N71-37503

NASA TECHNICAL MEMORANDUM

NASA TM X-2399

NASA TM X-2399

CASE FILE COPY

EFFECTS OF EXHAUST PRODUCTS FROM A BIPROPELLANT ATTITUDE CONTROL ENGINE ON TRANSMITTANCE OF QUARTZ

by Ernie W. Spisz, Robert L. Bowman, J. Perry Campbell, and John F. Cassidy

Lewis Research Center
Cleveland, Ohio 44135

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • SEPTEMBER 1971

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM X-2399		

4. Title and Subtitle EFFECTS OF EXHAUST PRODUCTS FROM A BIPROPELLANT ATTITUDE CONTROL ENGINE ON TRANSMITTANCE OF QUARTZ	5. Report Date September 1971 6. Performing Organization Code
7. Author(s) Ernie W. Spisz, Robert L. Bowman, J. Perry Campbell, and John F. Cassidy	8. Performing Organization Report No. E-6444
9. Performing Organization Name and Address Lewis Research Center National Aeronautics and Space Administration Cleveland, Ohio 44135	10. Work Unit No. 124-09 11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D. C. 20546	13. Type of Report and Period Covered Technical Memorandum 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Preliminary results are presented on the effects of deposits from the exhaust products from a 22.5-newton (5-lbf) thrust, bipropellant, attitude control engine on the transmittance of four quartz samples. Transmittance measurements were obtained with an ultraviolet spectrometer over the wavelength range from 0.2 to 0.6 micrometer and from 0.32 to 2.2 micrometers with an integrating sphere, lithium fluoride prism monochromator. The changes in transmittance of the four samples were quite significant and were due to both scattering and absorption effects. Scattering was found to be the primary degradation mechanism in the visible and near ultraviolet wavelength range; absorption was the predominant effect in the ultraviolet wavelength range.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Attitude control engines Contamination by liquid propellants Transmittance and degradation of quartz	Unclassified - unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	12	$3.00

*For sale by the National Technical Information Service, Springfield, Virginia 22151

EFFECTS OF EXHAUST PRODUCTS FROM A BIPROPELLANT ATTITUDE CONTROL ENGINE ON TRANSMITTANCE OF QUARTZ

by Ernie W. Spisz, Robert L. Bowman J. Perry Campbell and John F. Cassidy

Lewis Research Center

SUMMARY

Preliminary results are presented on the effects of deposits from the exhaust products from a 22.5-newton (5-lbf) thrust, bipropellant, attitude control engine on the transmittance of four quartz samples. Transmittance measurements were obtained with an ultraviolet spectrometer over the wavelength range from 0.2 to 0.6 micrometer and from 0.32 to 2.2 micrometers with an integrating sphere, lithium fluoride prism monochromator. The changes in transmittance of the four samples were quite significant and were due to both scattering and absorption effects. Scattering was found to be the primary degradation mechanism in the visible and near ultraviolet wavelength range; absorption was the predominant effect in the ultraviolet wavelength range.

INTRODUCTION

A 22.5-newton (5-lbf) thrust, bipropellant, attitude control engine is being used at the Lewis Research Center to determine the relation between thruster operating parameters and the deposits from the engine exhaust plume on surrounding spacecraft surfaces. One aspect of this study is to investigate the effects of the thruster discharge on the transmitting characteristics of optical elements and window type materials. At the present time, the thruster, thruster control system, vacuum facility, and the facility instrumentation are being evaluated for performance characteristics and compatibility. During this preliminary evaluation period, four quartz samples (along with a number of thermal control coatings) were mounted in the vicinity of the thruster plume in order to establish the character and level of contamination and to evaluate various transmittance measuring techniques used to isolate and identify the effects of contamination. The transmittance measurements made on the four quartz samples before and after exposure to the thruster discharge are presented.

EXPERIMENT

The experimental program is being carried out at the Lewis Research Center in the solar simulator facility described in reference 1. The engine is located within the test chamber as shown in figure 1. The thruster is a scaled (22.5-N or 5-lbf thrust) version of the 100-newton (22-lbf) thrust RCS engine which had been planned for Skylab. The engine is a pressure-fed, bipropellant, single-doublet unit. The propellant is monomethyl hydrazine with nitrogen tetroxide as the oxidizer. The engine is operated in a pulse mode which consists, in general, of a train by four firing pulses with the thruster on for 50 milliseconds and off for 100 milliseconds. The duration of test firings covered a period of 20 days and the thruster was fired 1139 times with a total exposure time of 57.4 seconds.

The four quartz samples were mounted within the test chamber on the test pallet shown in figure 2. The samples are Amersil T-08 commercial grade quartz and are 2.5 centimeters in diameter and 5 millimeters thick. The samples are mounted within an aluminum cup-shaped holder, which itself is mounted to the test pallet so that only the top surfaces of the sample are exposed to the thruster discharge.

Transmittance measurements were made both before and after exposure to the thruster discharge. The after-exposure measurements were made after the thruster had been fired 1139 times. The measurements were made during a period of 3 to 20 days after the samples were removed from the test facility. No special precautions were taken during the measurement period to insure that the surface contamination layer did not change. The samples were handled as carefully as possible but were stored at room conditions.

Two different spectrometers were available for making bench type spectral transmittance measurements. These are (1) a Gier-Dunkle magnesium oxide coated integrating sphere with lithium fluoride prism monochromator (refs. 2 and 3) and (2) a concave grating vacuum ultraviolet spectrometer (ref. 4).

A schematic drawing of the integrating sphere-monochromator system is shown in figure 3. Transmittance measurements are made by the sample-in/sample-out technique with the sample mounted at the inlet port of the sphere for the wavelength range from 0.32 to 2.2 micrometers. Absorptances and reflectances of the contaminated and uncontaminated sample were obtained by mounting the sample in the center of the integrating sphere rather than at the inlet port position used for the transmittance measurements.

A schematic drawing of the vacuum ultraviolet spectrometer is shown in figure 4. The instrument is a 1-meter, 15° Robin mount, ultraviolet scanning spectrometer with a 590 grooves per millimeter concave grating blazed at 0.15 micrometer. A 1-kilowatt tungsten filament bulb located 50 centimeters from the sample is used as the source for

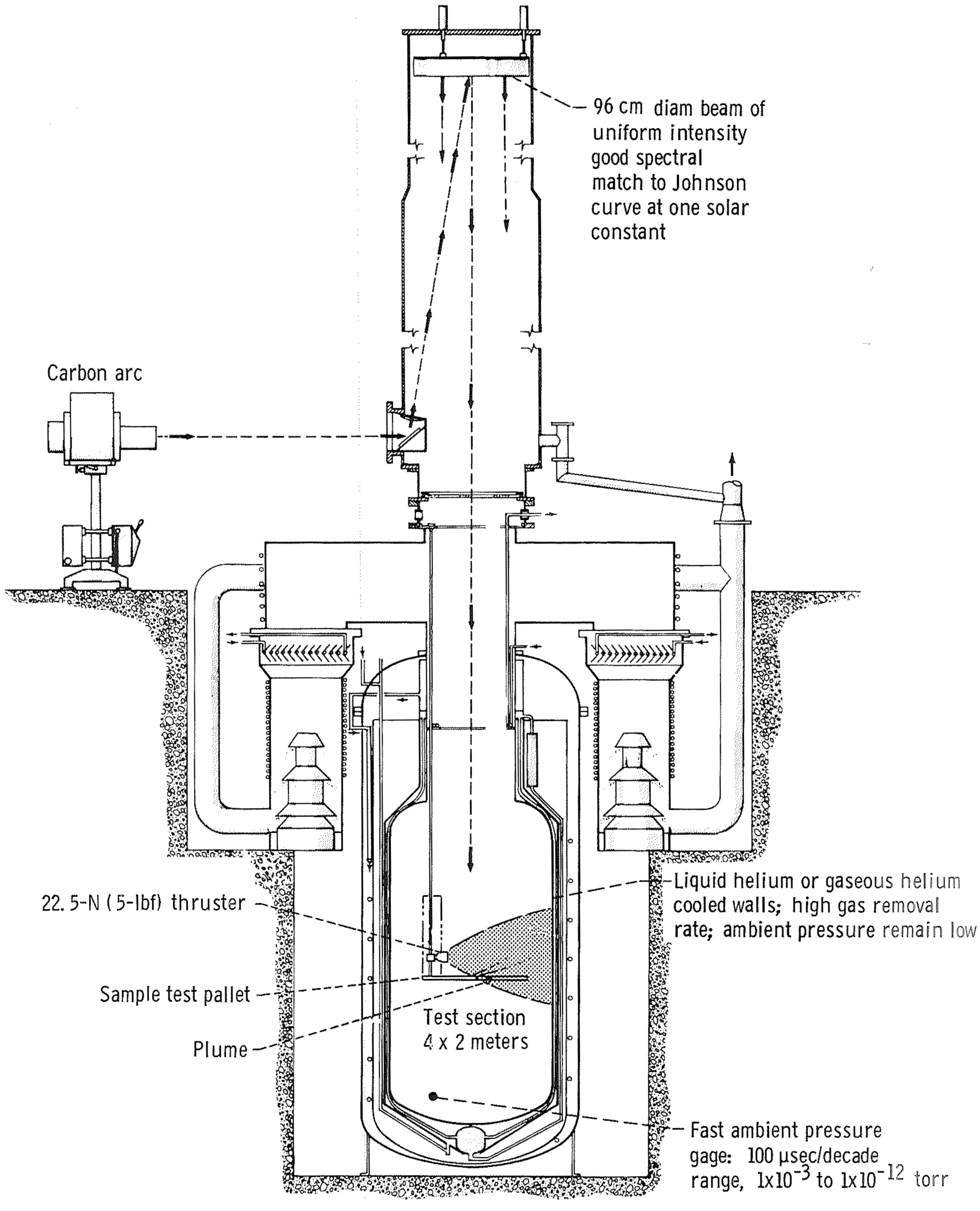


Figure 1. - In-situ rocket plume effects facility.

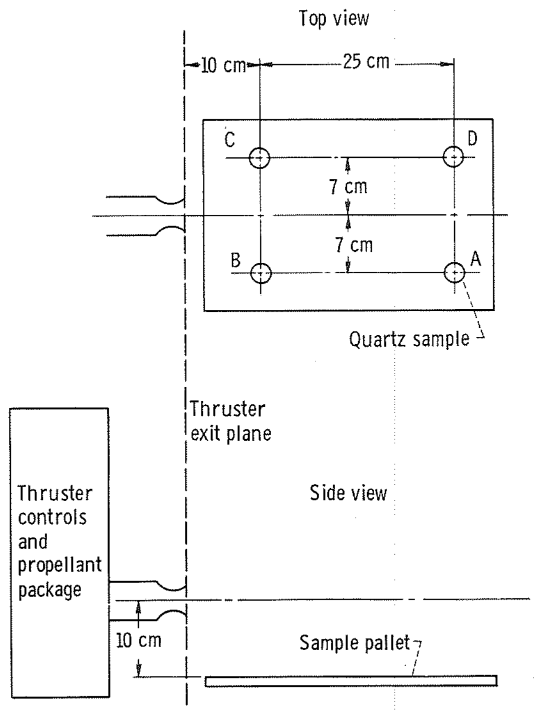


Figure 2. - Sample location.

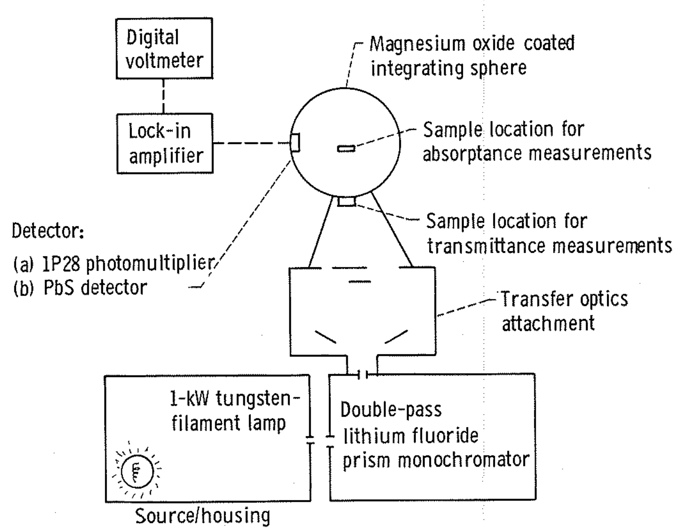


Figure 3. - Integrating sphere arrangement for transmittance and absorptance measurements.

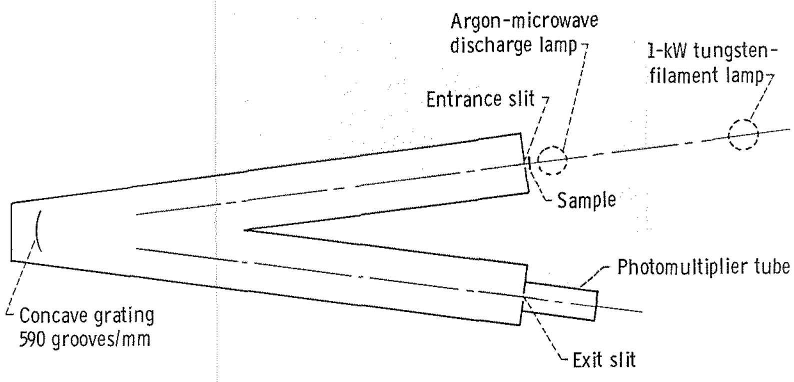


Figure 4. - Ultraviolet spectrometer arrangement for transmittance measurements.

the wavelength range from 0.26 to 0.60 micrometer and a microwave excited low-pressure argon discharge lamp (OPTHOS Instrument Company) located approximately 5 centimeters from the sample is used for the wavelength range from 0.20 to 0.30 micrometer. Transmisttance measurements are made by the sample-in/sample-out technique with the sample mounted at the entrance port of the spectrometer. Slit widths of 40 micrometers are used for the 1-kilowatt lamp source and 200 micrometers for the argon discharge lamp in order to maintain the detector output current in the useful range from 10^{-9} to 10^{-6} ampere.

RESULTS

The contamination on the surface of the quartz samples can qualitatively be described as composed of small, discrete droplets that are transparent. Figure 5 is a photograph of the contaminated sample showing a field of view of approximately 1.5 by 1.5 millimeters. The surfaces of the samples are not uniformly wetted. The droplets are of irregular shape and size with mean diameters ranging up to 500 micrometers. Microscopic examination of the contaminated surface also indicates that some particulate matter in the 5- to 20-micrometer size is evident on the sample. The source of the particulate matter is not known. Visual examination of the samples indicates that samples A, B, and C (fig. 2) were contaminated to a similar degree and that sample D was more heavily contaminated. The reason for the increased contamination of sample D is also not known.

The measured transmittances of the four quartz samples are shown in figure 6 before and after exposure to the thruster discharge. The change in transmittance as measured with the integrating sphere for wavelengths between 0.6 and 2.2 micrometers are negligible and are not included. Thus, data are shown only for the wavelength range

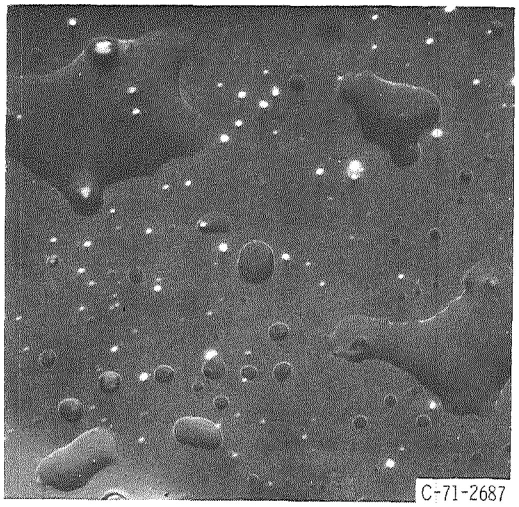


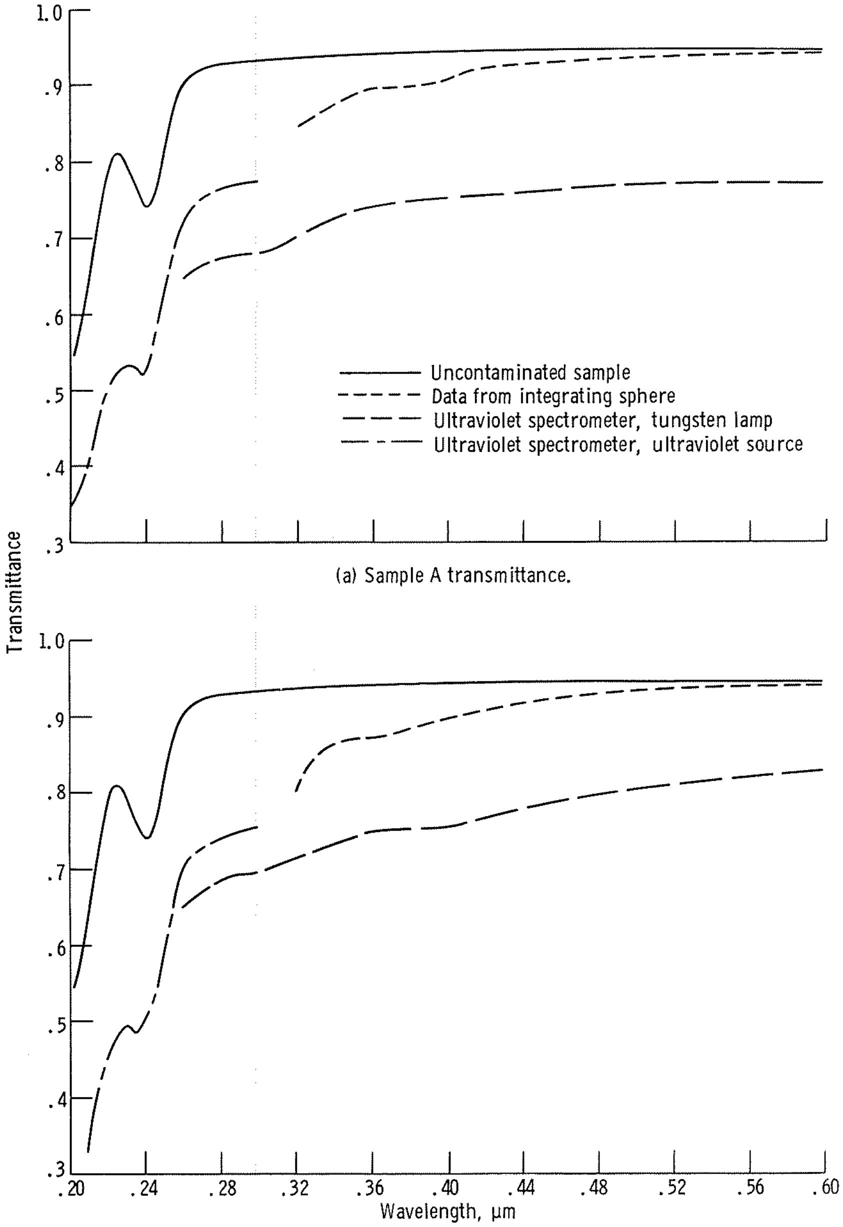
Figure 5. - Contaminated sample surface. Field of view approximately 1.5 x 1.5 millimeters.

from 0.2 to 0.6 micrometer. No measurements were obtained with the ultraviolet spectrometer for wavelengths greater than 0.60 micrometer.

The degrading effect of the thruster discharge on transmittance is similar for all four samples in that the predominant change in transmittance occurs at the shorter wavelengths. The magnitude of the transmittance changes for samples A, B, and C (fig. 6(a) to (c)) are approximately the same. The transmittance changes for sample D (fig. 6(d)) are much greater than those for the other three samples and correspond to the increased contamination level visually observed on sample D. A comparison between the transmittance measurements for samples A and D can be used to qualitatively illustrate the effect of contamination level on the transmittance changes.

As can be noted in figure 6, the transmittance measurements obtained with the integrating sphere differ from those obtained with the ultraviolet spectrometer. In fact, there is also some difference between the two ultraviolet spectrometer measurements when different sources are used. The ultraviolet spectrometer measurements obtained with the ultraviolet source indicate a smaller change than do those measurements obtained with the 1-kilowatt lamp as the source. (The transmittance measurements of the clean, uncontaminated sample did not differ noticeably for the various measuring instruments or sources.)

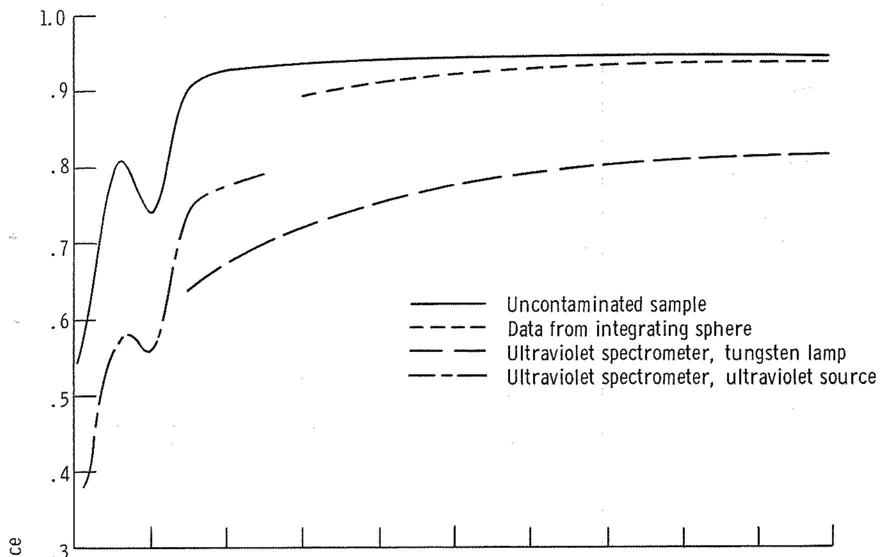
Some of the difference between the various measurements may be due to the nonuniformity of the contaminant on the sample surface and the small area actually sampled by the spectrometer beam. The sampled area for the integrating sphere measurements is 2 by 5 millimeters, while the sampled area (or slit size) for the ultraviolet spectrometer measurements is 0.04 by 20 millimeters for the 1-kilowatt tungsten filament lamp and 0.20 by 20 millimeters for the ultraviolet source. It is believed that the difference in



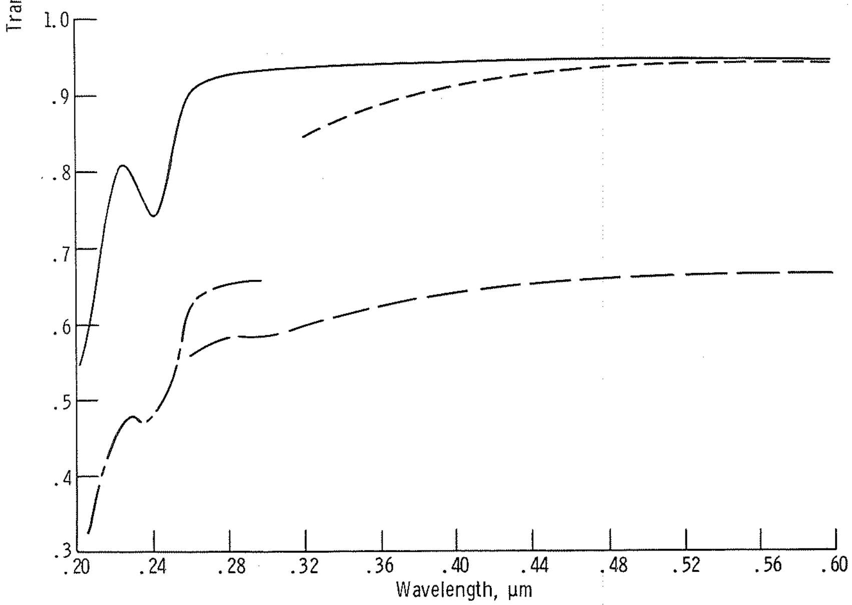
(a) Sample A transmittance.

(b) Sample B transmittance.

Figure 6. - Contamination effects. Material, commercial grade quartz.



(c) Sample C transmittance.



(d) Sample D transmittance.

Figure 6. - Concluded.

the ultraviolet spectrometer measurements is due to the different slit widths and also to the source-slit distances. The smaller slit width and greater slit-source distance used with the 1-kilowatt source tend to exaggerate any effects due to nonuniformities of the contaminant on the sample surface or any scattering of the transmitted beam that may occur.

The primary reason for the difference between the integrating sphere and ultraviolet spectrometer measurements, however, is due to the completely different transmittance measurement that is made. The transmittance measurement made with the integrating sphere is the ratio of the total energy passing through the sample to the total energy incident on the surface of the sample. The transmittance measurement made with the ultraviolet spectrometer is a more directional (or specular) measurement and does not include all of the energy transmitted by the sample. Only the transmitted energy that is contained within a small solid angle alined along the optical axis is measured. Thus, the difference between the measurements of the two instruments is basically due to the scattering effect of the contaminant. The integrating sphere measurements include the scattered radiation, whereas the ultraviolet spectrometer measurements do not. Consequently, the changes in transmittance measured with the integrating sphere are less than

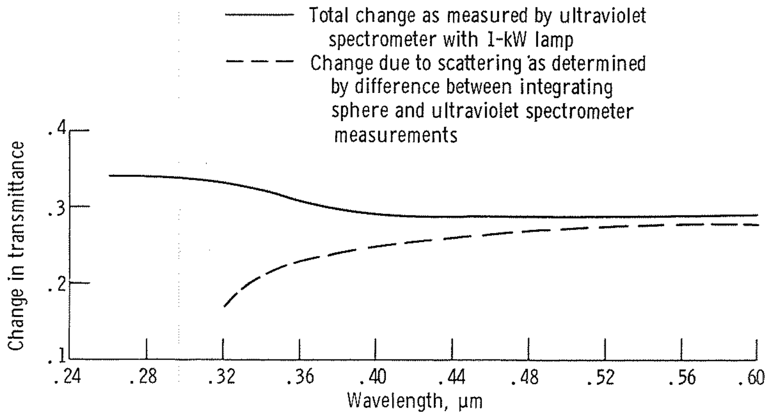


Figure 7. - Transmittance changes for sample D.

those measured with the ultraviolet spectrometer. Figure 7 shows the difference between the two spectrometer readings (i.e., the changes due to scattering) for sample D. Also shown in figure 7, for comparison purposes, is the total change in directional transmittance due to contamination as given by the difference between the ultraviolet spectrometer transmittance measurements for the contaminated and uncontaminated sample. The effect of scattering by the contaminant is signficant in the visible wavelength range and accounts for the major portion of the total measured transmittance change. The effect of scattering decreases as the wavelength decreases and accounts for only one-half of the total change at 0.32 micrometer.

The difference between the two curves in figure 7 is due to absorption by the contaminant and by changes in the front surface reflection of the sample. The absorption by the contaminant can be determined from integrating sphere measurements of the uncontaminated and contaminated sample with the sample mounted in the center of the integrating sphere (ref. 2). Figure 8 compares the measured absorptance of sample D with the difference between the two curves of figure 7. The close agreement between the two curves indicates that absorption by the contaminating layer accounts for a significant

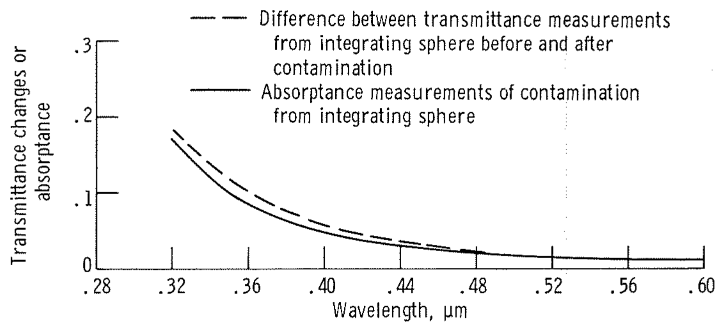


Figure 8. - Transmittance changes and measured absorptance for sample C.

change in the sample transmittance and that the changes in front surface reflectance are minor. Absorption is the primary degradation mechanism in the near ultraviolet wavelength region. The effect of absorption decreases as the wavelength increases and becomes negligible for wavelengths greater than 0.50 micrometer and less than 2.2 micrometers.

CONCLUDING REMARKS

The effect of exhaust products from a 22.5-newton (5-lbf) thrust bipropellant attitude control engine on the transmitting characteristics of quartz materials is quite significant. The contaminant results in increased absorption in the near ultraviolet wavelength range and considerable light scattering in the visible wavelength range. Future experiments under more controlled conditions will be necessary to provide quantitative data on the degree of contamination to be expected for a given application.

Possibly the most important result from this preliminary study was the recognition of the need to make several different measurements to understand and interpret the effects that contamination may have on the optical characteristics of transmitting material.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, July 22, 1971,
124-09.

REFERENCES

1. Mark, Herman; Sommers, Ralph D.; and Mirtich, Michael J.: Effect on Surface Thermal Properties of Calibrated Exposure to Micrometeoroid Environment. AIAA J., vol. 4, no. 10, Oct. 1966, pp. 1811-1817.
2. Edwards, D. K.; Gier, J. T.; Nelson, K. E.; and Roddick, R. D.: Integrating Sphere for Imperfectly Diffuse Samples. J. Opt. Soc. Am., vol. 51, no. 11, Nov. 1961, pp. 1279-1288.
3. Anon.: Instruction Manual - Perkin Elmer Infrared Equipment. Vol. 3A. Perkin Elmer Corp., Norwalk, Conn., 1956.
4. Anon.: Model 78-751, 1 meter, 15° Robin Mount Vacuum Ultraviolet Scanning Spectrometer. Engineering Publ. no. 78-751, Jarrell-Ash Co., July 1966.

NATIONAL AERONAUTICS AND SPACE ADMISTRATION
WASHINGTON, D.C. 20546

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

FIRST CLASS MAIL

POSTAGE AND FEES PAID
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION

U.S.MAIL

POSTMASTER: If Undeliverable (Section 158 Postal Manual) Do Not Return

---

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION OFFICE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546