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N71-35074

FACILITY FORM 602	(ACCESSION NUMBER)	(THRU)
	32	~~2~~ G3
	(PAGES)	(CODE)
	CR-121753	31
	(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

**Active Cleaning Technique for Removing
Contamination From Optical Surfaces In Space**

**Quarterly Progress Report No. 2
May 1, 1971 to August 1, 1971**

by

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Prepared under Contract No. NAS 8-26385 by

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Aerospace Group
Seattle, Washington**

for

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2nd Quarterly Report NAS 8-26385

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1.0 SUMMARY

This report discusses work accomplished during the second quarter of NASA contract NAS 8-26385. This program is aimed at developing an active cleaning technique (ACT) for removing contaminants from optical surfaces in space. During this reporting period, preparation of test facilities and specimens was completed, a plasma generator design was developed for introducing a reactive gas into high vacuum, contaminant film deposition experiments were conducted, and plasma cleaning experiments were completed on several ultraviolet mirrors and a silvered Teflon thermal control surface. The new plasma generator design minimizes the problem of atomic oxygen recombination on plasma tube walls, and thus introduces the possibility of "piping" the reactive gas to remote areas of a spacecraft. In contaminant film deposition experiments, hydrocarbon organic monomers evaluated were styrene, methane, and 1,3-butadiene. Butadiene produced the best results and thus was selected for subsequent experiments. In plasma cleaning experiments it was found that the hydrocarbon contaminant could be successfully removed from all surfaces without adverse effects.

2.0 INTRODUCTION

The need for developing an in-situ or active cleaning technique (ACT) for use in both space and vacuum chambers has recently become apparent. Manned spacecraft have experienced numerous contamination problems including deposition of volatile organic compounds onto windows, and light scattering from particulate contaminants surrounding the spacecraft. Sources of this contamination include outgassing of organic compounds, waste and water dumps, rocket plumes, and leakage from the life support system. It is believed that contaminant film deposition has also occurred on unmanned spacecraft surfaces. Data from a reflectometer experiment on the ATS-3 spacecraft (Reference 1) has indicated rather severe degradation on reflective surfaces, which may be the result of contaminant film deposition. Also, gratings in the extreme UV solar scanning experiment on OSO-V have degraded -- presumably the result of contaminant film deposition. Contamination on an unmanned spacecraft has been verified with quartz-crystal thin film monitors on OGO-6 (Reference 2). A recent review of the spacecraft contamination problem has been published in Reference 3.

Contamination can also occur during spacecraft testing in high vacuum chambers. A recent example of this was the extreme-UV solar spectroheliometer experiment for the Apollo Telescope Mount (ATM) vehicle. A film of back-streamed diffusion pump oil was apparently deposited on surfaces during thermal/vacuum testing (Reference 4). Another example of contaminant film deposition during environmental testing is discussed in Reference 5. In those experiments it was shown that an extremely stable organic film could be deposited onto telescope mirror surfaces during irradiation with low energy protons, in a relatively clean vacuum environment.

Based on existing knowledge, contamination problems anticipated for future spacecraft include: (1) deposition of non-volatile substances onto optical components, sensing elements, and temperature control surfaces; (2) particulate and gaseous contamination near the spacecraft (resulting in light scattering and absorption); and (3) chemical contamination which can interfere with upper atmosphere studies, analyses of interplanetary or planetary matter, and material processing experiments. It is anticipated that contamination effects can be reduced by changes in design, materials, operating procedures, and possibly control techniques. The use of more sensitive surfaces and longer term missions will, however, offset these improvements. Thus, the need exists for developing an ACT for space use.

The specific approach being investigated in this program involves exposing surfaces to a plasma containing atomic oxygen or combinations of other reactive gases. Experiments in Reference 5 have shown that this cleaning technique is very effective for removing contaminant films from optical surfaces in vacuum. Although detailed mechanisms of this process have not yet been studied, it is believed that oxidizable organic contaminant films are converted to volatile products such as CO_2 and H_2O which subsequently evaporate in vacuum. Recognizing that some contaminants will not be oxidizable into volatile compounds, cleaning by rf-sputtering will be evaluated on these materials.

In this research program, four different types of contaminant films are being applied to various types of mirrors, thermal control surfaces, and optical windows. Two types of contaminants are being applied to gratings. Contaminants are derived from a typical hydrocarbon monomer (1,3-Butadiene, $\text{CH}_2:\text{CHCH}:\text{CH}_2$), a typical silicone monomer (Methyl trimethoxysilane,

$\text{CH}_3\text{Si}(\text{OCH}_3)_3$, ethylene glycol, and urine. Mirror coatings include Pt, Au, and $1/2\lambda$ and $3/4\lambda$ MgF_2 (at 121.6 nm) over Al. Grating coatings include Pt and $1/2\lambda$ MgF_2 (at 121.6 nm) over Al. Thermal control surfaces are treated zinc oxide in methyl silicone (S-13G), zinc oxide in potassium silicate (Z-93), and silver-coated FEP Teflon.

3.0 TEST SPECIMENS

Preparation of all test specimens was completed during this quarter. Primary specimens include ultraviolet mirrors, thermal control surfaces, gratings and fused silica lenses. Secondary specimens include the quartz crystal (QCM) thin film monitors and interferometer mirrors (IFM). A detailed listing of all types of specimens by coded number is given in the following table for future reference.

<u>SPECIMEN TYPE</u>	<u>SIZE</u>	<u>COATING</u>	<u>CODE NUMBER</u>	<u>NUMBER OF SPECIMENS</u>
<u>UV MIRRORS:</u>				
	IFM	$3/4\lambda$ MgF/Al	MgF1-MgF32	32
	2"x2"	$3/4\lambda$ MgF/Al	MgF33-MgF42	10
	2"x2"	$\lambda/2$ MgF/Al	MgF43-MgF60	18
	QCM	$3/4\lambda$ MgF/Al	MgF61-MgF91	31
	IFM	$3/4\lambda$ * MgF/Al	MgF101-MgF110	10
	2x2	$3/4\lambda$ * MgF/Al	MgF111-MgF112	2
	2x2	$\lambda/2$ MgF/Al	MgF113-MgF120	8
	QCM	$3\lambda/4$ * MgF/Al	MgF121-MgF129	9
	IFM	Pt	Pt1-Pt10	10
	2x2	Pt	Pt11-Pt20	10
	QCM	Pt	Pt21-Pt29	9
	2x2	Au	Au1-Au10	10
	IFM	Au	Au11-Au40	30
	QCM	Au	Au41-Au90	50
*These coatings were thicker than $3/4\lambda$.				
<u>GRATINGS:</u>				
		$\lambda/2$ MgF/Al	GAL1-GAL4	4
		Pt	GPT1-GPT4	4

<u>SPECIMEN TYPE</u>	<u>SIZE</u>	<u>COATING</u>	<u>CODE NUMBER</u>	<u>NUMBER OF SPECIMENS</u>
<u>THERMAL CONTROL SURFACES:</u>				
		FEP TEFLON/Ag	FEP1-FEP10	10
		S-13G	S1-S10	10
		Z-93	Z1-Z10	10
<u>LENS:</u>				
		QUARTZ	L1-L8	8

4.0 EXPERIMENTAL RESULTS

4.1 Plasma Generator Development

It was determined during facility checkout experiments that the plasma generation scheme depicted in Figure 4 of the first quarterly report, did not perform satisfactorily. Apparently, the rate of atomic oxygen recombination on the quartz tube walls was too high to provide sufficient flux on the test specimen surfaces (in the test chamber). Several approaches were available for increasing the oxygen atom concentration in the gas plume leaving the quartz tubes. These included: (1) treating the tube walls with phosphoric acid or similar material to decrease the recombination coefficient; (2) decreasing the tube length-to-diameter ratio; (3) increasing the RF power input to the discharge; (4) increasing the gas mass flow rate; and (5) propagating the gas discharge at or near the exit end of the quartz tubes. Experiments showed that varying the RF power and gas flow rate could not solve the problem. A rather extensive effort was then undertaken to develop a technique for propagating the discharge at the exit end of the quartz tubes. This approach was selected because it should provide the maximum possible concentration of atomic oxygen in the plume gas, and it introduces a possible solution to the problem of conducting ("piping") a reactive gas to remote areas of a spacecraft.

As a result of the plasma generation studies, a technique was developed for creating a gas discharge at the quartz-tube exit aperture. As shown in the Figure 1 photograph, the gas discharge occurs in the plume and about 10 cm upstream in the tubes. The plasma plumes shown in Figure 1 were exiting into a vacuum of about 10^{-3} to 10^{-4} torr. RF power delivered

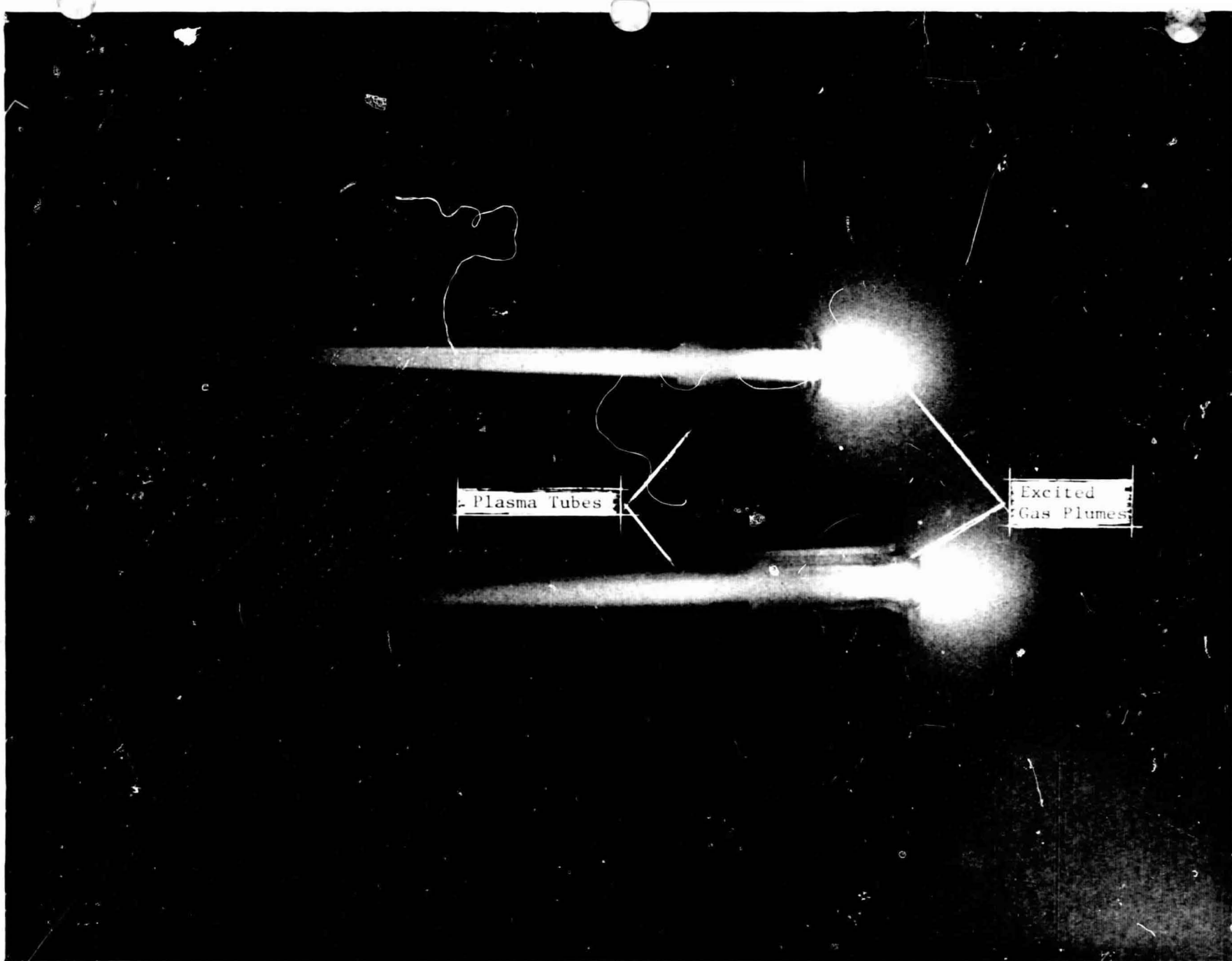


Figure 1: PLASMA GENERATION TUBES OPERATING IN HIGH VACUUM CHAMBER

to each plasma generation tube is about 20 watts. Test specimens are being cleaned at a satisfactory rate by placing them about 10 cm from the end of the quartz tubes as will be discussed later.

Although the plasma generation apparatus works sufficiently well for the present program, several questions regarding its operation need to be resolved in a follow-on effort before it can be included in a flight experiment. These include: (1) demonstration of operation in a higher vacuum environment; (2) prediction and measurement of oxygen atom flux (or concentration) within the plume; (3) development of electronics to operate a large number of plasma generation tubes using a common RF power supply; and (4) evaluating the effect of tube length-to-diameter ratio on performance.

4.2 Contaminant Film Deposition Experiments

As discussed in the first quarterly report, it was planned to deposit hydrocarbon polymer films from styrene gas in the presence of UV and proton radiation. In attempting to deposit films from styrene, however, it was found that its low vapor pressure at ambient temperature produced undesirable effects. Increasing vapor pressure, by heating, resulted in condensation of liquid in the inlet tubing to the vacuum chamber. This ultimately allowed droplets of liquid styrene to enter the vacuum chamber at pressures in the order of 10^{-4} torr, and to deposit non-uniformly on the test specimens. Furthermore, the styrene re-condensed in the vacuum pumping system reducing the pumping capability. As a result of these problems the use of styrene was abandoned.

The next contaminant investigated was methane. Experiments were conducted to determine the effect of pressure on the contaminant film

deposition rates onto specimens irradiated in a methane gas environment. The range of pressures investigated was from 10^{-5} torr to 4 torr. It was found that thin films could be successfully deposited at pressures from 10^{-3} torr to 4.2 torr and irradiation exposure times up to 141 minutes. It was also noted that the proton accelerator could only be operated at pressures less than 10^{-3} torr. It was concluded that contaminant films sufficiently thick to degrade MgF_2 /Aluminum-coated films could be deposited. However, these films were not thick enough to degrade thermal control surfaces. Therefore the use of methane was abandoned.

The third hydrocarbon contaminant investigated was 1,3-butadiene. This compound was introduced into the vacuum system in the gas phase from a pressurized bottle (similar to methane), and thus could be easily pumped out prior to plasma cleaning experiments. Deposition of polymer films from butadiene gas has been discussed in detail in References 6 and 7. Experiments with this contaminant showed that it produces satisfactory hydrocarbon films for cleaning experiments. Unfortunately, the rate of deposition dictates that films be deposited at pressures above the operating limit of the proton accelerator. Therefore, only UV is being used for depositing butadiene polymer films at the present time. One problem experienced during deposition is that a contaminant deposits on the quartz vacuum chamber window, thus changing the UV transmittance as a function of time. This in turn will effect the contaminant deposition rate. To minimize this problem, the quartz window is cleaned between each run with CaCO_3 abrasive.

Considerable problems have been experienced in obtaining thickness data on the butadiene polymer films. In attempting to deposit films at pressures below 10^{-2} torr, the drift rate of the QCM was larger than the change in

frequency caused by the deposited film. The drift rate problem was eventually eliminated by increasing the deposition rate (accomplished by increasing butadiene pressure to 4 torr). A plot of the change in frequency experienced during the contamination and cleaning of specimen No. MgF-43 is shown in Figures 2 and 3. As can be noted in the figures, a linear rate of deposition was experienced up to a frequency change of about 1000 hz. The fact that the frequency decreased to zero early in the run and then began increasing may have been caused by improper setting of the QCM tuning circuit. During plasma cleaning the frequency decreased rather non-linearly as shown.

Subsequent data taken on platinum and gold-coated QCM's showed that neither deposition nor removal of the contaminant is linear. In fact, the frequency changed rather radically during cleaning.

Measurement of film thicknesses by interferometry has been complicated by microscopic roughness on the polymer films, and difficulty in locating the step between coated and uncoated areas. The latter problem can be minimized by properly marking the interferometer reference mirrors to identify areas to be examined.

As of the reporting date, insufficient data exists to allow correlation of QCM frequency changes with contaminant film thicknesses.

4.3 Plasma Cleaning Experiments

4.3.1 Test Procedure - The following is a description of the procedures used to test samples in this program.

Initial Optical Properties Measurement:

Depending on the type of samples, the optical properties are measured in one or more of the following facilities (see 1st quarterly report,

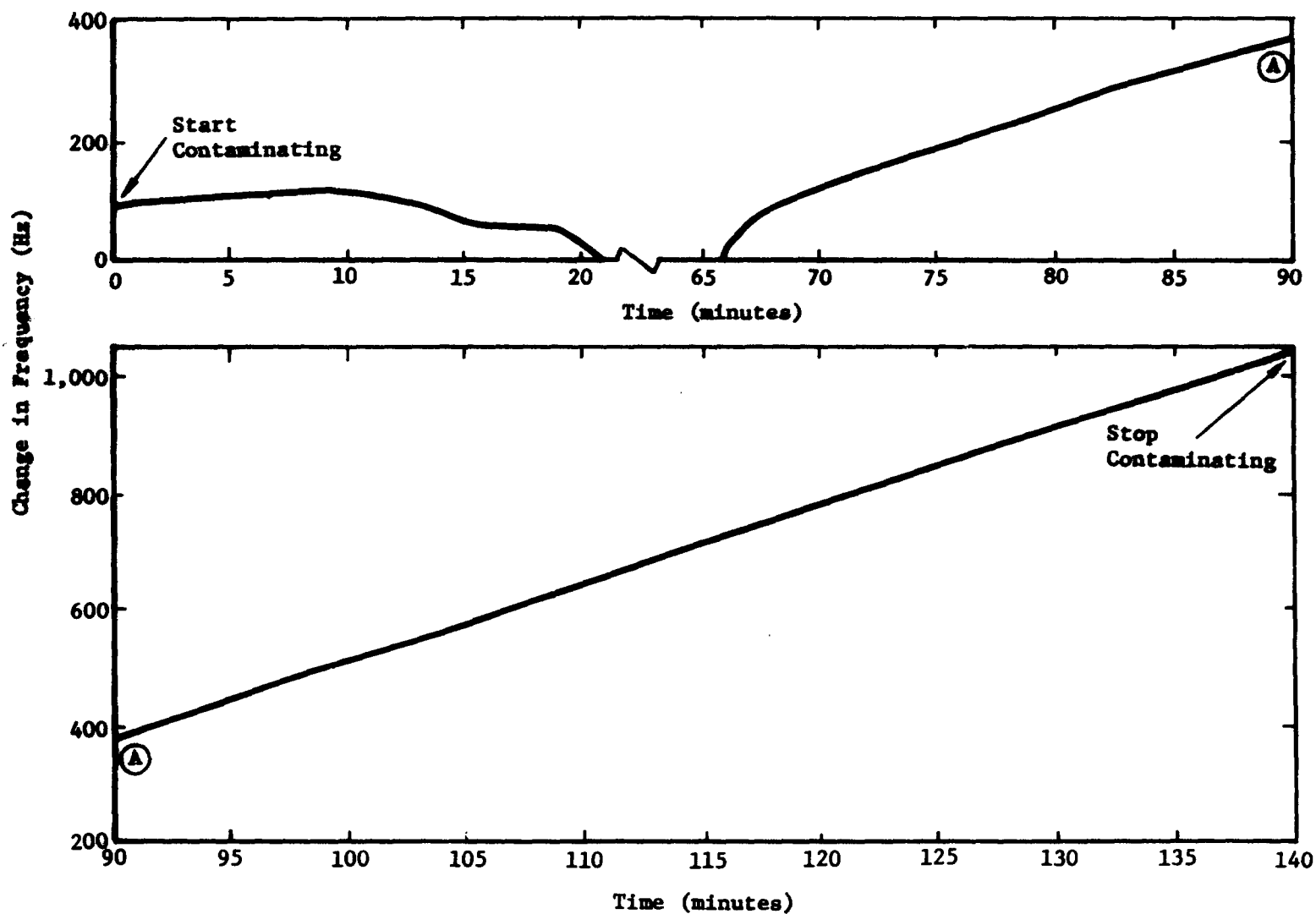


Figure 2 : TIME RATE OF CHANGE OF FREQUENCY FOR QCM DURING BUTADIENE DEPOSITION

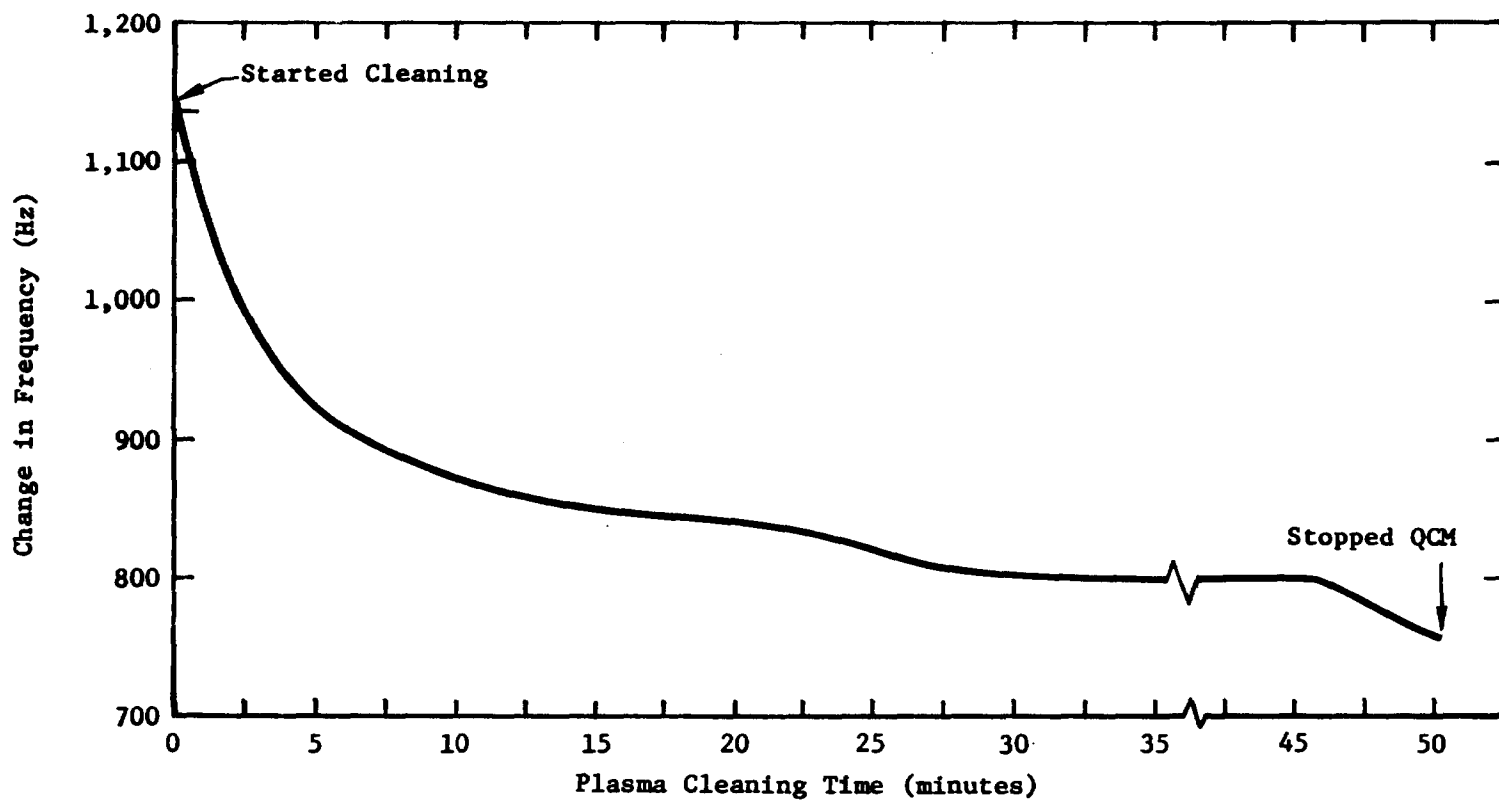


Figure 3 : TIME RATE OF CHANGE OF FREQUENCY FOR QCM DURING O_2 PLASMA CLEANING OF BUTADIENE CONTAMINANT FILM

Reference 8, for description of facilities):

<u>Facility</u>	<u>Type of Sample</u>
1. Ultraviolet Reflectometer	Mirrors
2. Vacuum Solar Reflectometer* or Gier-Dunkle Integrating Sphere Reflectometer**	Thermal Control Surfaces
3. Grating Efficiency Measurement Apparatus	Gratings

Contaminant Film Deposition:

The test specimen, quartz crystal (QCM), and interferometer reference mirror (IFM) are mounted on the sample plate (see Figure 4). The thin mask (Figure 4) is positioned over the IFM so that only a portion of it will be coated. The sample holding plate is then installed in the test chamber and oriented perpendicular to the UV lamp. The chamber and contaminant flow lines are then evacuated to about 5×10^{-2} torr. If "in-situ" tests of thermal control surfaces are being performed, the vacuum-transfer-assembly airlock would be opened at this point, to allow insertion of the sample into the chamber. The contaminant gas is then bled into the chamber until the pressure reaches about 1 torr. The contaminant flow is shut off, and the mechanical pump is allowed to evacuate the chamber again to about 5×10^{-2} torr. This is done to flush out any remaining gases in the chamber. The valve between the mechanical pump and chamber is then closed, and the contaminant gas is bled in until chamber pressure is 4 torr. The UV lamp is then turned on and deposition begins. During the contaminant deposition period, the valve to the residual gas analyzer system (Figure 4, Ref. 8) is opened to allow a mass spectrometer scan to be made. After the desired contaminant film thickness is obtained, the UV lamp is turned off.

* If "in situ" data is to be taken, samples are first measured in the Gier-Dunkle Reflectometer to obtain "in air" data. Samples are then mounted on a vacuum transfer apparatus before inserting in the vacuum solar reflectometer.

** The Gier-Dunkle Integrating Sphere Reflectometer consists of a modified Beckman DK-2A monochromator and a Gier-Dunkle Integrating Sphere attachment. This reflectometer is used to provide absolute reflectance data in the 0.25 - 2.5 micron wavelength region with an advertised accuracy of $\pm 0.5\%$.

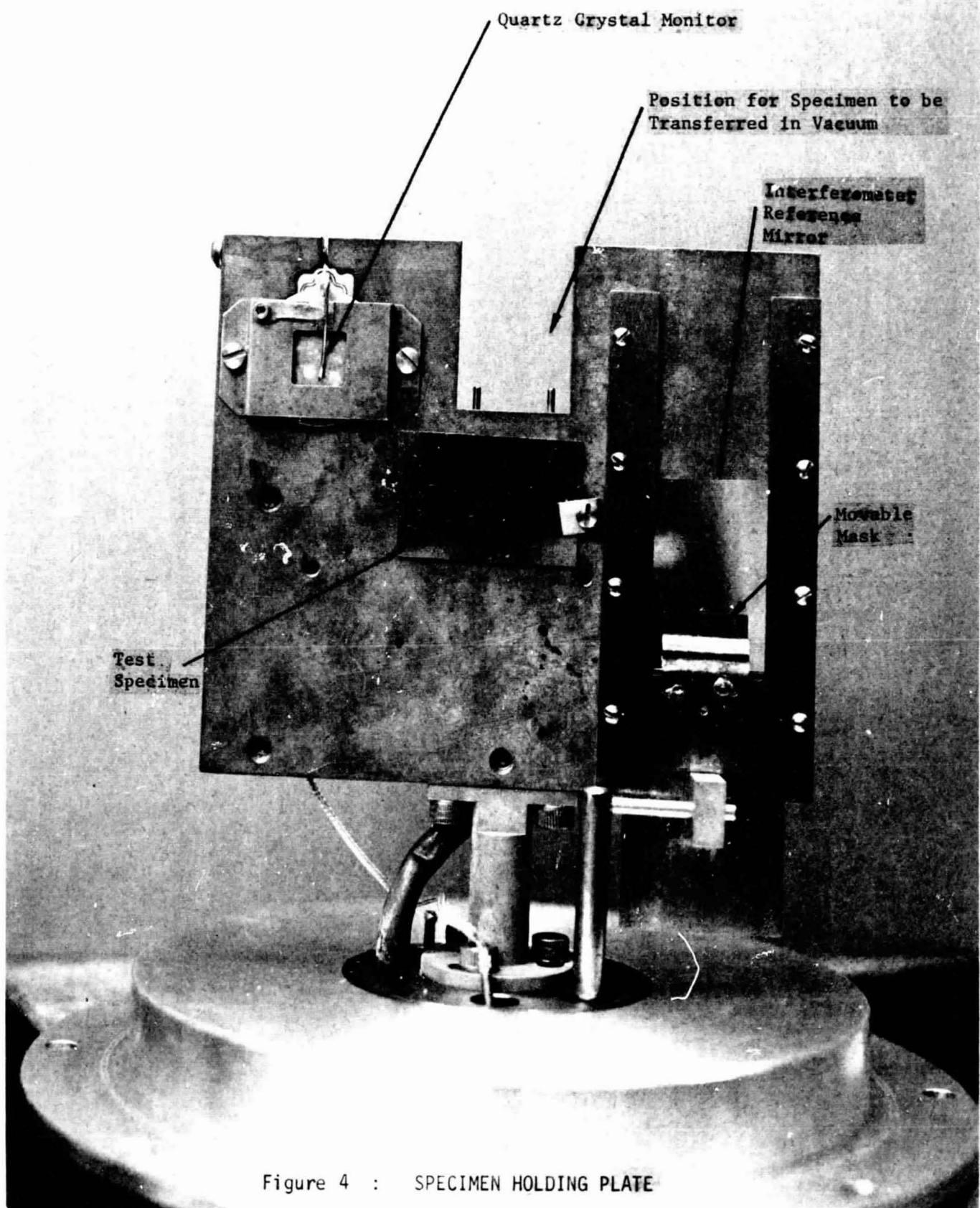


Figure 4 : SPECIMEN HOLDING PLATE

Following contaminant deposition, the chamber pressure is reduced to about 5×10^{-2} torr. In the case of "in situ" tests of thermal control surfaces, the sample is withdrawn by the vacuum transfer assembly and closed off from the chamber. For all other measurements the chamber is cycled two or three times between atmospheric pressure and 5×10^{-2} torr to flush out the contaminant gas. The sample plate and specimens are then removed and measurements are made in the appropriate facility. The IFM mask is moved to cover a portion of the contaminated surface.

Oxygen Plasma Cleaning:

After re-installing the specimen holding plate, the chamber and oxygen plasma generation system is evacuated to about 10^{-5} torr. Oxygen flow is then initiated in the quartz tubes such that a pressure of about 4 torr is established in the manifold upstream of the tubes, and about 3×10^{-3} torr in the chamber. The RF power is turned on and impedance electronics are tuned until the plasma ignites. A power level of about 20 watts per tube is presently being used.

Plasma cleaning is continued until the QCM indicates the desired thickness has been removed. The RF power is shut off, the oxygen flow is stopped, and the chamber pressure is reduced to the 10^{-5} torr range. Again, if "in situ" tests are being made, the sample is removed via the vacuum transfer assembly. Otherwise, the chamber is let up to atmosphere, and the specimen holding plate removed as before. Appropriate optical measurements are then performed on the test specimen.

4.3.2 Experimental Results - A summary of contamination and plasma cleaning experiments conducted thus far is given in Table I.

Specimen Type	Specimen No.	OCM No.	IFM No.	Contamination Data				Plasma Cleaning Data				Comments	
				Type	Time (min)	Pressure (torr)	Radiation	Film Thickness (Å)	Chamber Pressure (torr)	Manifold Pressure (torr)	Exposure Time (min)		Film Thickness (Å)
UV Mirror	MgF-1			styrene	216	1×10^{-4} to 2×10^{-3}	UV + Protons*	—	—	—	—	—	Coating was very non-uniform and unsatisfactory
UV Mirror	MgF-2			styrene	27	$\sim 10^{-3}$	UV + Protons	—	—	—	—	—	Coating was very non-uniform and unsatisfactory
UV Mirror	MgF-3			methane	31	5×10^{-3}	UV + Protons	—	2×10^{-3} to 3.5	~ 4	4	—	Specimen destroyed by failure of plasma generator tube
UV Mirror	MgF-33			none	—	—	—	—	$\sim 2 \times 10^{-3}$	4	15	—	No degradation observed
				methane	30	5×10^{-3}	UV + Protons	—	—	—	—	—	Small degradation produced
				methane	82	5×10^{-3} to 1×10^{-2}	UV + Protons	—	$\sim 2 \times 10^{-3}$	4	3	—	More degradation produced, all removed with plasma
UV Mirror	MgF-5A			methane	141	4.2	UV	—	—	—	—	—	
				methane	61	$< 1 \times 10^{-3}$	UV + Protons	n.m.**	—	—	—	—	—
UV Mirror	MgF-5B			styrene	160	2.5 to 9.5	UV	n.m.	—	—	—	—	Contaminant film too rough to measure with interferometer
UV Mirror	MgF-6A			butadiene	60	8×10^{-5}	UV + Protons	n.m.	—	—	—	—	Thin contaminant film produced, no cleaning attempted
UV Mirror	MgF-6B			butadiene	65	1.5 to 2.5×10^{-2}	UV	—	—	—	—	—	
				butadiene	975	1 to 4	UV	5640	—	—	—	—	—
UV Mirror	MgF-7A			butadiene	120	4	UV	n.m.	—	—	—	—	
UV Mirror	MgF-7B			butadiene	240	4	UV	126	—	—	—	—	
UV Mirror	MgF-8A			butadiene	480	4	UV	242	—	—	—	—	
Thermal Surface (silvered FEP Teflon)	FEP-1			butadiene	660	4-760	UV	—	—	—	—	—	Test abandoned because pressure rose to atmospheric
Thermal Surface	FEP-2		MgF-9	butadiene	1060	4	UV	6100	$\sim 2 \times 10^{-3}$	4	65	2060	Measured reflectance in vacuum
									$\sim 2 \times 10^{-3}$	3.5	64	0	Measured reflectance in vacuum
Thermal Surface	FEP-3		MgF-10	butadiene	939	4	UV	()***	—	—	—	—	No contaminant deposited on specimen because of cooling problem
	FEP-3		MgF-8B	butadiene	964	4	UV	()	$\sim 2 \times 10^{-3}$	4	30	()	Contaminant film deposited and cleaned successfully
UV Mirror	MgF-35		MgF-10	butadiene	939	4	UV	()	$\sim 2 \times 10^{-3}$	4	42	()	Contaminant film deposited and cleaned successfully
UV Mirror	MgF-43	MgF-86	MgF-11	butadiene	833	4	None	—	—	—	—	—	No contamination deposited without radiation
	MgF-43	MgF-86	MgF-11	butadiene	142	4	UV	()	$\sim 2 \times 10^{-3}$	4	112	()	Contaminant film deposited and partially removed
UV Mirror	MgF-36		MgF-12	butadiene	951	4 to 7	UV	()	—	—	—	—	Evaluation of cleanability of film irradiated with larger UV dose. Cleaned easily.
	MgF-36			none	494	2×10^{-5}	UV	()	$\sim 3 \times 10^{-3}$	4	5	()	
UV Mirror (gold coated glass)	Au-1	Au-42	Au-11	butadiene	98	4	UV	()	$\sim 3 \times 10^{-3}$	4	15	()	Contaminant film deposited and cleaned successfully
UV Mirror (platinum coated glass)	Pt-11	Pt-21	Pt-1	butadiene	38	4	UV	()	$\sim 3 \times 10^{-3}$	4	16	()	Negligible contamination, and negligible effects of plasma cleaning in UV wavelengths. Specimen visibly darkened during cleaning.

*** data still being processed

** not measurable

* 10 keV energy, about 6×10^{11} protons/cm² sec

Δ residual film thickness

Table I - Test Summary

Data are listed chronologically by the specimen type and code number. Numerous exploratory contamination experiments were conducted on portions of MgF_2 overcoated IFM's. The majority of these mirrors were not plasma cleaned, although their reflectance in the 250 to 2500 nm wavelength region was measured before and after contamination. Following the contamination experiments, plasma cleaning experiments were conducted on both $1/2\lambda$ and $3/4\lambda$ MgF_2 overcoated mirrors, gold and platinum coated mirrors, and a silvered-Teflon thermal control surface. Experiments were also conducted on MgF_2 overcoated mirrors to determine whether: (1) a higher dose of UV radiation would affect cleanability; and (2) the effects of the oxygen plasma on an uncontaminated surface. It will be noted in the table that, in addition to the test specimen code number, the numbers of the QCM and IFM included in the same run are recorded in adjacent columns. Other data are recorded as either contamination test conditions or plasma test conditions.

Results of the methane contamination experiment on a $3/4\lambda$ MgF_2 overcoated mirror (No. MgF-33) are shown in Figure 5. Specular reflectance data for different exposure conditions are plotted vs. wavelength over the region from 90 to 290 nanometers. This specimen was exposed for 15 minutes in the oxygen plasma produced by one quartz tube. No significant change in reflectance occurred during the plasma exposure. This indicates that mirrors of this type will not be damaged by exposure to the plasma following removal of a contaminant film (over-cleaning). A contaminant film was then deposited on the mirror by irradiating it with protons and UV radiation for 82 minutes in the presence of methane at 5×10^{-3} to 1×10^{-2} torr. The contaminant film produced reflectance changes that were consistent with those observed in earlier experiments (Refs. 5 and 9), i.e., large degradation in the regions of interference

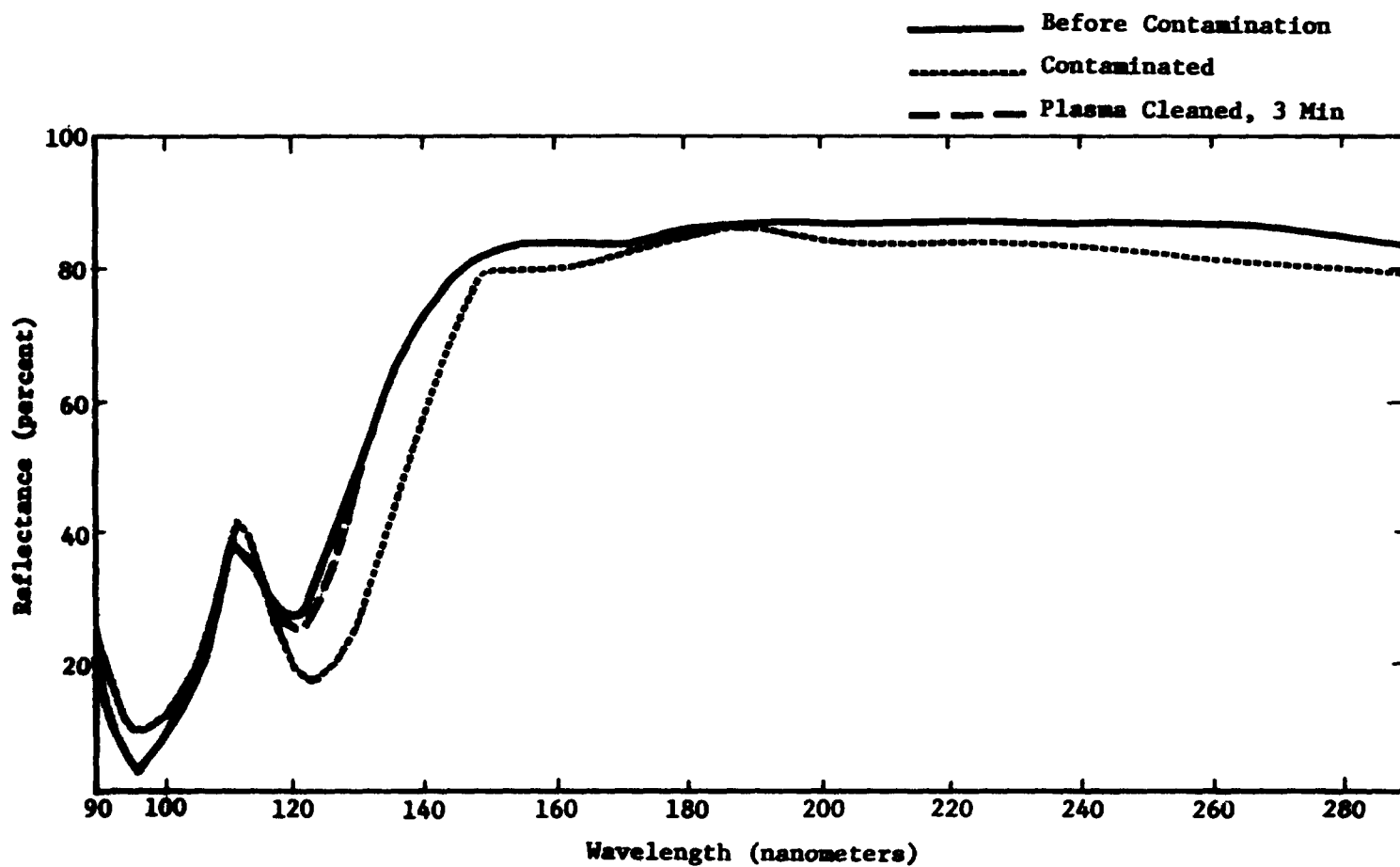


Figure 5 : EFFECT OF METHANE CONTAMINATION AND PLASMA CLEANING ON REFLECTANCE OF $3/4 \lambda$ MgF_2/Al -COATED MIRROR (NO. MgF-33)

minima and either small degradation or increases in reflectance at interference maxima positions. Exposing the mirror to the oxygen plasma for 3 minutes restored the reflectance to its initial value, presumably because the contaminant film was removed.

The next $3/4\lambda$ MgF_2 overcoated mirror (No. MgF-35) was contaminated with a thick film deposited from butadiene monomer in the presence of UV radiation. It was irradiated for 939 minutes at a pressure of 4 torr. Reflectance data are shown in Figure 6. The film was sufficiently absorbing to eliminate MgF_2 /contaminant-film interference phenomena, as evidenced by the uniform-low (~ 5 percent) reflectance in the region from 95 to 210 nm. Reflectance data are shown for plasma exposure times of 5, 10, 25 and 42 minutes. A progressive increase in reflectance occurred as plasma exposure time increased. After 42 minutes the reflectance was within about 2 percent of its original value at all wavelengths.

The third $3/4\lambda$ MgF_2 mirror (No. MgF-36) was exposed to additional UV radiation after a butadiene contaminant film had been deposited. This was done to evaluate whether the additional radiation effects (crosslinking, etc.) on the contaminant would affect the cleanability. Results of this test are shown in Figure 7. The contaminant was deposited in 951 minutes, and an additional 494 minutes of UV irradiation was provided thereafter. Results of the test showed that a 5 minute plasma exposure was sufficient to restore the reflectance to within a few percent of original values at all wavelengths. Comparison of oxidation or cleaning rate data for specimen Nos. MgF-35 and 36 cannot be made yet because film thicknesses have not been measured on IFM's.

Results of a contamination/cleaning test on a $\lambda/2\text{MgF}_2$ overcoated mirror (No. MgF-43) are shown in Figure 8. This mirror was first exposed to

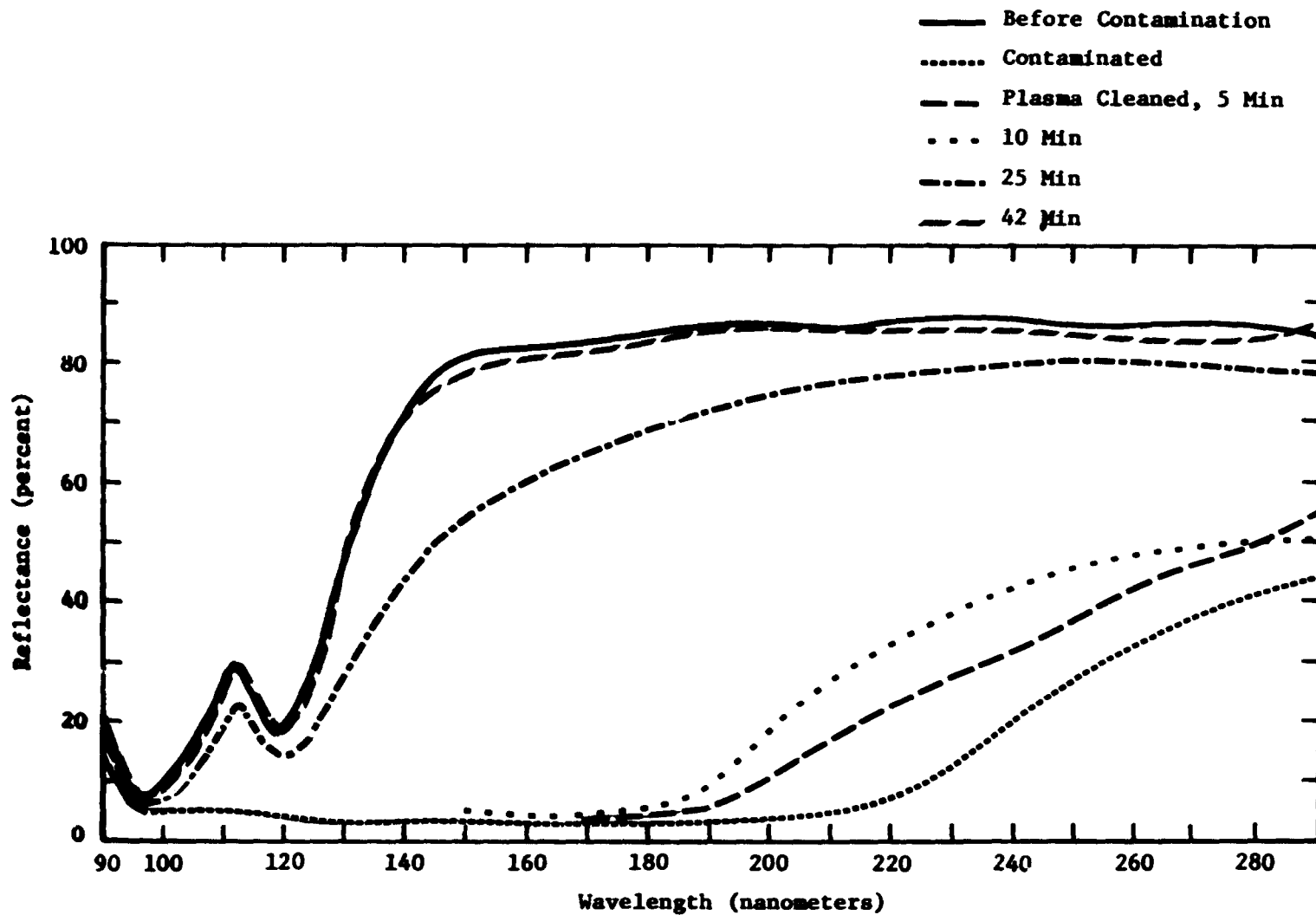


Figure 6 : EFFECT OF BUTADIENE CONTAMINATION AND PLASMA CLEANING ON REFLECTANCE OF MgF_2/Al -COATED MIRROR (NO. MgF-35)

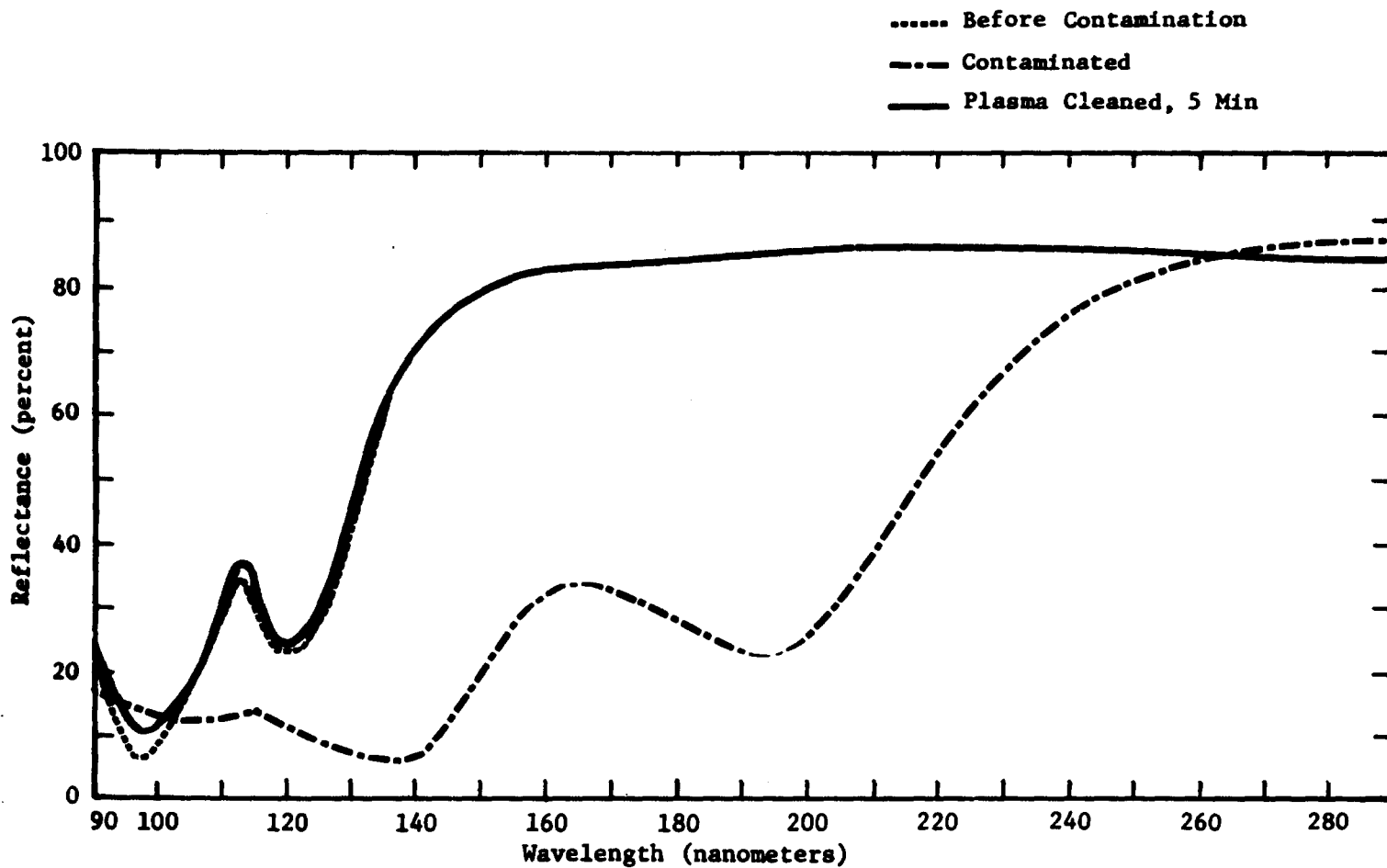


Figure 7 : EFFECT OF BUTADIENE CONTAMINATION AND PLASMA CLEANING ON REFLECTANCE OF $3/4 \lambda$ MgF_2/Al -COATED MIRROR (NO. MgF-36)

butadiene at a pressure of 4 torr for 833 minutes, without UV radiation. No degradation in reflectance occurred during this exposure, thus indicating that the contaminant will not deposit without radiation. Based on this test, no attempt will be made to deposit a hydrocarbon contaminant on other specimens without radiation. The same mirror was then contaminated during an exposure of 142 minutes using UV radiation and butadiene. Reflectance was reduced to 5 to 7 percent in the wavelength region shorter than 200 nm. After a 112 minute oxygen plasma exposure, the reflectance was completely restored in the wavelength region below 115 nm. At longer wavelengths, however, as much as 10 percent degradation remained. It is believed that the residual degradation could be eliminated by additional plasma exposure.

Results of a contamination/cleaning experiment on a gold coated specimen (No. Au-1) are shown in Figure 9. The mirror was exposed to butadiene for 98 minutes at a pressure of 4 torr in the presence of UV radiation. A substantial decrease in reflectance occurred as can be noted in the figure. Oxygen plasma exposure for 15 minutes resulted in a complete restoration of reflectance in the wavelength region from 100 to 230 nm, although some degradation remained at longer wavelengths.

Contamination/cleaning data for a platinum-coated mirror are shown in Figure 10. This mirror was only exposed to the contaminant gas for 38 minutes and thus showed much less degradation than the gold-coated mirror. Oxygen plasma exposure induced an increase in reflectance in the wavelength region from about 110 nm to 250 nm. Visual observations on this specimen indicated a slight discoloration after plasma treatment which was not visible after contamination. Additional experiments will

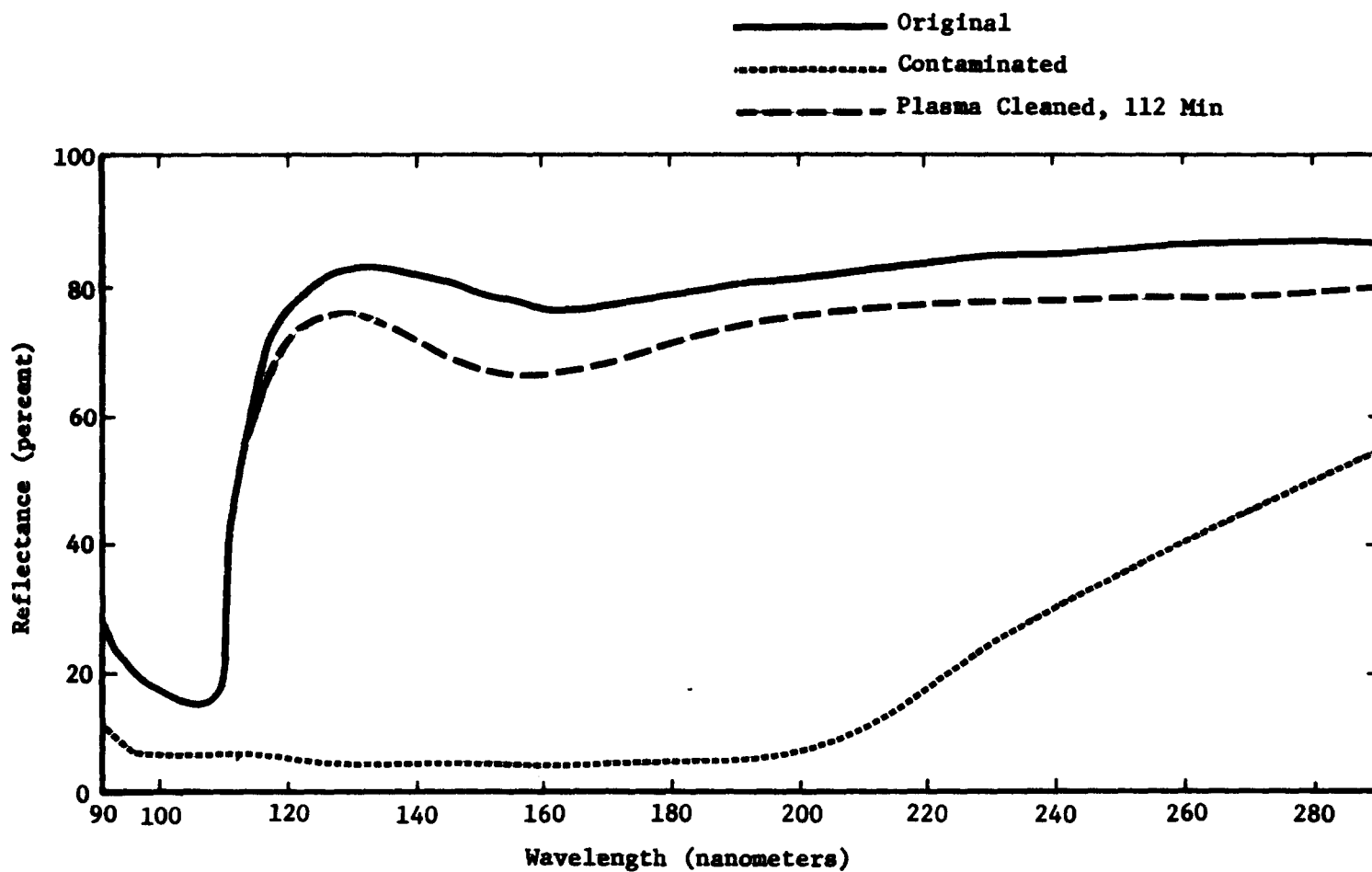


Figure 8 : EFFECT OF BUTADIENE CONTAMINATION AND PLASMA CLEANING ON REFLECTANCE OF $1/2 \lambda$ MgF_2/Al -COATED MIRROR (NO. MgF-43)

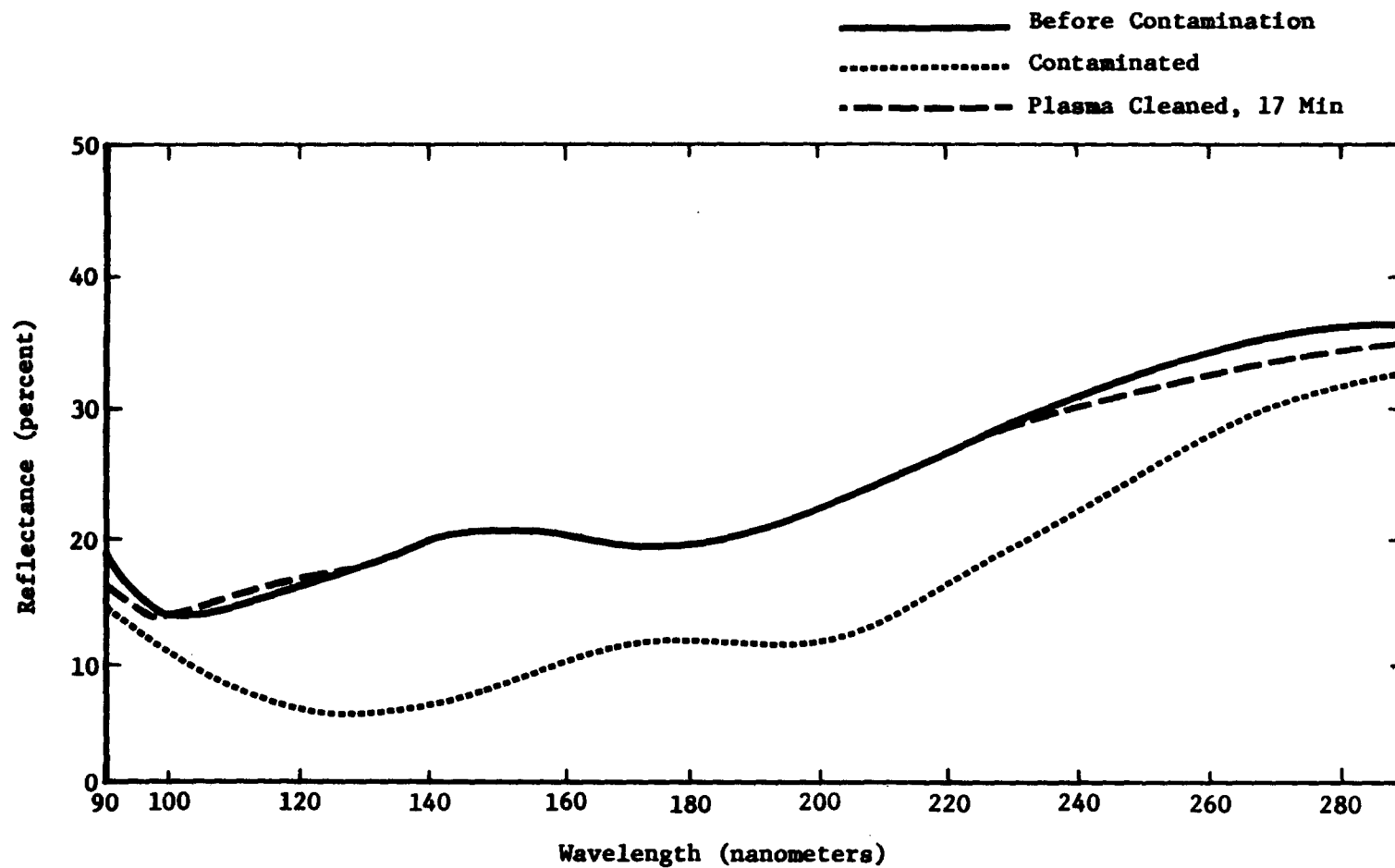


Figure 9 : EFFECT OF BUTADIENE CONTAMINATION AND PLASMA CLEANING ON REFLECTANCE OF GOLD-COATED MIRROR (NO. AU-1)

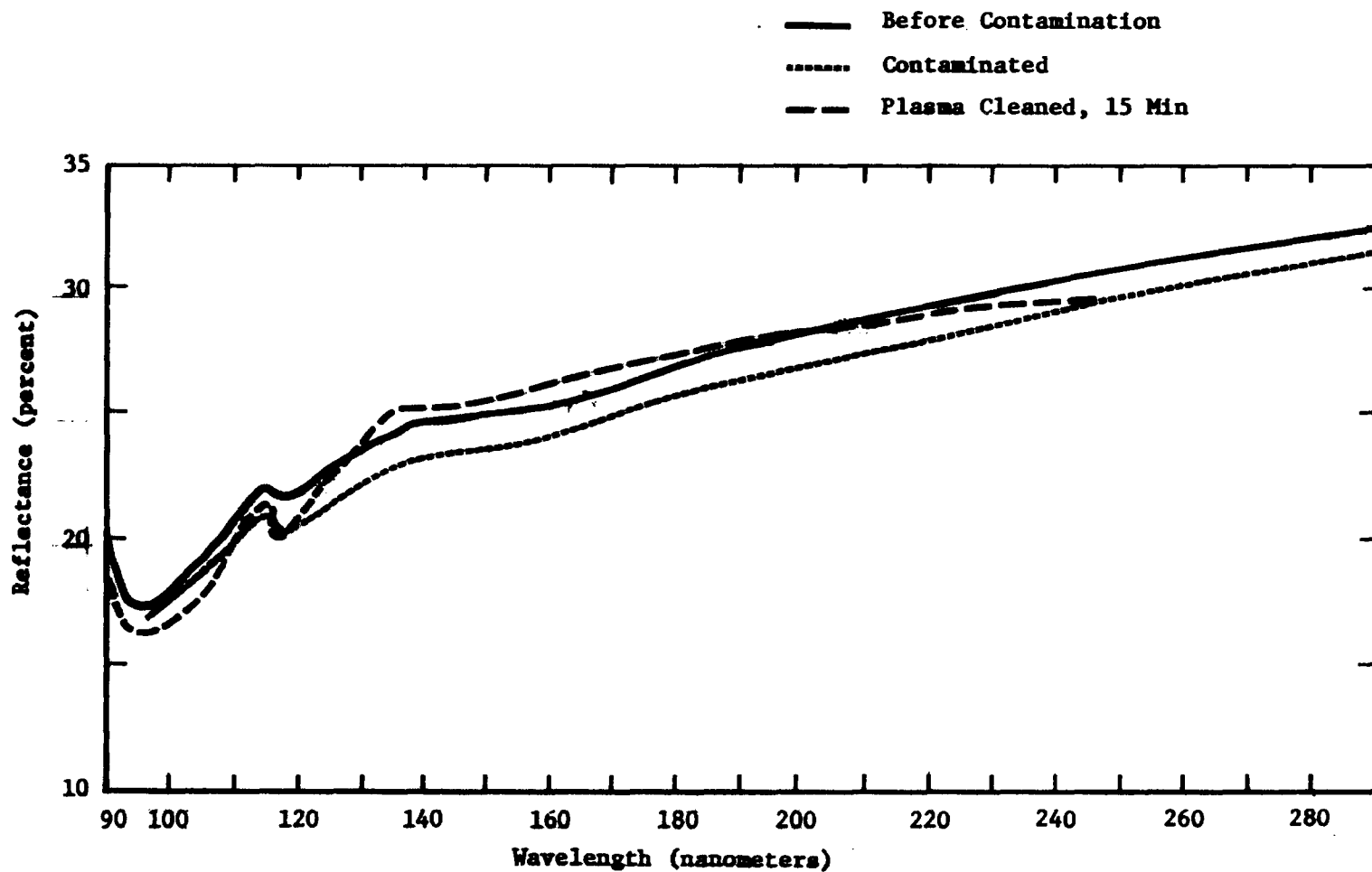


Figure 10: EFFECT OF BUTADIENE CONTAMINATION AND PLASMA CLEANING ON REFLECTANCE OF PLATINUM-COATED MIRROR (NO. Pt-11)

be conducted on platinum mirrors using thicker contaminant films and reflectance measurements at longer wavelengths.

Three, silvered-Teflon specimens were tested for the primary purpose of: (1) determining whether reflectance data will be effected by an air exposure between contamination and cleaning experiments; and (2) whether an intermediate air exposure affects cleanability. In the case of No. FEP-1, the chamber pressure increased to ambient during contamination and thus invalidated the test. Results on Specimen No. FEP-2 were in doubt because of a failure of the vacuum reflectometer. IFM data from the latter test showed that a contaminant film thickness of about 6100 Angstroms was deposited initially, about 4000 Angstroms were removed in the first 65 minute plasma exposure, and that about 2100 Angstroms were removed in the second 64 minute exposure.

The third silvered-Teflon specimen (No. FEP-3) was contaminated for about 964 minutes and plasma cleaned for 30 minutes. Reflectance data (Figure 11), measured in air, indicate that the contaminant was successfully removed and that the oxygen plasma did not degrade the Teflon film.

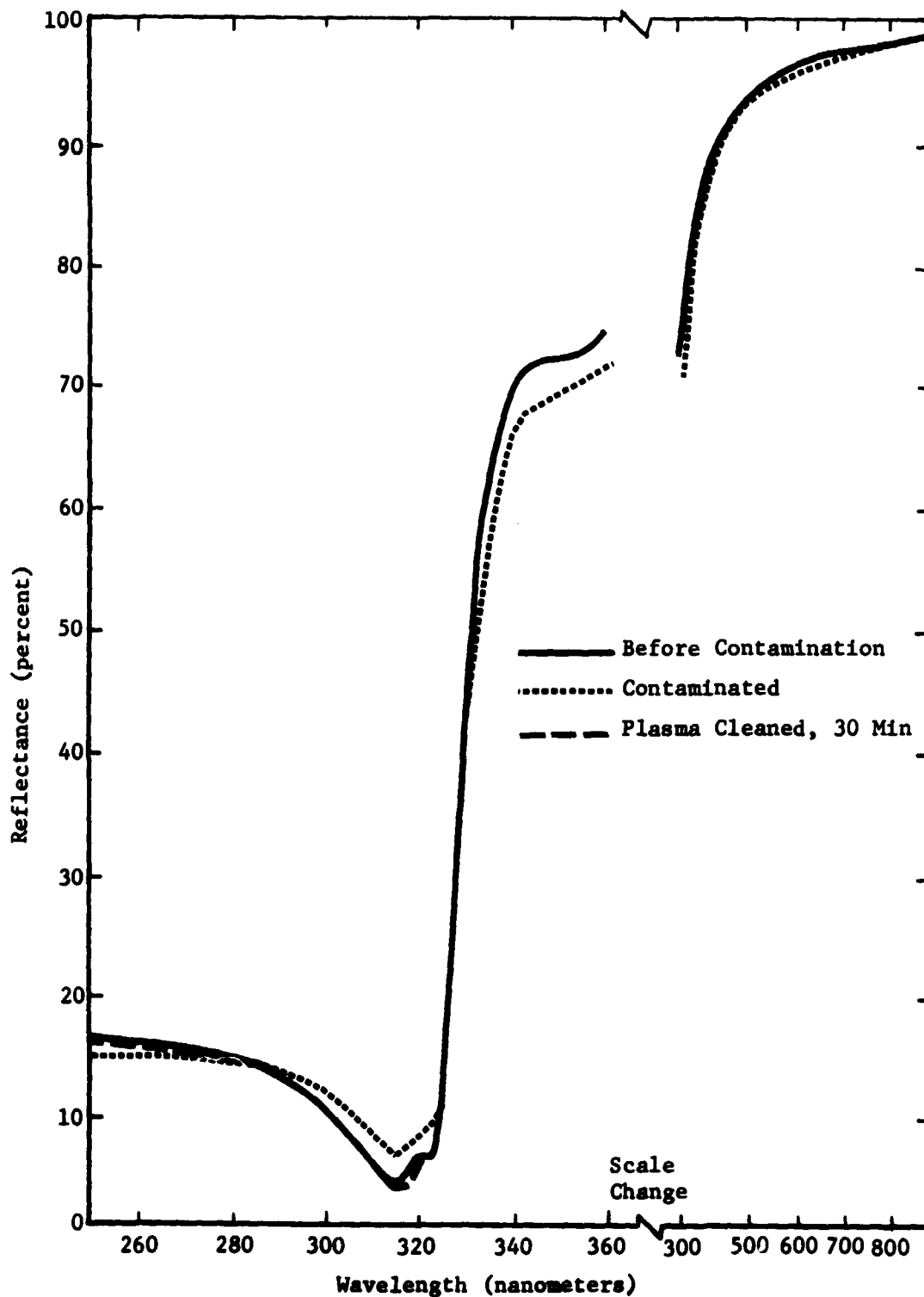


Figure 11 : EFFECT OF BUTADIENE CONTAMINATION AND PLASMA CLEANING ON REFLECTANCE OF SILVER-COATED FEP TEFLON SURFACE (NO. FEP-3)

5.0 PROGRAM PROGRESS

5.1 Schedule

A schedule for the overall program is shown in Figure 12. Solid bars represent work completed, and open bars represent work planned. As of this reporting date all test specimens have been prepared, facility preparation is complete, exploratory experiments are nearly complete, and work has begun on comprehensive testing. The nearly two-month delay in starting tests was the result of unanticipated difficulties in operating the plasma generator, depositing contaminant films, and in moving facilities. The effort expended to improve the design of the plasma generator, although delaying the present program, will be of benefit to follow-on hardware development programs.

It appears at present that a 14-month time period will be required to complete the program.

5.2 Expenditures

Cumulative expenditures as of August 1, 1971, were about \$19,869. Approximately \$24,704 will be required to complete the program, including fee. No cost overrun is anticipated.

5.3 Future Work Planned

During the next reporting period the following items will be initiated or completed:

1. Exploratory experiments will be completed,
2. Comprehensive tests will be continued,
3. A study to define operational parameters of a flight unit will be initiated.

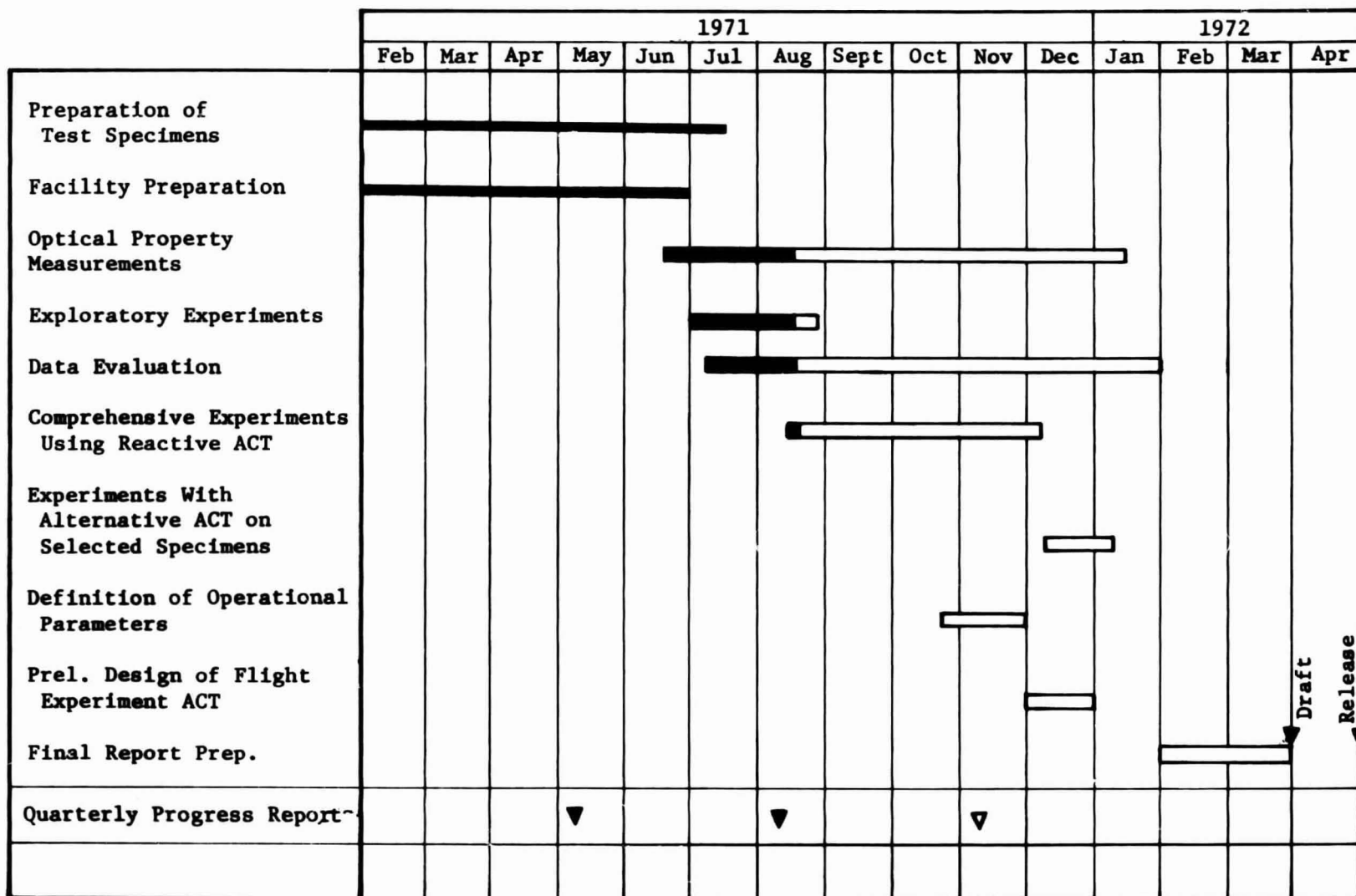


Figure 12 PROGRAM SCHEDULE

6.0 REFERENCES

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