{(R)}$	P	2.5	2.5
2		NP	2.5	2.5
3		P	5.0	5.7
4		NP	5.0	5.7
5		P	7.5	8.6
6		NP	7.5	8.6
7	Panel, PVF/fiberglas-phenolic/Nomex paper-phenolic honeycomb/ fiberglass-phenolic	P	2.5	2.5
8		P	5.0	5.7
9		NP	5.0	5.7
10		P	7.5	8.6
11		NP	7.5	8.6
12	Wool carpet 74 oz/yd^2	P	2.5	2.5
13		NP	2.5	2.5
14		P	5.0	5.7
15		NP	5.0	5.7
16		P	7.5	8.6
17		NP	7.5	8.6
18	Polycarbonate, thermoformed parts	P	2.5	2.5
19		P	5.0	5.7
20		NP	5.0	5.7

*P=Piloted NP=nonpiloted

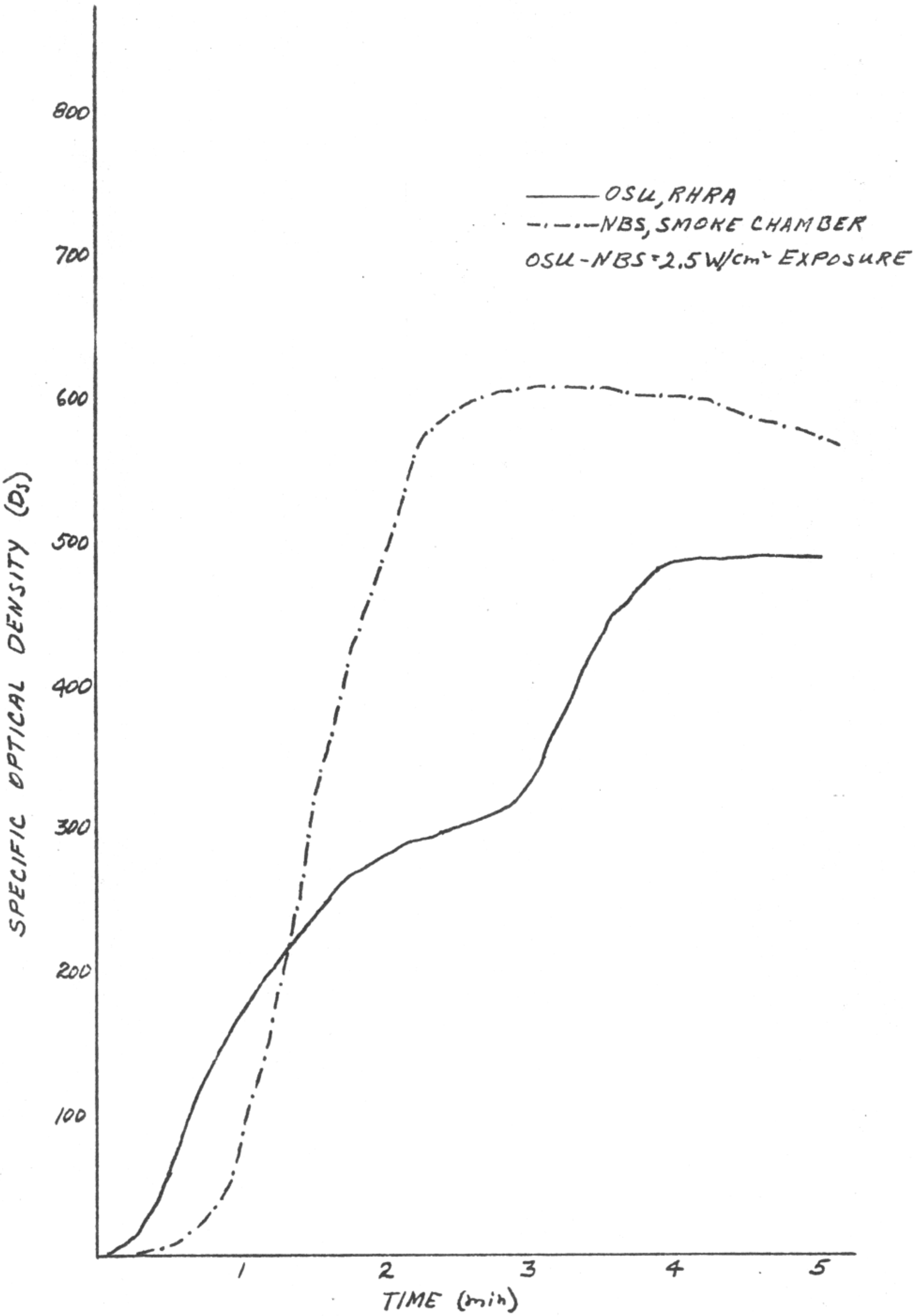

FIG. 1 FABRIC "NAUGAFOAM®" - PILOTED

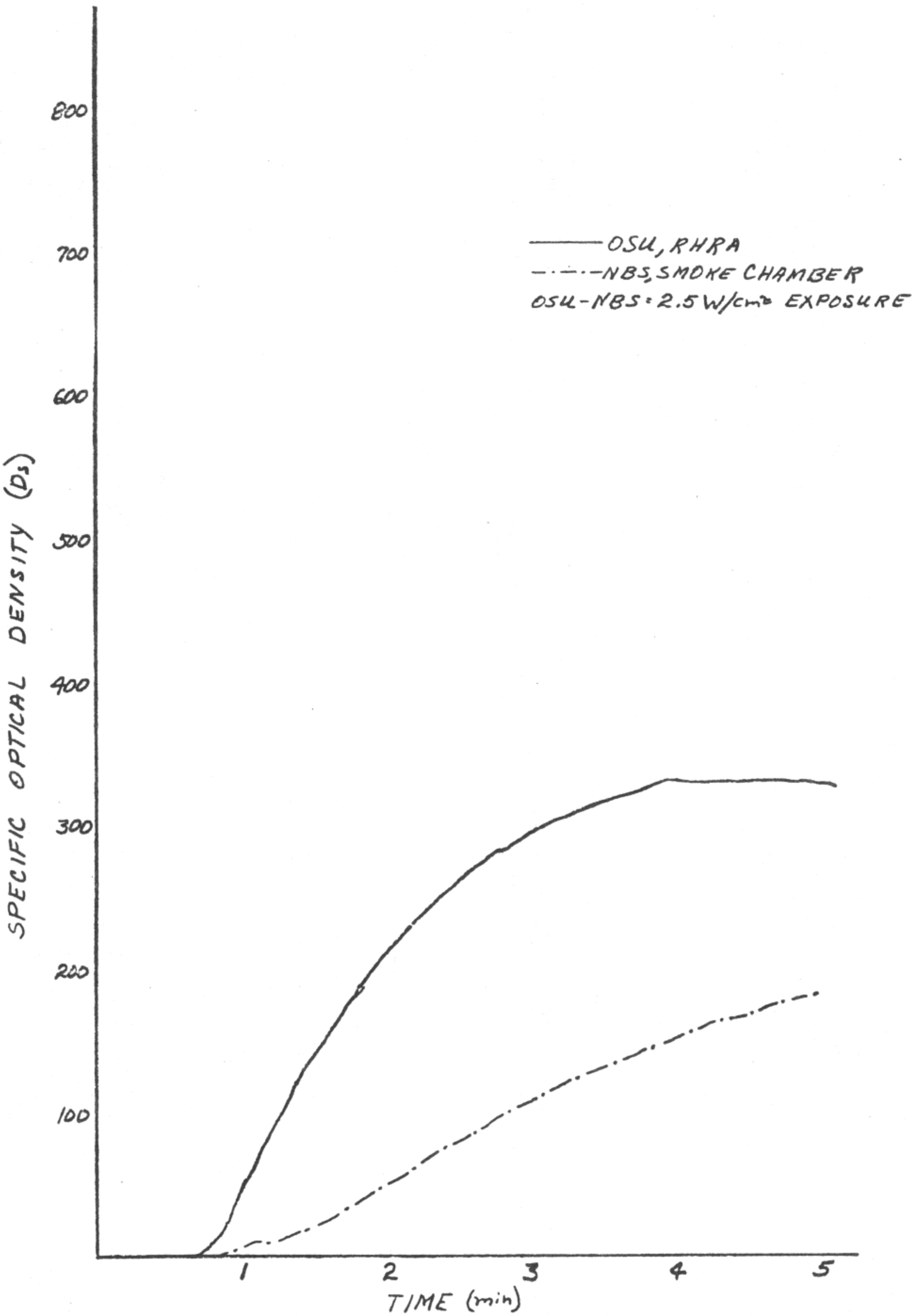

FIG. 2 FABRIC "NAUGAFOAM®" NONPILOTED

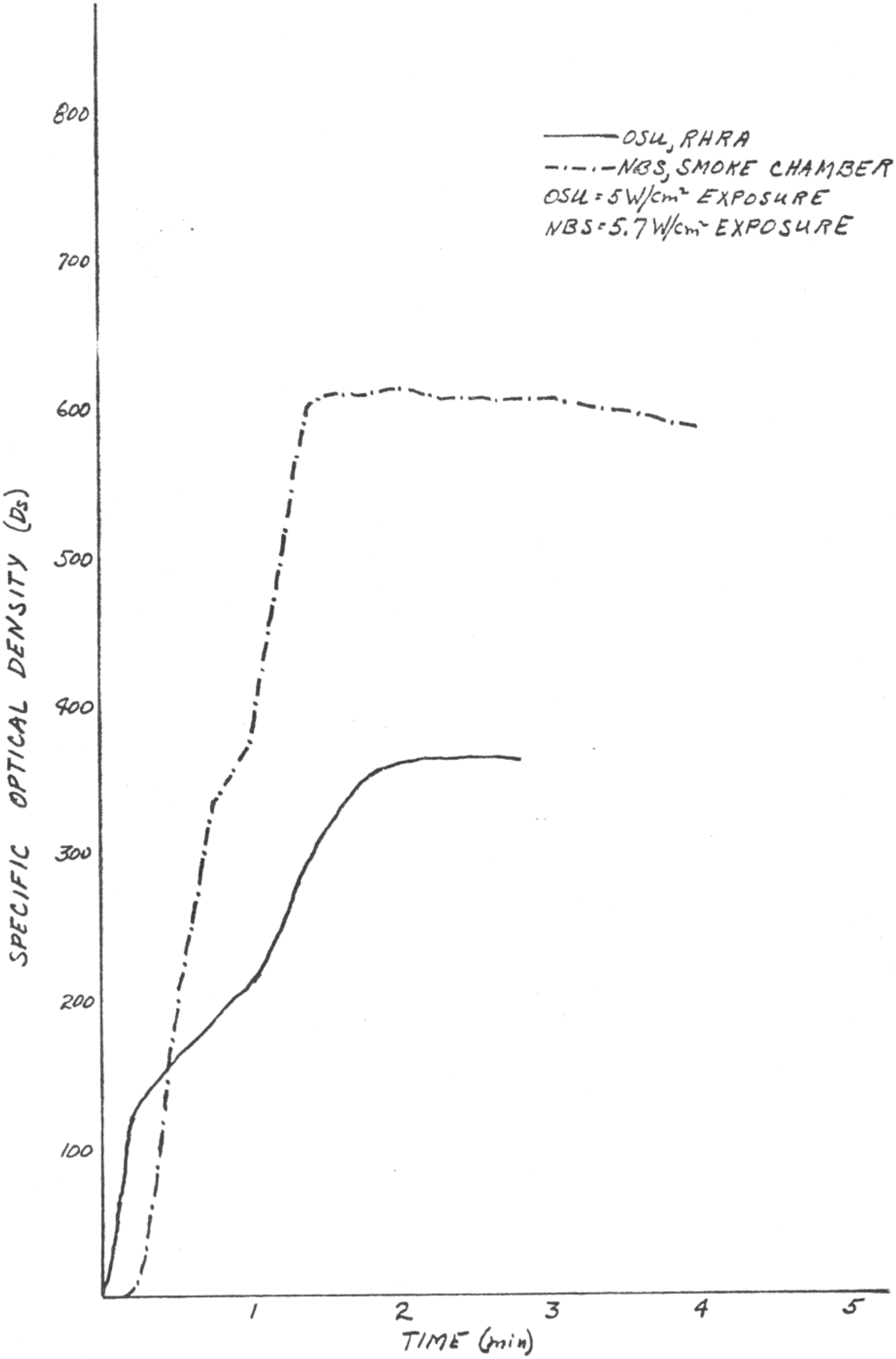

FIG. 3 FABRIC "NAUGAFOAM - PILOTED

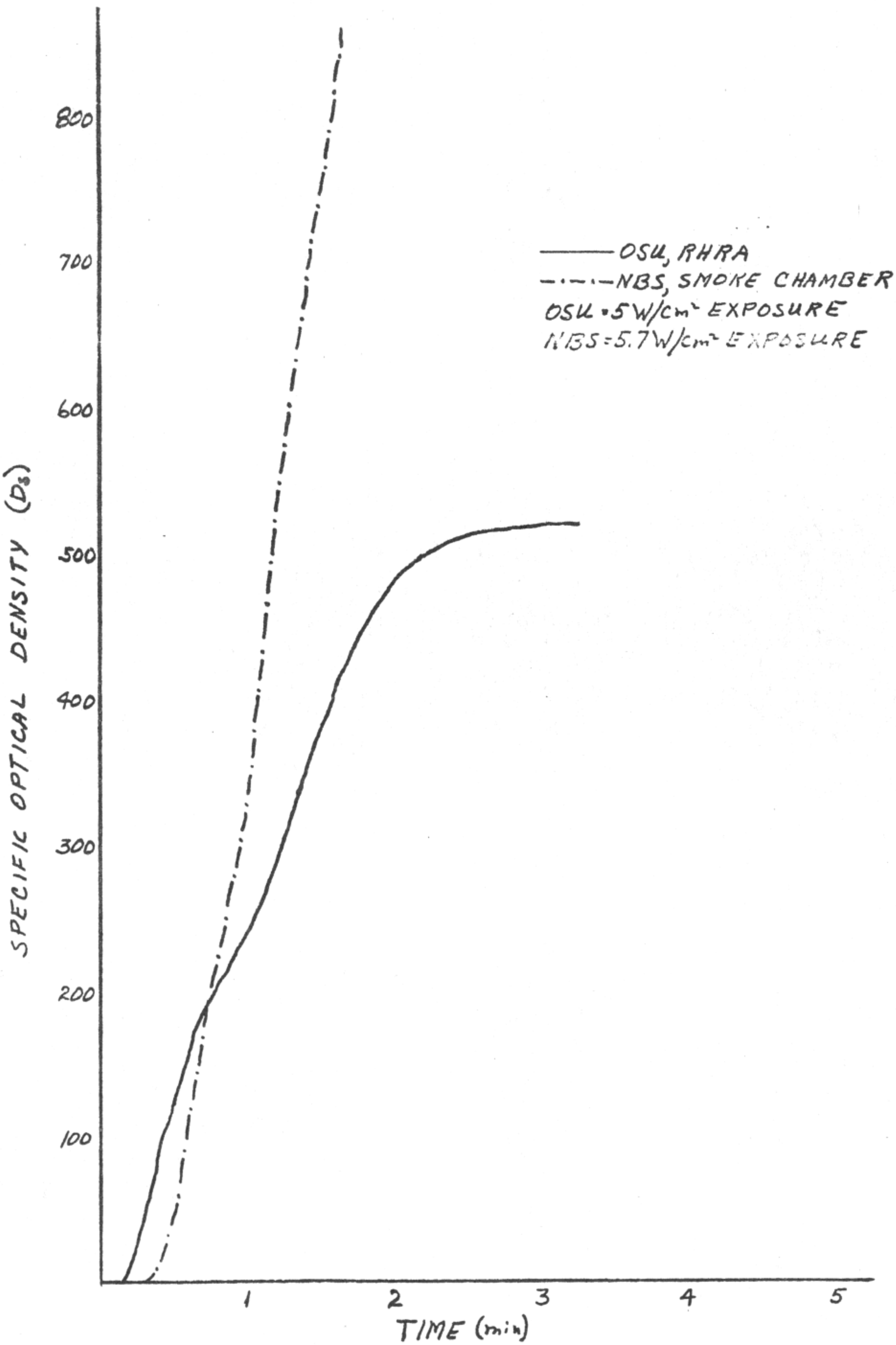

FIG. 4 FABRIC "NAUGAFOAM®" - NON PILOTED

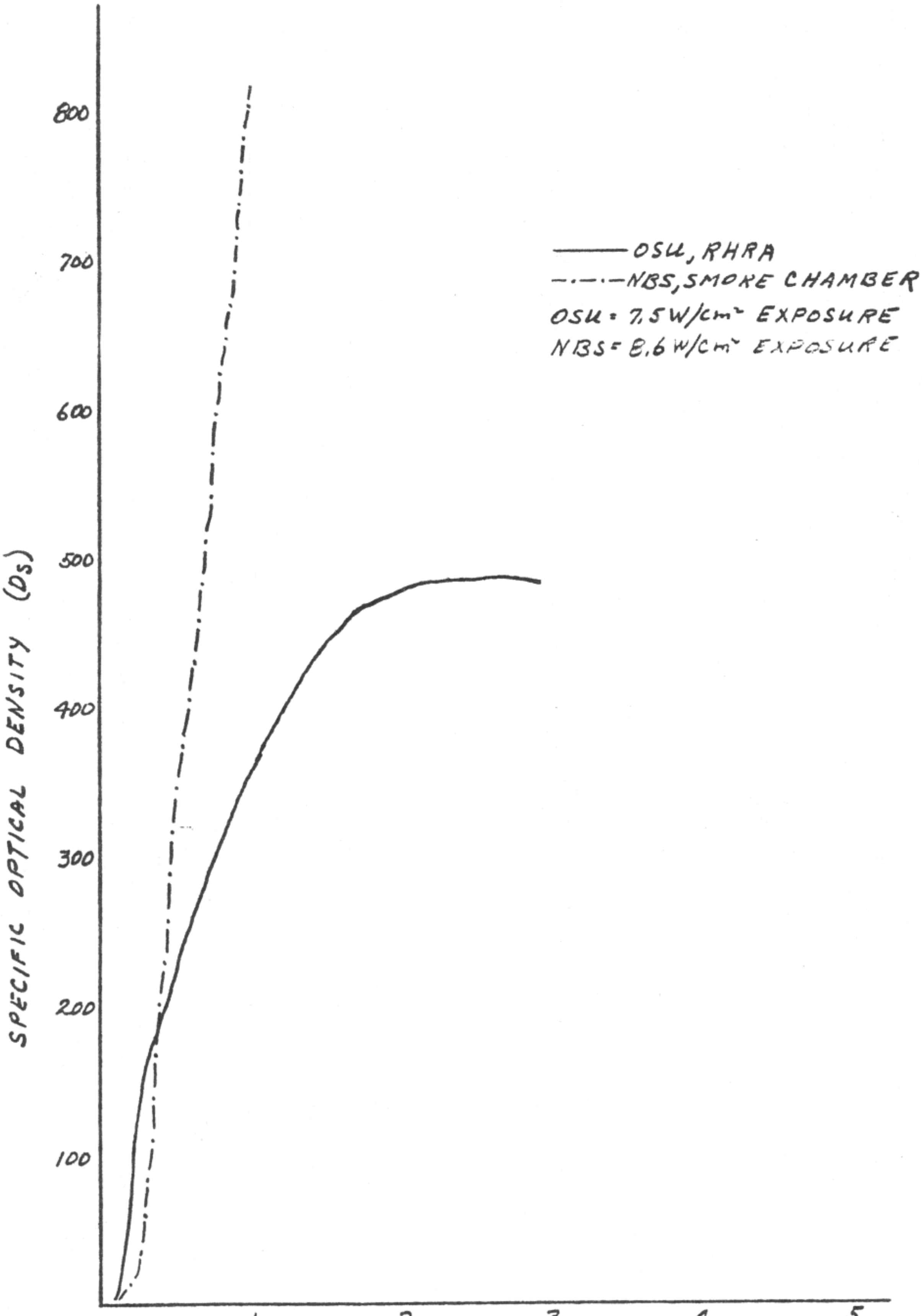

FIG. 5 FABRIC "NAUGAFOAM®" - PILOTED

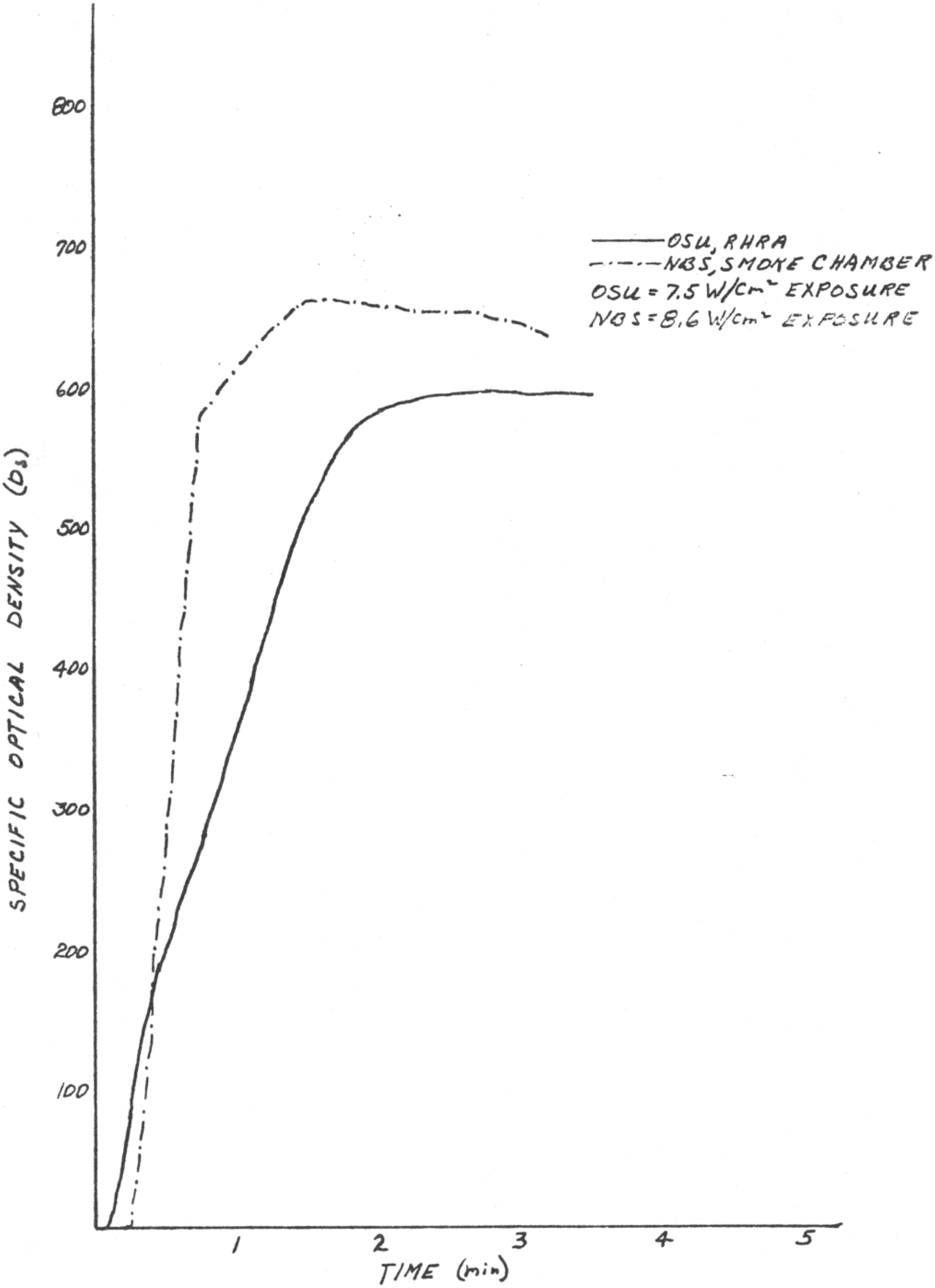

FIG. 6 FABRIC "NAUGAFOAM®" - NONPILOTED

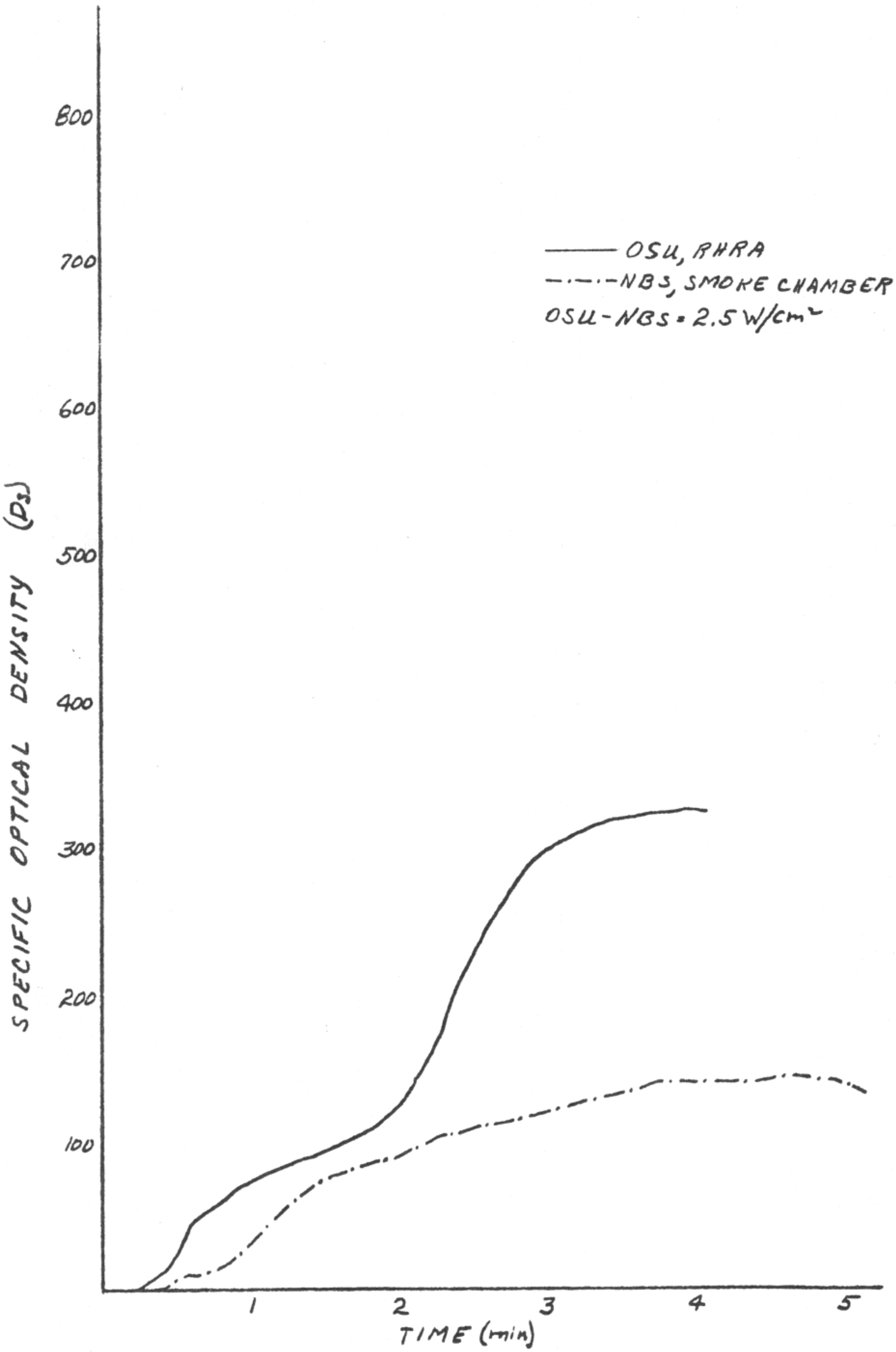

FIG. 7 PANEL - PILOTED

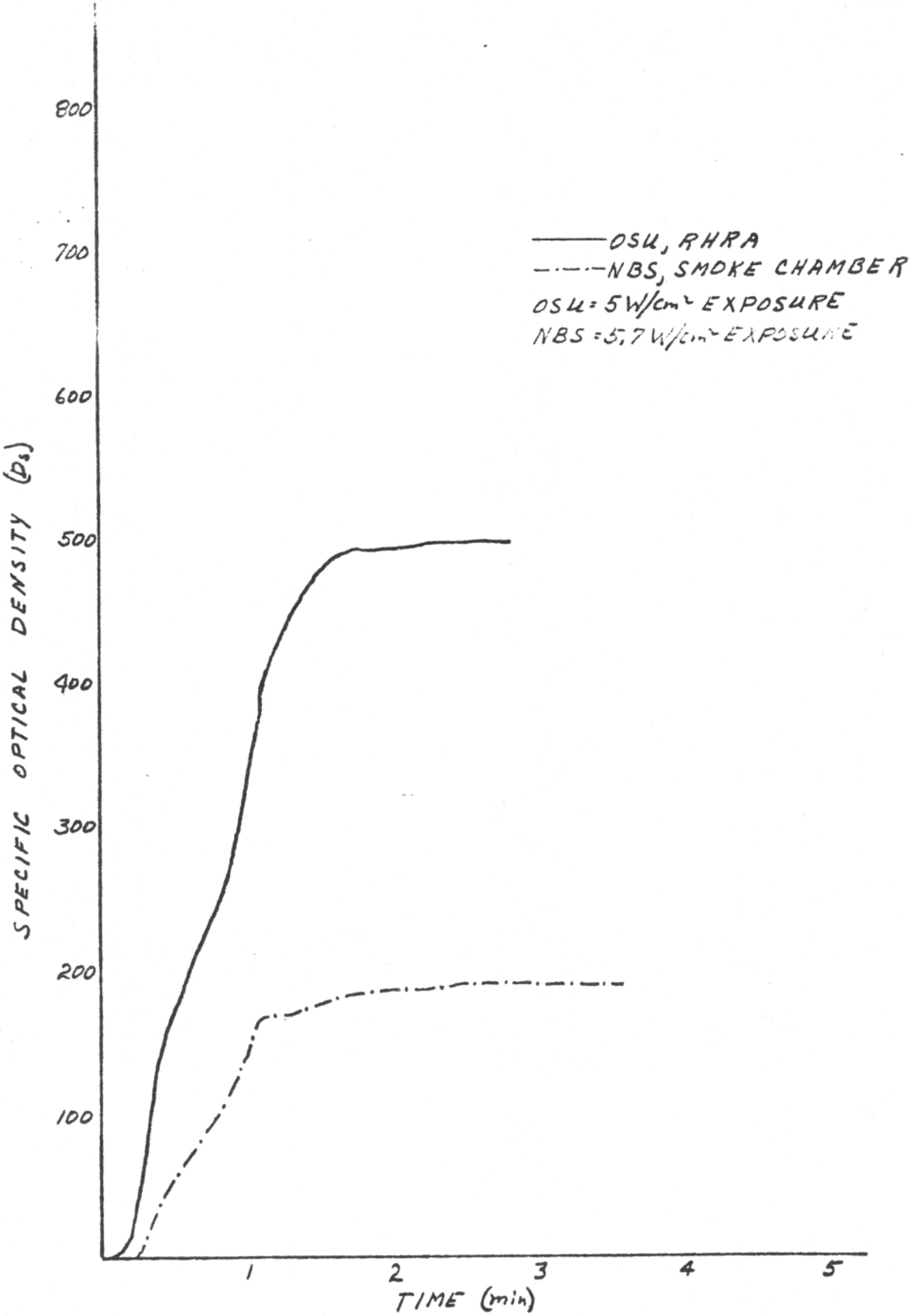

FIG. 8 PANEL - PILOTED

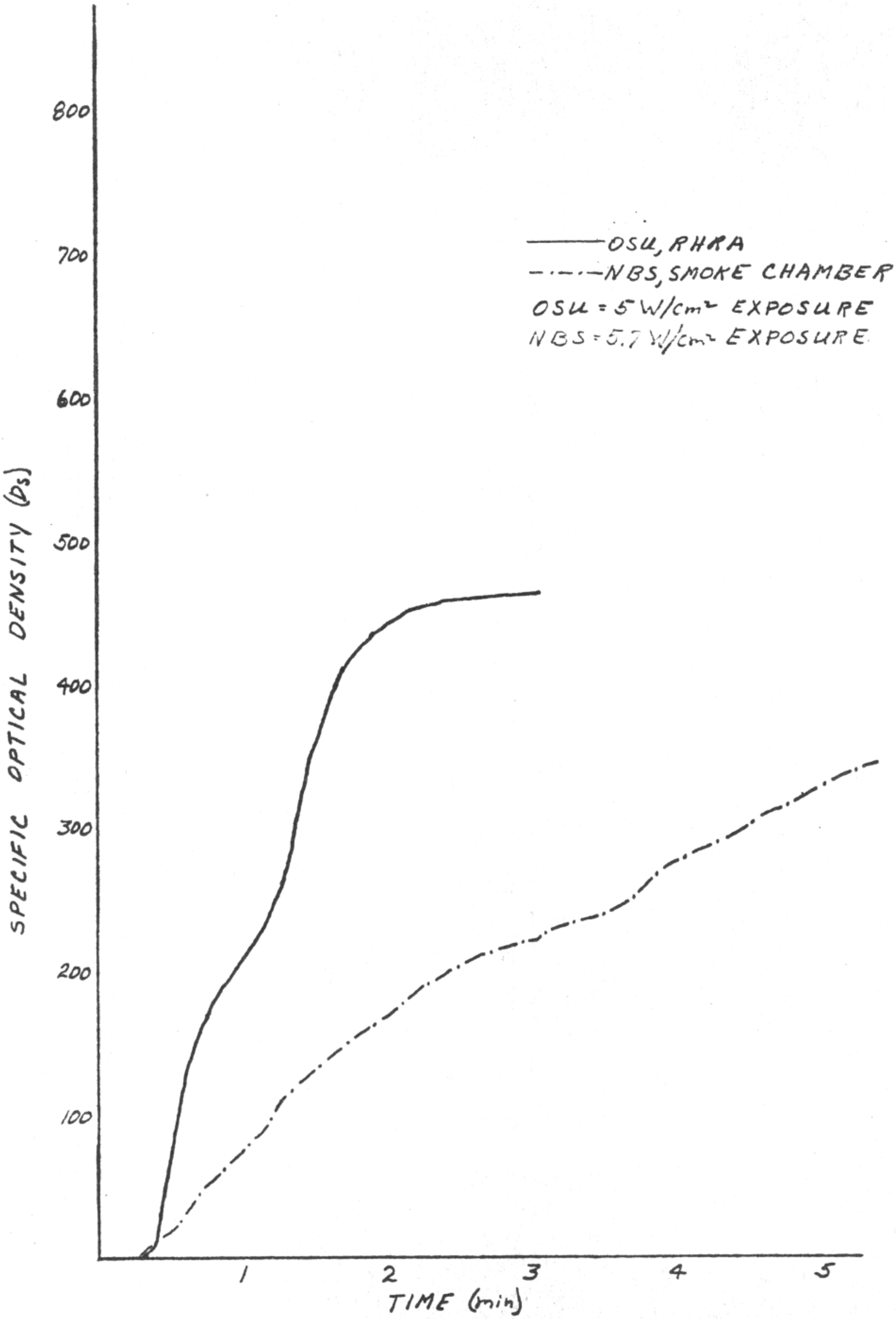

FIG. 9 PANEL - NONPILOTED

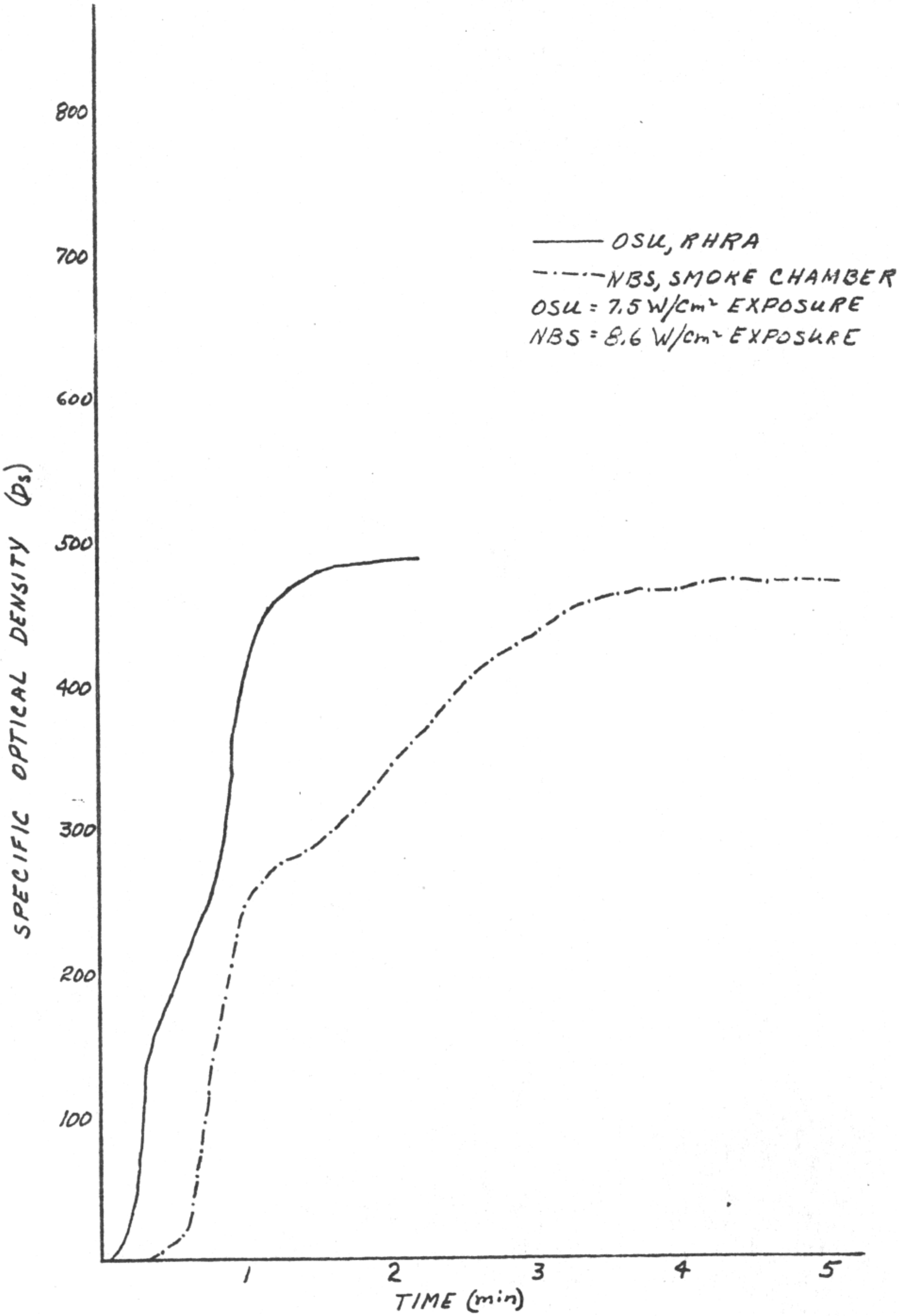

FIG. 10 PANEL - PILOTED

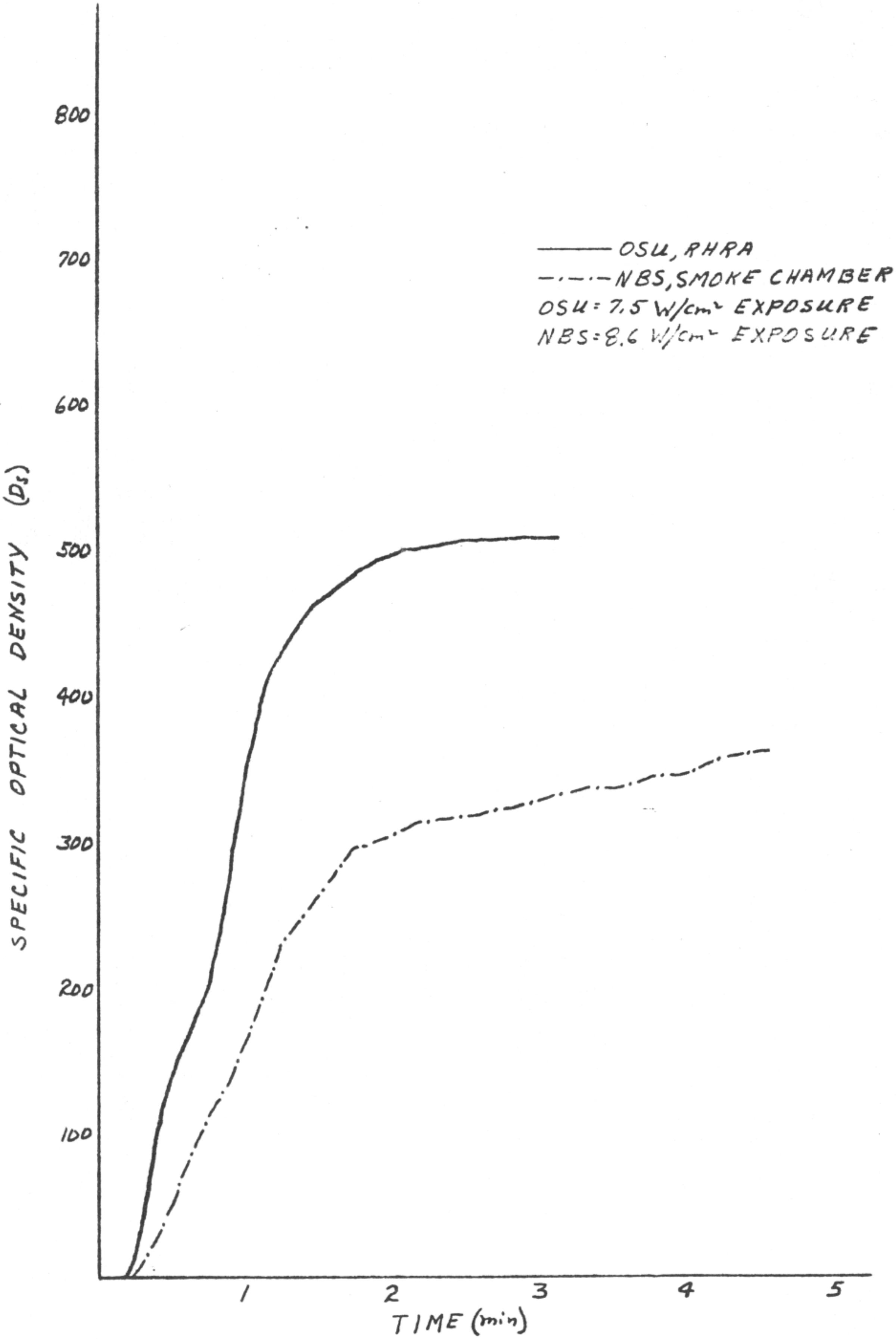

FIG. 11 PANEL - NONPILOTED

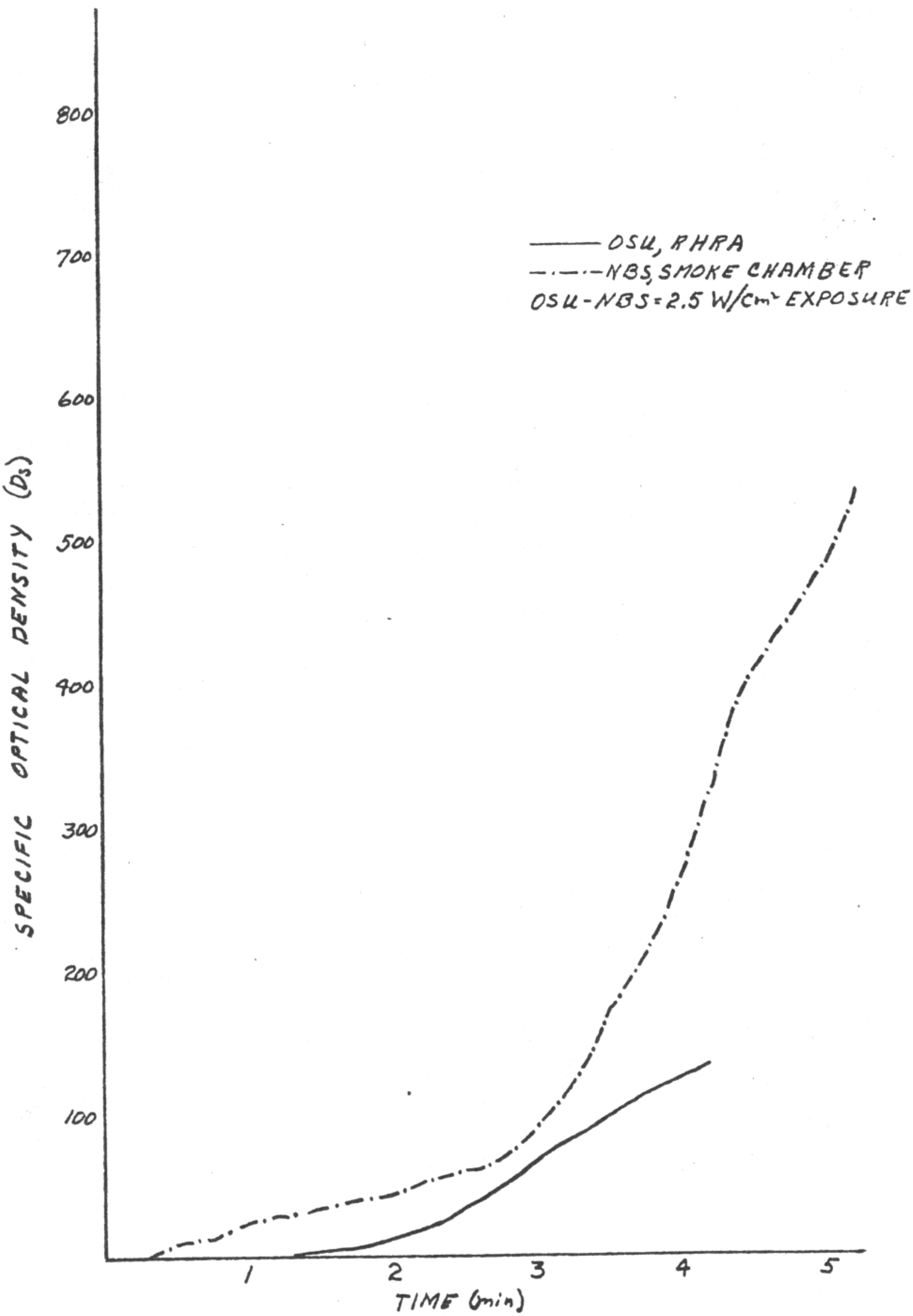

FIG. 12 WOOL CARPET - PILOTED

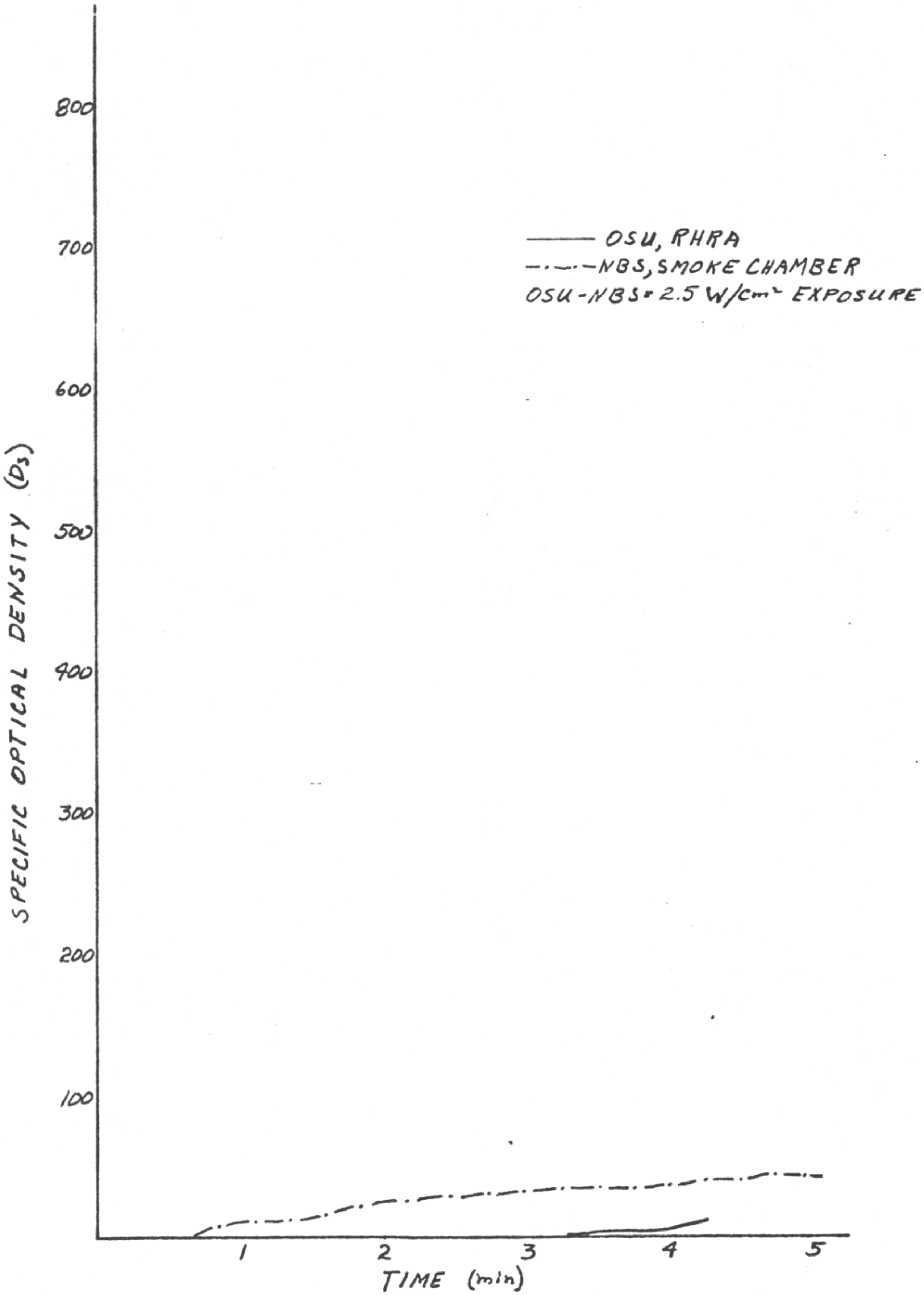

FIG. 13 WOOL CARPET - NONPILOTED

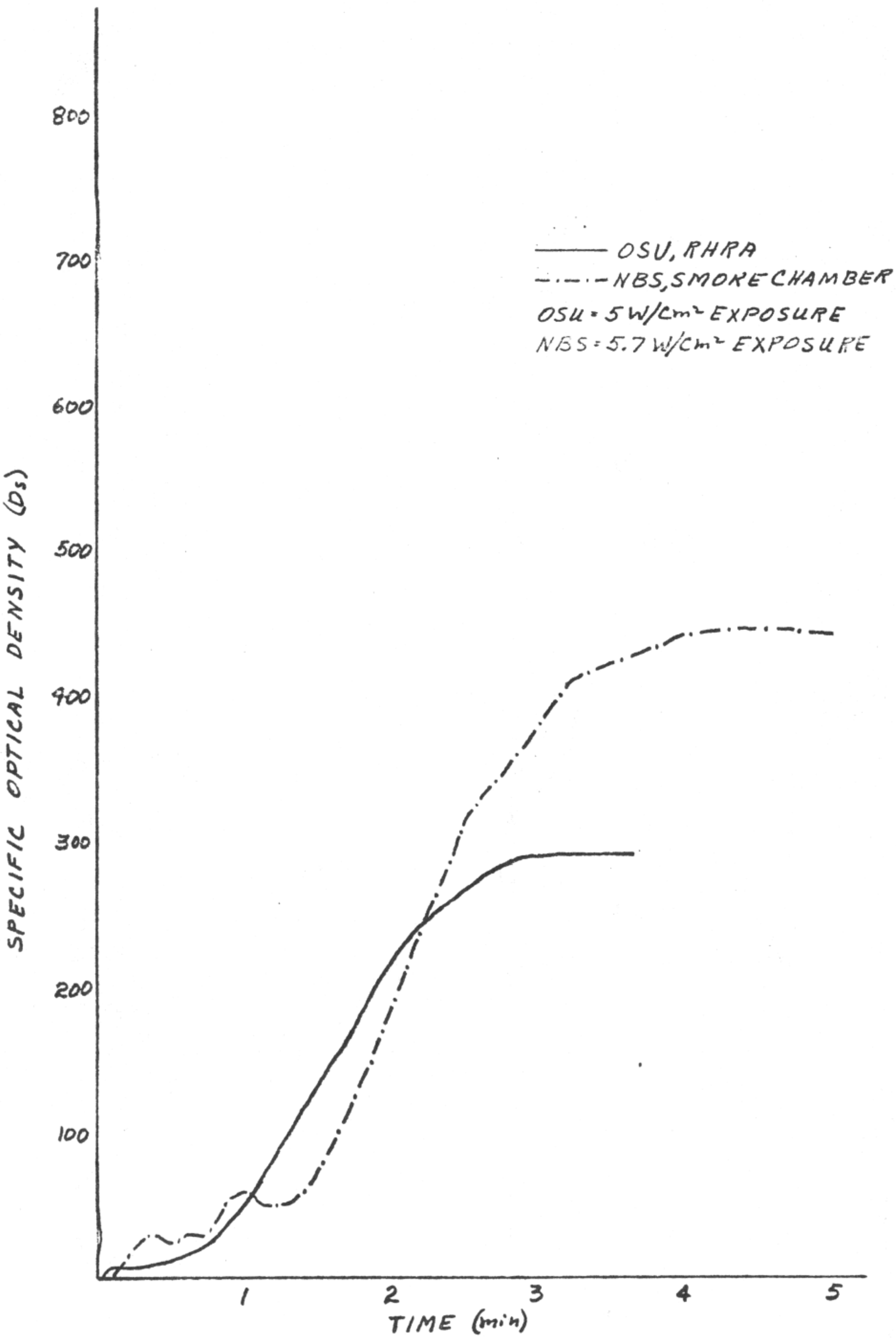

FIG. 14 WOOL CARPET - PILOTED

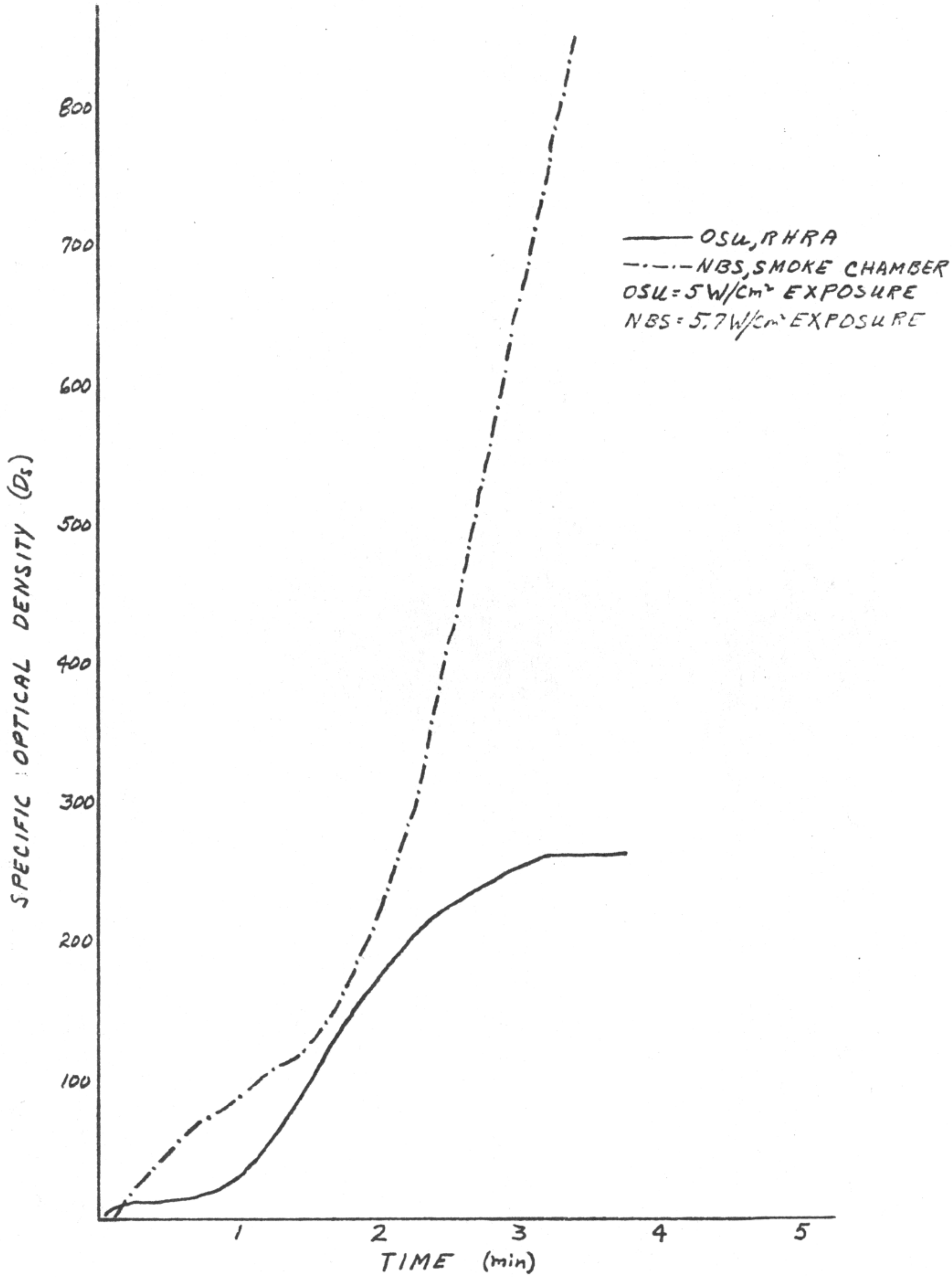

FIG. 15 WOOL CARPET - NONPILOTED

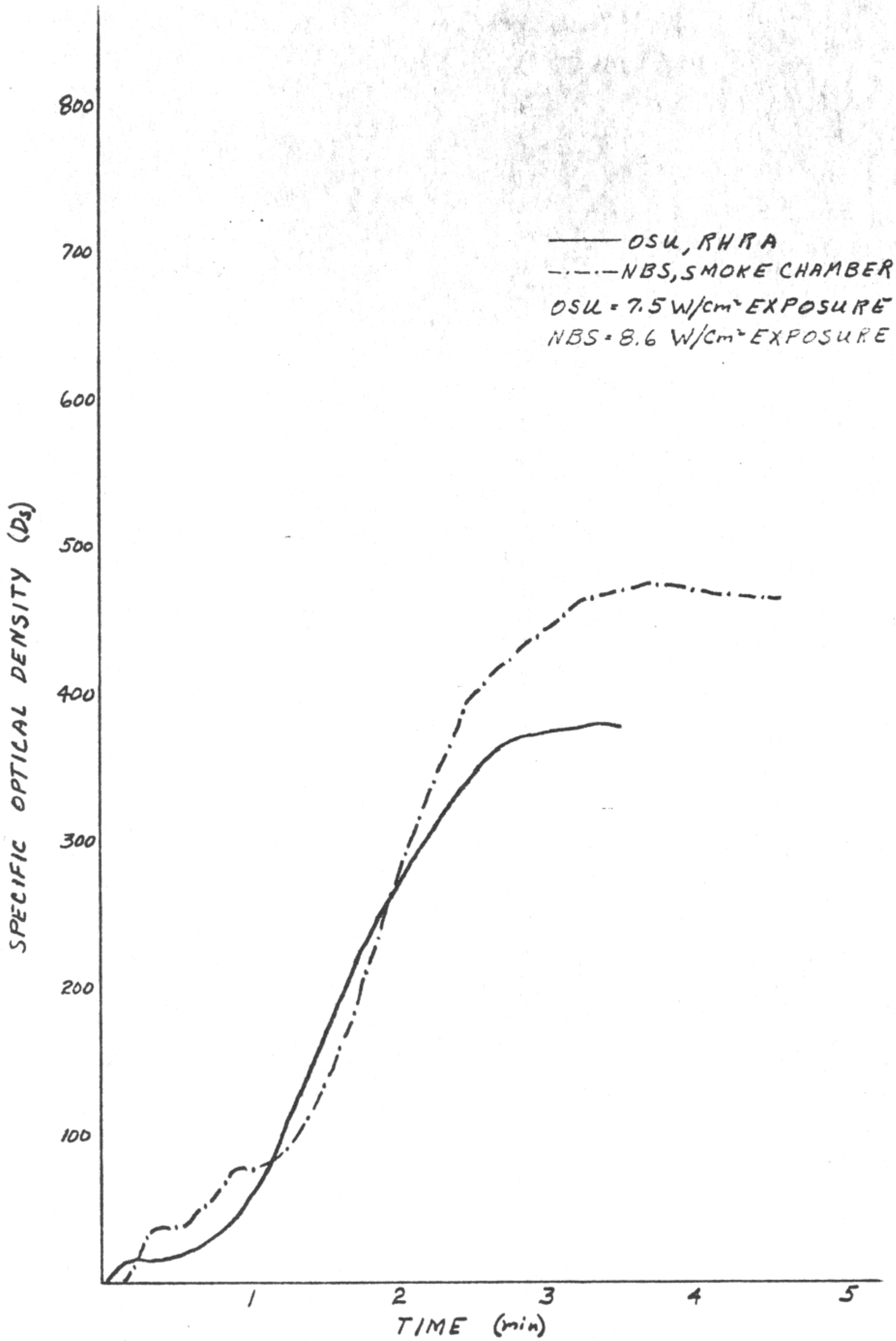

FIG. 16 WOOL CARPET - PILOTED

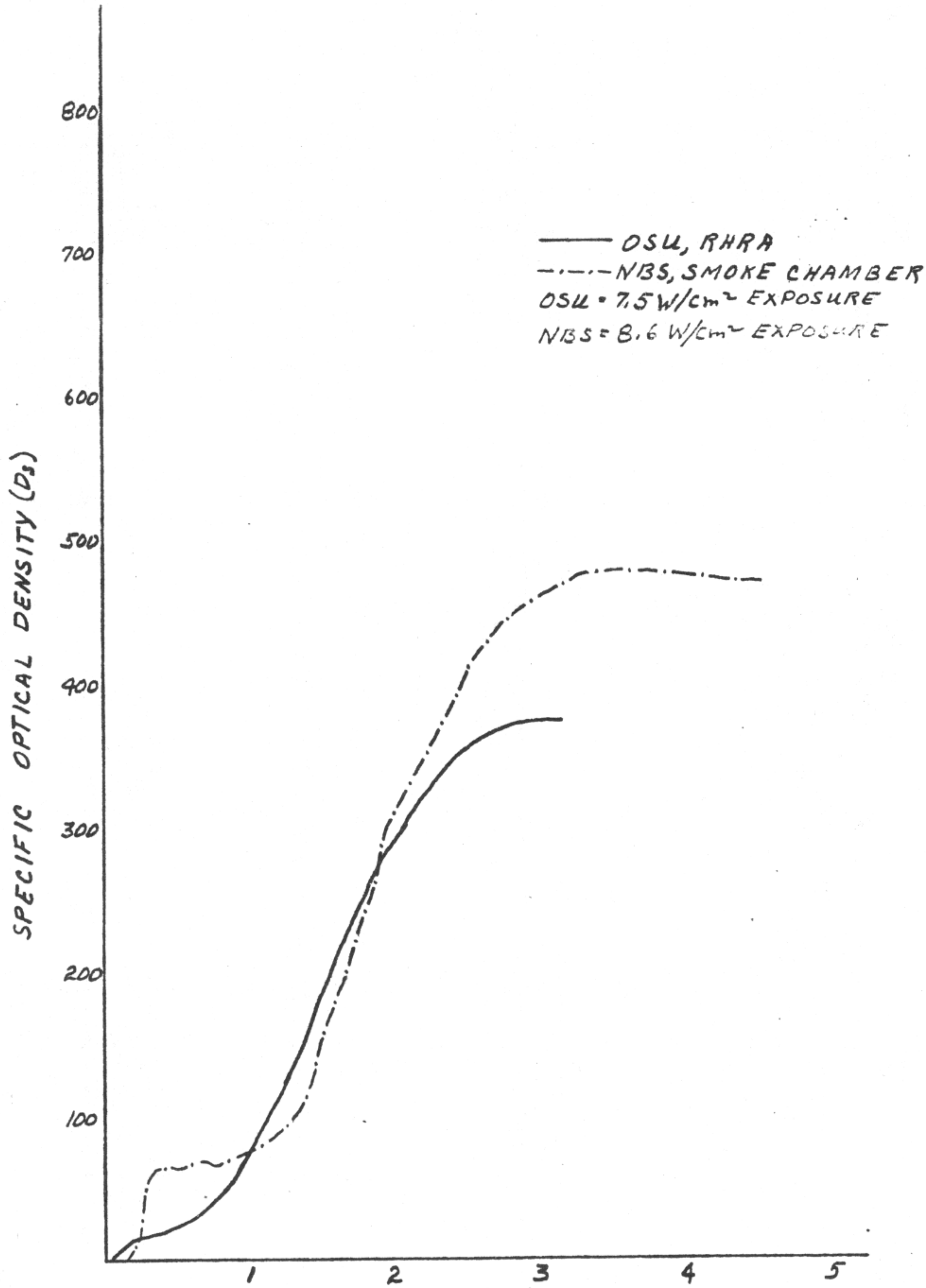

FIG. 17 WOOL CARPET - NONPILOTED

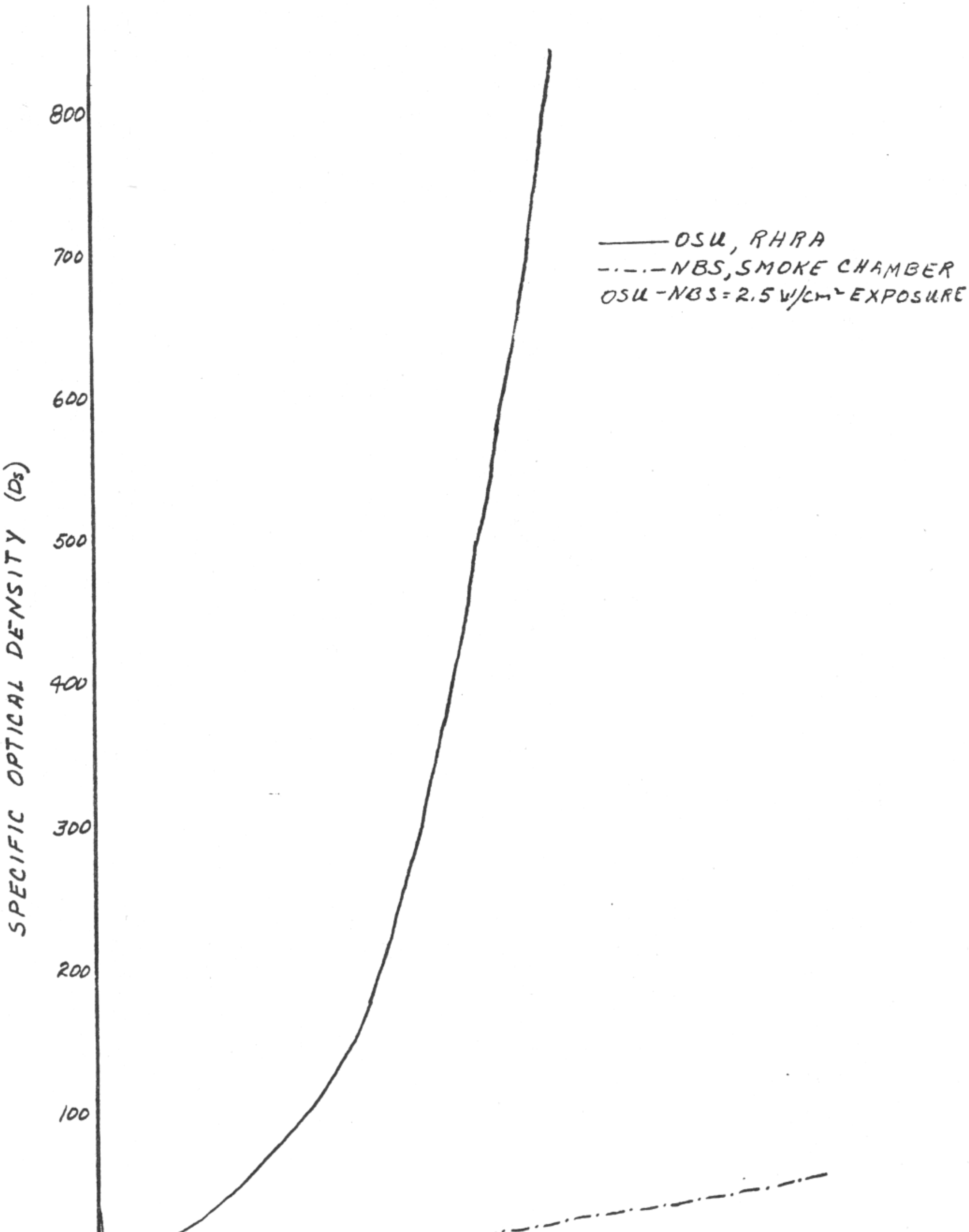

FIG. 1B POLYCARBONATE - PILOTED

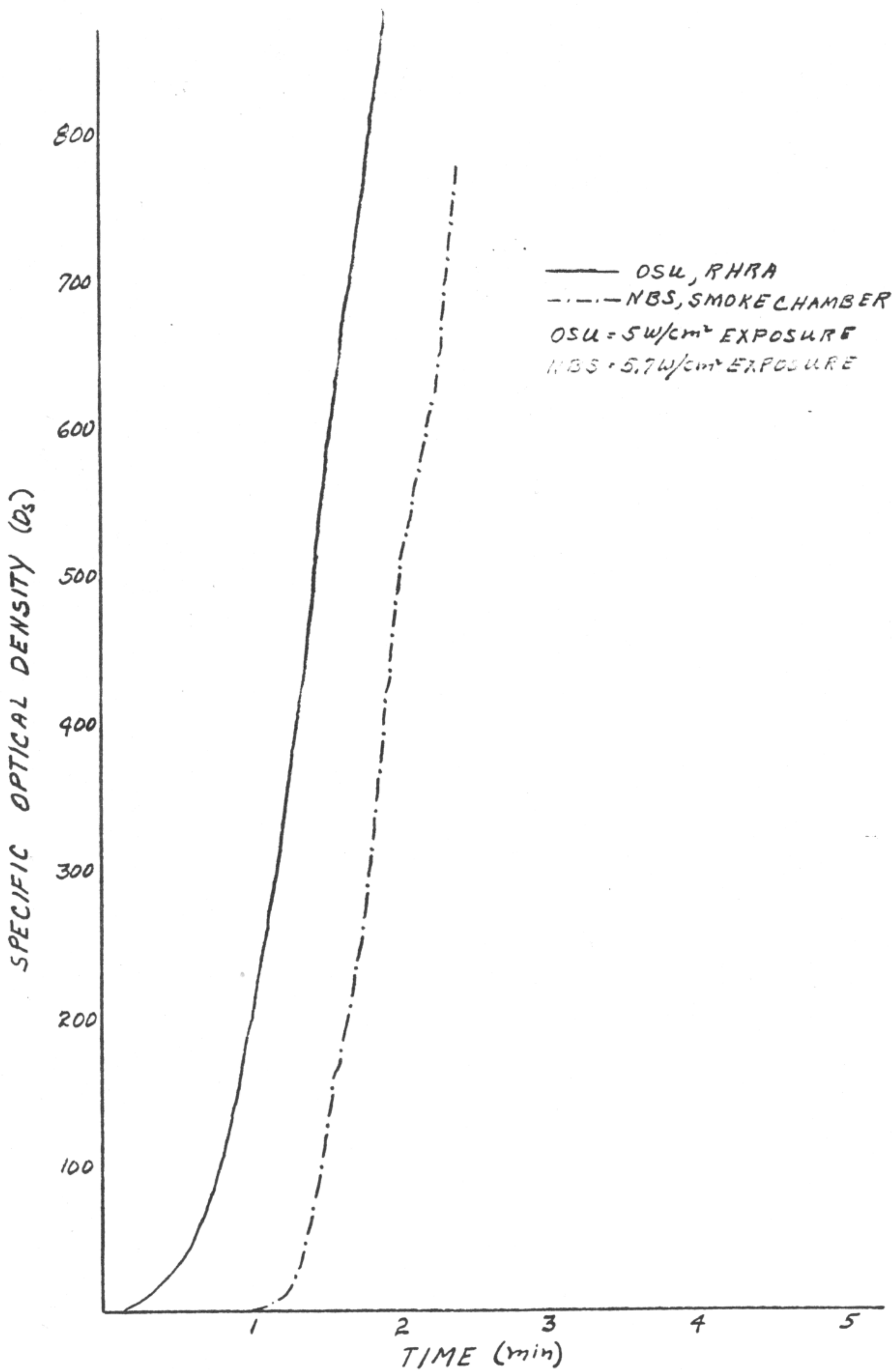

FIG. 19 POLYCARBONATE - PILOTED

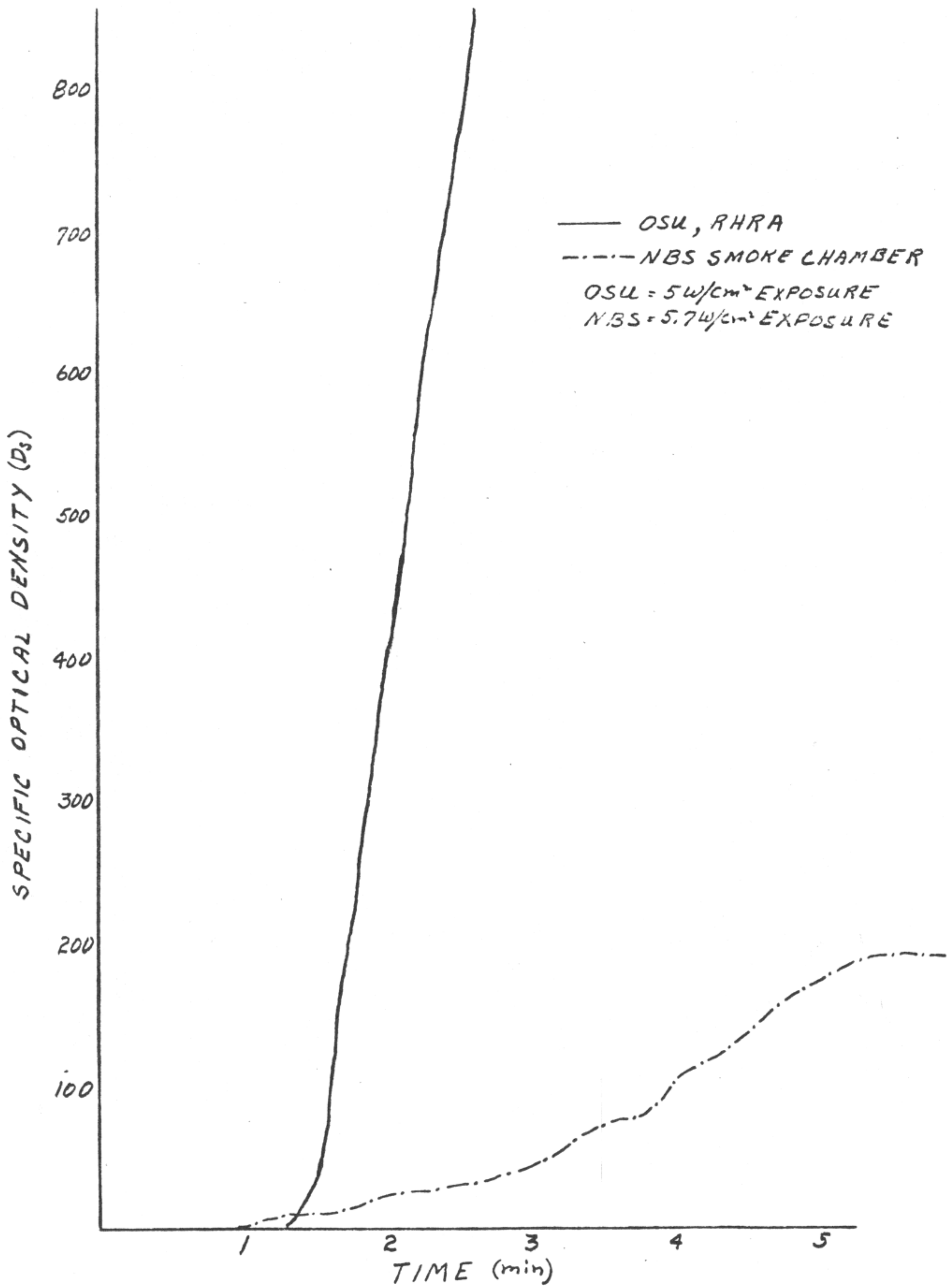

FIG. 20 POLYCARBONATE - NONPILOTED

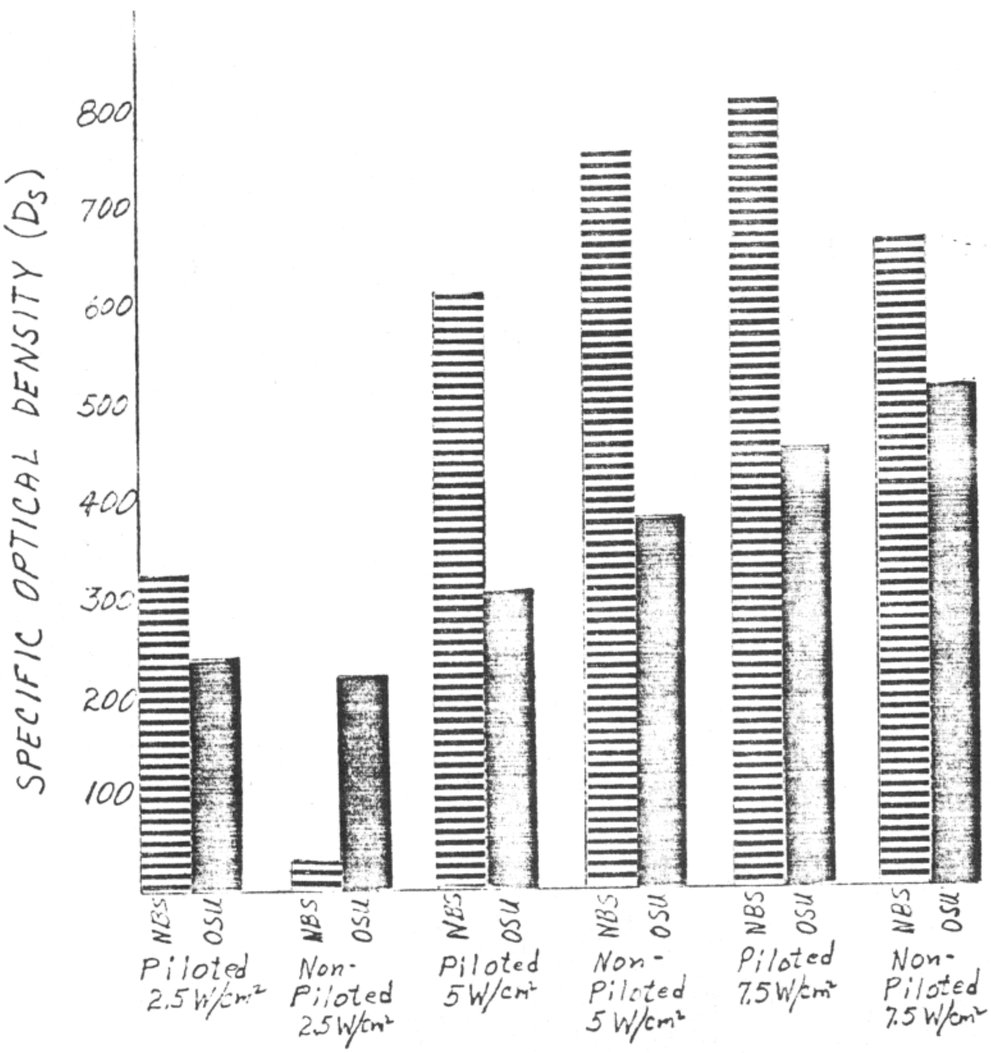

FIG. 21 FABRIC "NAUGAFOAM®" - SPECIFIC OPTICAL DENSITY (D_s) AT 90 SECONDS

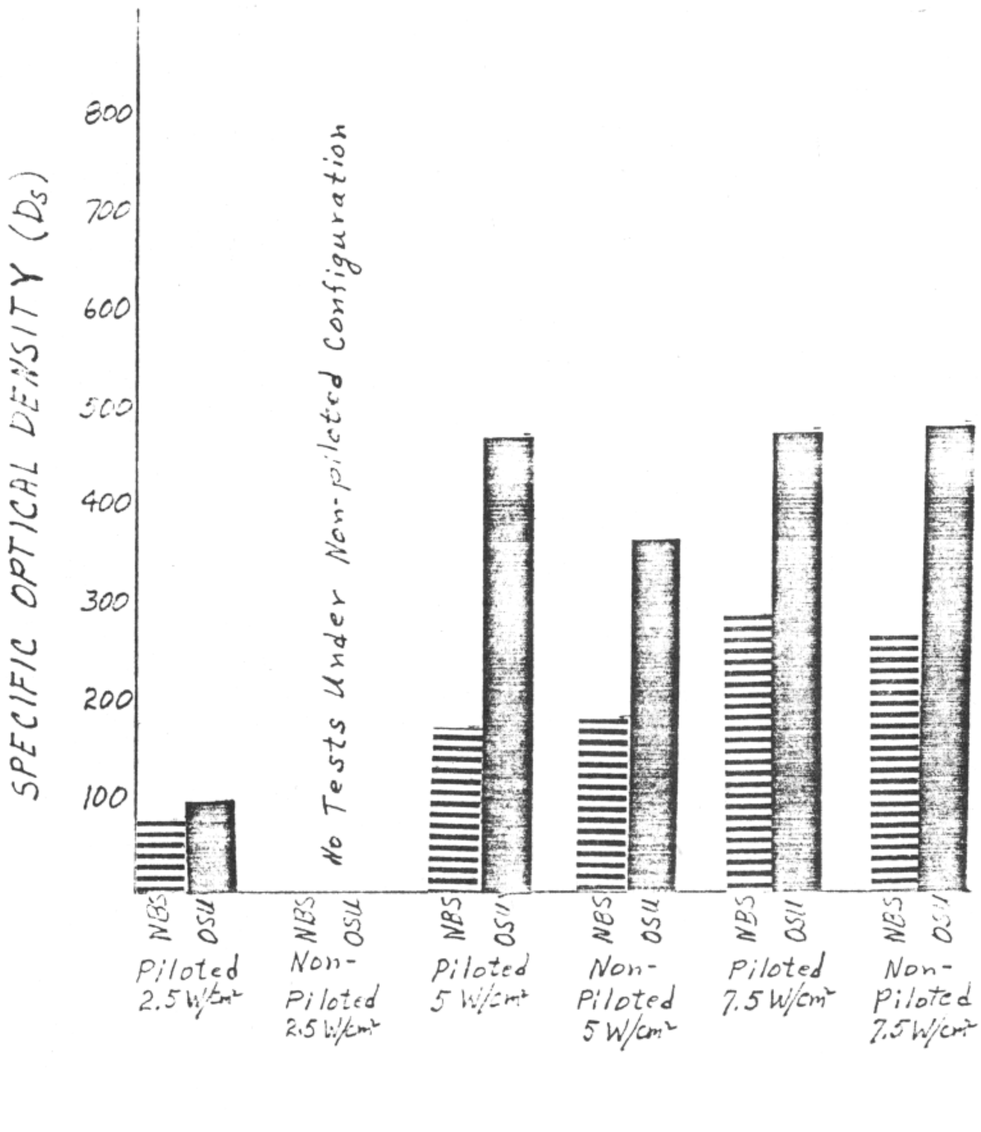

FIG. 22 PANEL - SPECIFIC OPTICAL DENSITY (D_s) AT 90 SECONDS

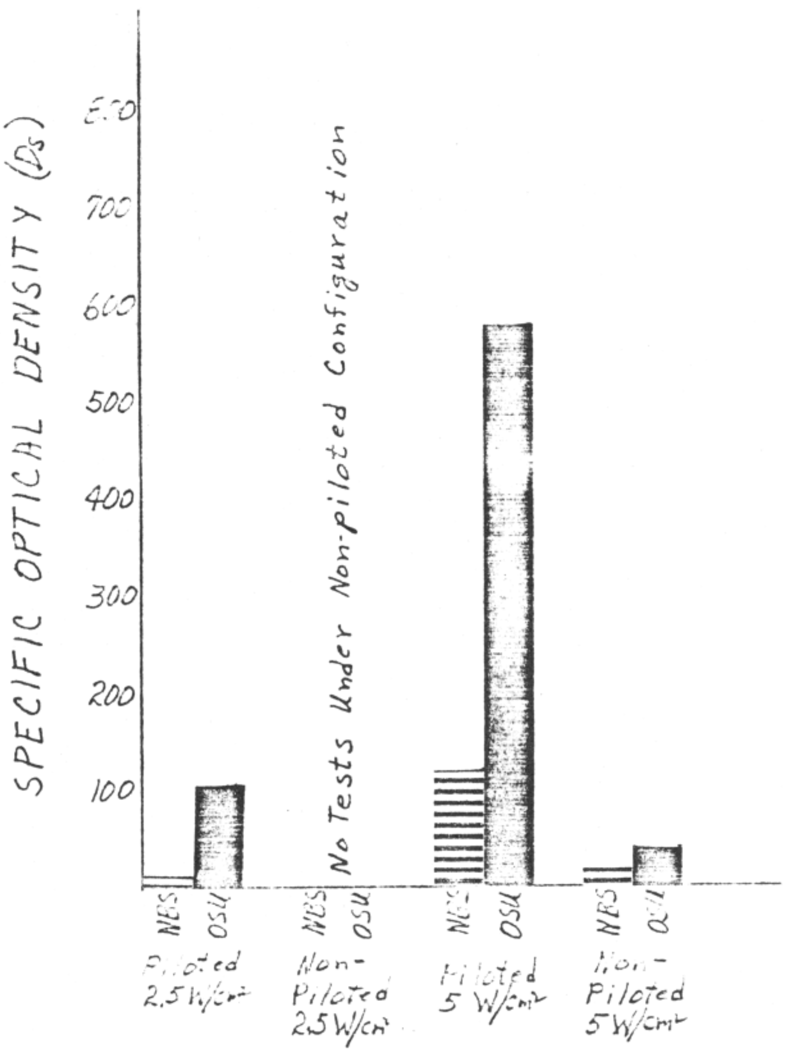

FIG. 24 THERMOPLASTIC - SPECIFIC OPTICAL DENSITY (D_s)
AT 90 SECONDS

DISTRIBUTION

AED-1
AEM-1
AWS-1
AWS-100
AWS-120
AWS-120 (Henri Branting)
ANA-2 (2 copies)
ANA-4 (2 copies)
ANA-5
ANA-64 (3 copies)
ANA-5
ANA-64 (3 copies)
ANA-64B
ANA-100
ANA-200
ANA-300
ANA-350 (20 copies)
ANA-400
ANA-600
ANA-700
ARD-1
ARD-54
ASF-1