N92-27097

VACUUM DEPOSITED OPTICAL COATINGS EXPERIMENT

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SUMMARY

The 138-4 Frecopa experiment consisted of 20 sorts of optical components and coatings subjected to space exposure. They covered a large range of use from UV to IR spectrum : filters, mirrors, dichroïcs, beam splitters and anti-reflection coatings made of several different materials as layers and substrates. By comparing pre and post flight spectral performances it was possible to put into evidence the alterations due to space exposure.

1 - INTRODUCTION

All layers were deposited by evaporation under vacuum. Five samples of each component or coating were manufactured. Two flight samples were mounted in the canister, one directly exposed to space, the other looking backwards. In a same arrangement 2 spare samples were stored on ground and kept under vacuum during the LDEF flight. Endly one set of reference samples was stored in a sealed canister under dry nitrogen atmosphere.

Description of the components was as follows :

- 3 UV filters
- 1 NIR cemented filter
- 5 metallic mirrors including 2 for specific UV use
- 5 dielectric mirrors including 2 for specific UV use
- 1 visible beam splitter
- 1 visible-IR dichroïc beam-splitter
- 1 IR dichroïc beam-splitter
- 3 antireflection coating including - 2 for IR use

The flight samples were located on the trailing edge.

2 - UV COMPONENTS

2.1 - BAND PASS FILTERS

The 3 double halfwave filters are respectively centered at 1216, 1270 and 2430 Å. The Al-M_gF_2 layers are deposited on M_gF_2 substrates for the 1216 and 1270 filters and quartz for the last one. The transmittance results are as follows (* = exposed) :

		M_gF_2				QUARTZ	
		1216		1270		2430	
		PRE	POST	PRE	POST	PRE	POST
MAX TRANSMIT. (%)	FLIGHT	12.2* 11.4	6* 7.9	12* 12.6	8.4* 8.4	22.1* 22.7	19.8* 20.8
	SPARE	10.6	9.3	11	9.4	22.1	20.9
	REFERENCE	11.3	8.8	8.5	7.4	22.8	21
RELATIVE TRANSMIT. LOSS (%)	FLIGHT		51* 31		30* 33		10* 8
	SPARE		12		14		5
	REFERENCE		22		13		8

See figures 1 ⇨ 6

2.2 - METALLIC MIRRORS

The 2 M_gF_2 protected Al mirrors are respectively deposited on B1664 glass and kanigened aluminium. In the following table the reflectance averages are calculated over 1200-2000 Å spectral range.

		GLASS		KANIGEN	
		PRE	POST	PRE	POST
REFLECTANCE AVERAGE (%)	FLIGHT	80.5* 80.3	67.7* 73.7	74.9* 76.9	57.9* 72.7
	SPARE	83.2	80.7	75.2	76.3
	REFERENCE	81.7	80	76.3	75.8
RELATIVE REFLECTANCE LOSS (%)	FLIGHT		16 8.2		23 6
	SPARE		3		-
	REFERENCE		2		1

See figures 7 ⇨ 10

2.3- DIELECTRIC MIRRORS

Two kinds of coatings were manufactured :

- MgO/MgF_2 mirror on B1664 glass substrate centered at 250 nm
- LaF_3/chiolite/M_gF_2 mirror on B1664 glass substrate centered at 170 nm. This last one did not survive because of highly stressed layers. All samples (flight spare and reference) failed with cracks and blisters.
  (hr measurements made)

M_gO / M_gF_2 MIRROR		PRE	POST
SPECTRAL WIDTH (R > 0.9) (%)	FLIGHT	11.2* 12	6.9* 9.6
	SPARE	11.1	10.9
	REFERENCE	12.2	10.9
RELATIVE WIDTH CHANGE (%)	FLIGHT		38* 20
	SPARE		2
	REFERENCE		10

See figures 11 ⇨ 12

3 - 820 nm BANDPASS FILTER

This double half-wave filter was made of ZnS-chiolite layers deposited on BK7G18 and RG780 cemented glasses.

		PRE	POST
CENTER nm	FLIGHT	820.5* 819.7	819.5 818.7
	SPARE	820.7	820.3
	REFERENCE	818.2	818.5
MAX TRANSMITTANCE (%)	FLIGHT	73.6 75.8	69.7 73.2
	SPARE	75.4	73.9
	REFERENCE	77.8	74.6
RELATIVE TRANSMITTANCE LOSS (%)	FLIGHT		5* 3
	SPARE		2
	REFERENCE		4

See figures 13 ⇨ 14

4 - VISIBLE + INFRARED METALLIC MIRRORS

Three types of coating were tested :

- gold mirror on B1664 glass
- Al_2O_3 protected Ag mirror on kanigened aluminium substrate
- ThF_4 protected Ag mirror on B1664 glass

In its useful spectral range (> 700 nm) the gold mirror does not show particular change due to space exposure.

Some results concerning the Ag mirrors follow :

		Al_2O_3 PROTECTED		ThF_4 PROTECTED	
		PRE	POST	PRE	POST
REFLECTANCE AVERAGE (%)	FLIGHT	96.1* 96.8	94.9* 95.7	97.6* 97.6	97.4* 97.6
	SPARE	96.6	95.8	97.5	97.6
	REFERENCE	96.7	96.3	97.3	97.6
RELATIVE REFLECTANCE LOSS (%)	FLIGHT		1.2 1.1		
	SPARE		0.8		
	REFERENCE		0.4		

The average is calculated over 400-1200 nm spectral range

See figures 15 ⇨ 18

5 - ANTIREFLECTION COATINGS

Three types of coating were tested :

- (450-1100nm) wide band AR coating on B1664 glass substrate using Al_2O_3-MgF_2 MERK11611 layers materials
- 15 microns AR coating on Germanium (single ZnS layer)
- (8-12) microns AR coating on Germanium using Ge-ZnS-ThF_4 LAYERS

There is no significant difference between pre and post flight optical performances for the two last coatings.

For the first one we obtained :

AR COATING/ B1664		PRE	POST
TRANSMITTANCE AVERAGE (%)	FLIGHT	98.3* 98.3	97.9* 98
	SPARE	98.3	98.3
	REFERENCE	98.3	98.3
RELATIVE TRANSMITTANCE LOSS (%)	FLIGHT		0.4* 0.3
	SPARE		0
	REFERENCE		0

The average is calculated over 400-1100 nm spectral range

See figures 19 ⇨ 20

6 - VISIBLE AND IR DIELECTRIC MIRRORS

Three types of coating were tested :

- Visible + 1060 nm mirror on B1664 glass with TiO_2-SiO_2 layers materials
- 1060 nm mirror in the same materials configuration as above
- 10.6 microns mirror on B1664 glass with Ge-ZnS-ThF_4 layers materials

The first one shows thin cracks in the coating for flight and spare samples but still remains optically efficient with reflectance comparable to the reference one.

For the second one flight and spare samples are degraded by peeling of the coating. These coatings are highly stressed and withstand with difficulty vacuum or thermal cycling.

The last case shows no significant change after space exposure

7 - BEAM-SPLITTERS

Three types of coating were tested :

- Visible beam-splitter (R=T) with TiO_2-ZrO_2-SiO_2 layers materials deposited on B1664 glass substrate
- Visible reflective/IR transmittive (8-12) microns dichroïc beam-splitter on ZnSe substrate and with ZnSe-ZnS-ThF_4 layers materials

In all cases any significant difference in spectral performances after the flight was not found

8 - CONCLUDING REMARKS

- UV filters and mirrors are usually space exposure-sensitive. Probably MgF_2 material is the main factor of weakness
- Components and coatings for visible and infrared applications have been little or not affected in their optical performances by space exposure
- Coatings including many high-stressed layers (oxides and fluorides) show an evident risk of mechanical degradation (vacuum cycling)

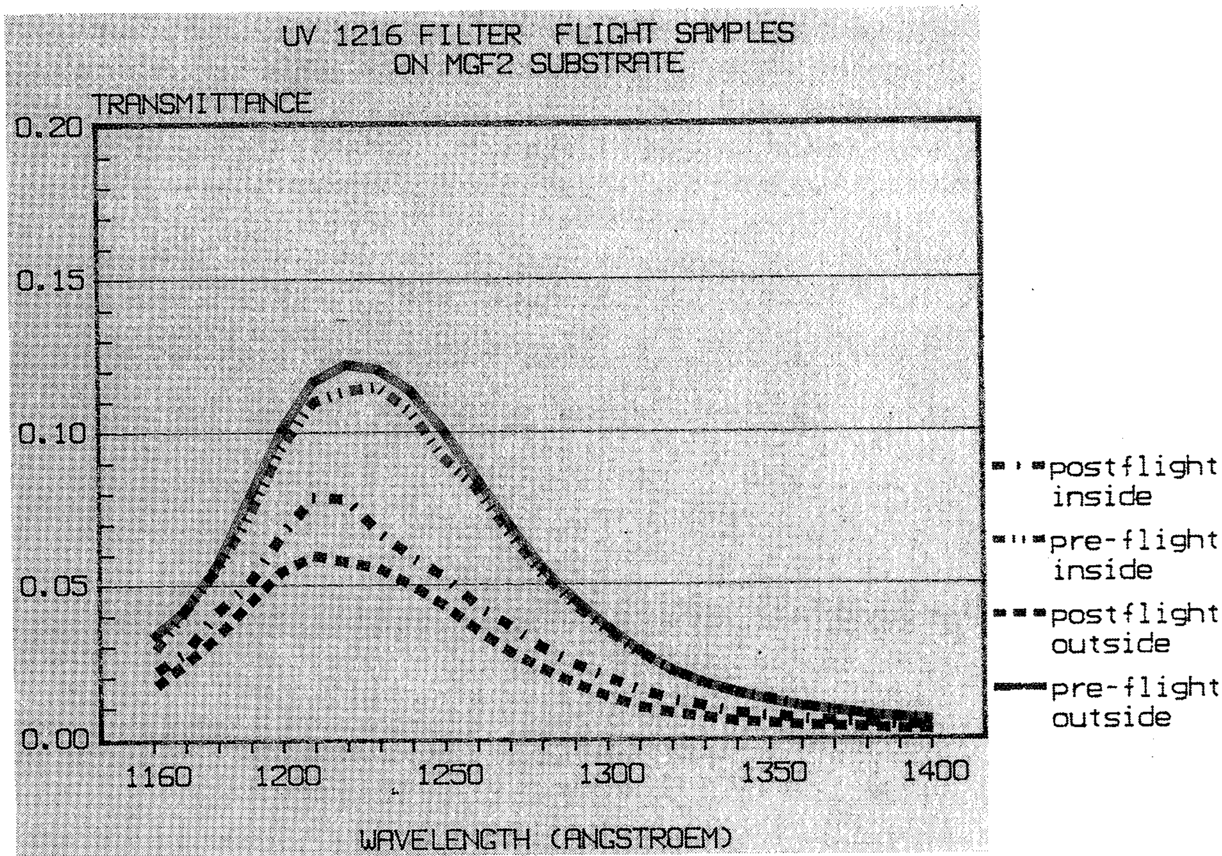


FIGURE 1

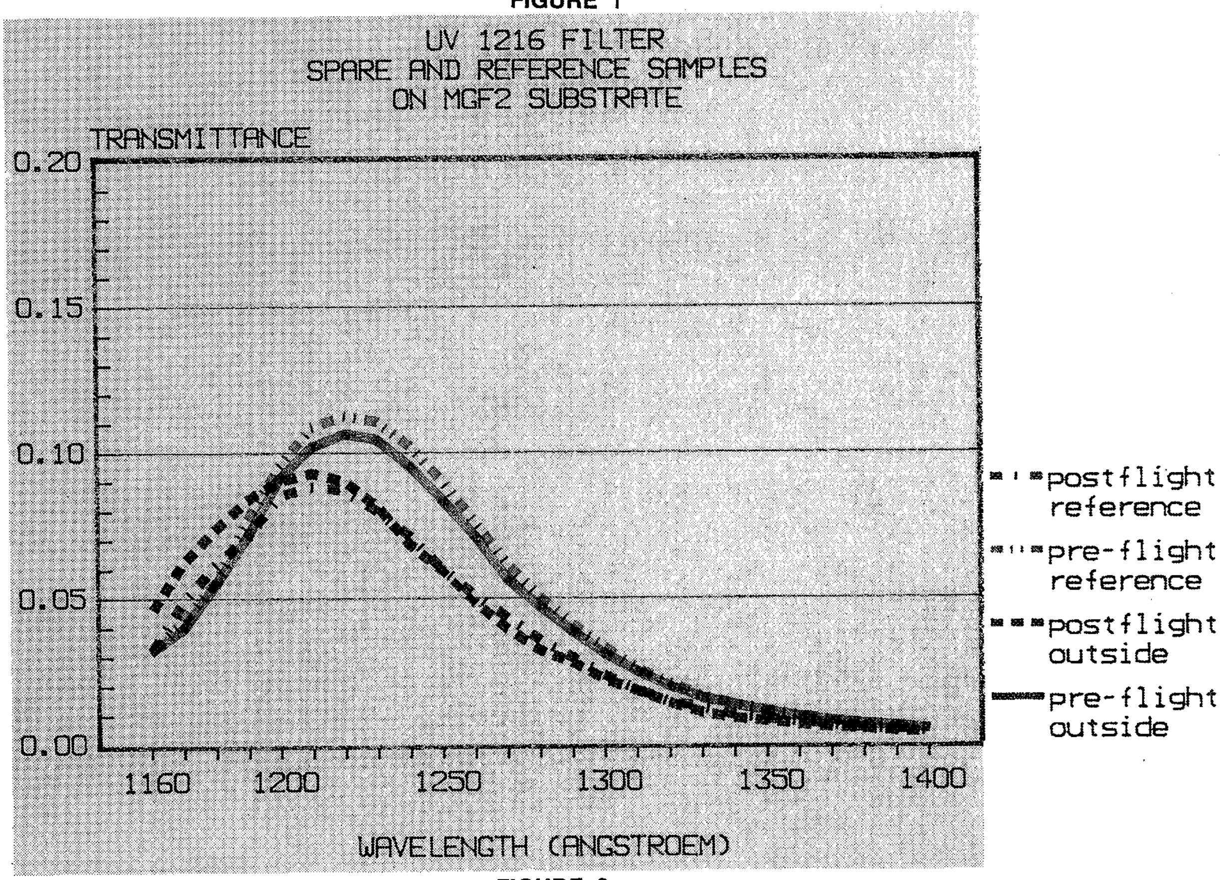
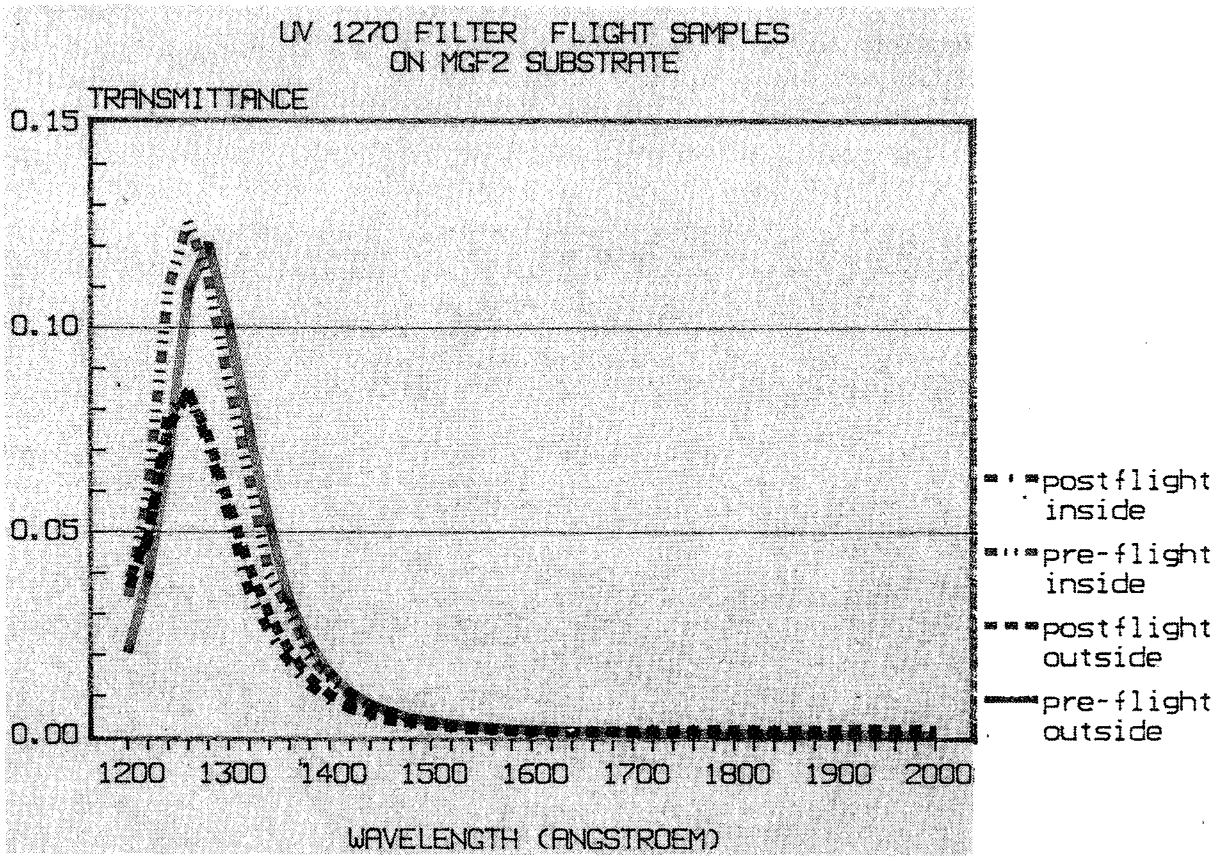


FIGURE 2



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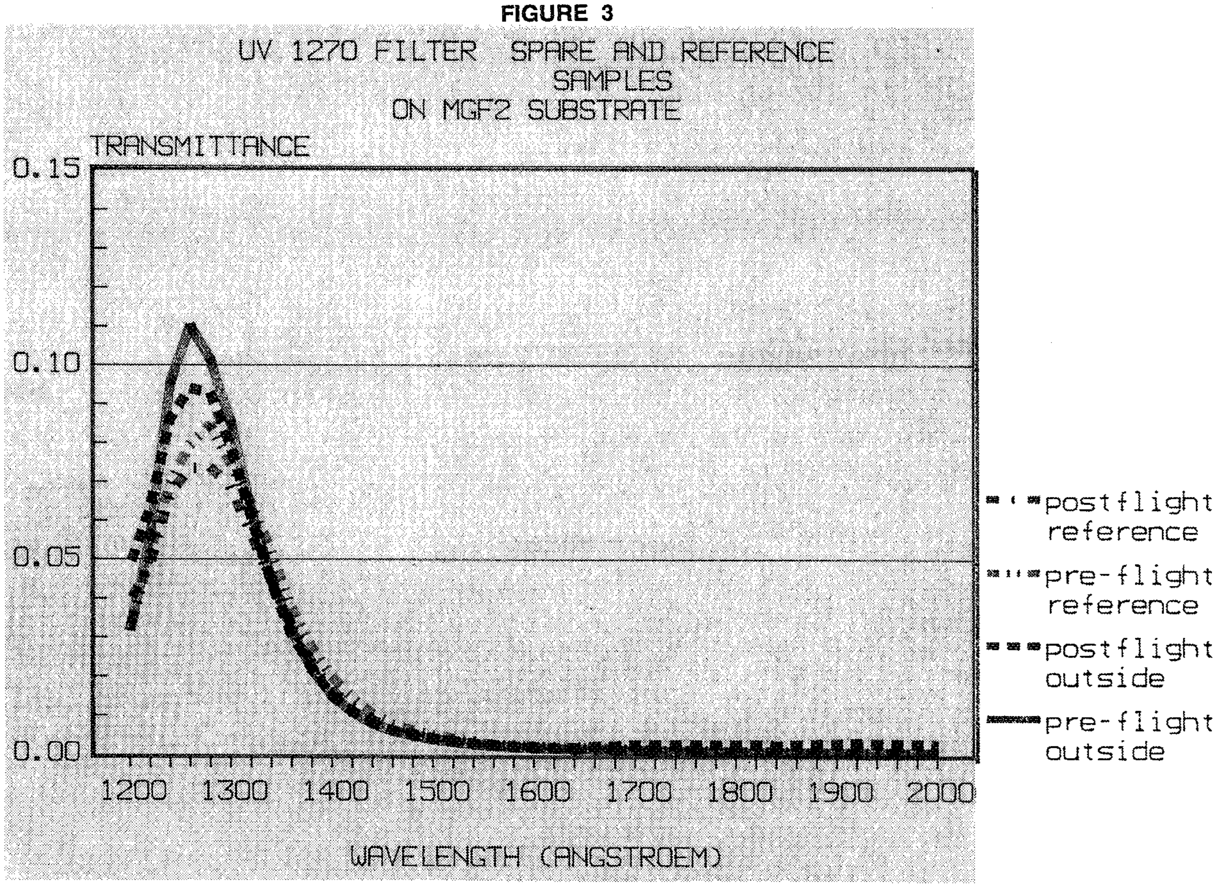

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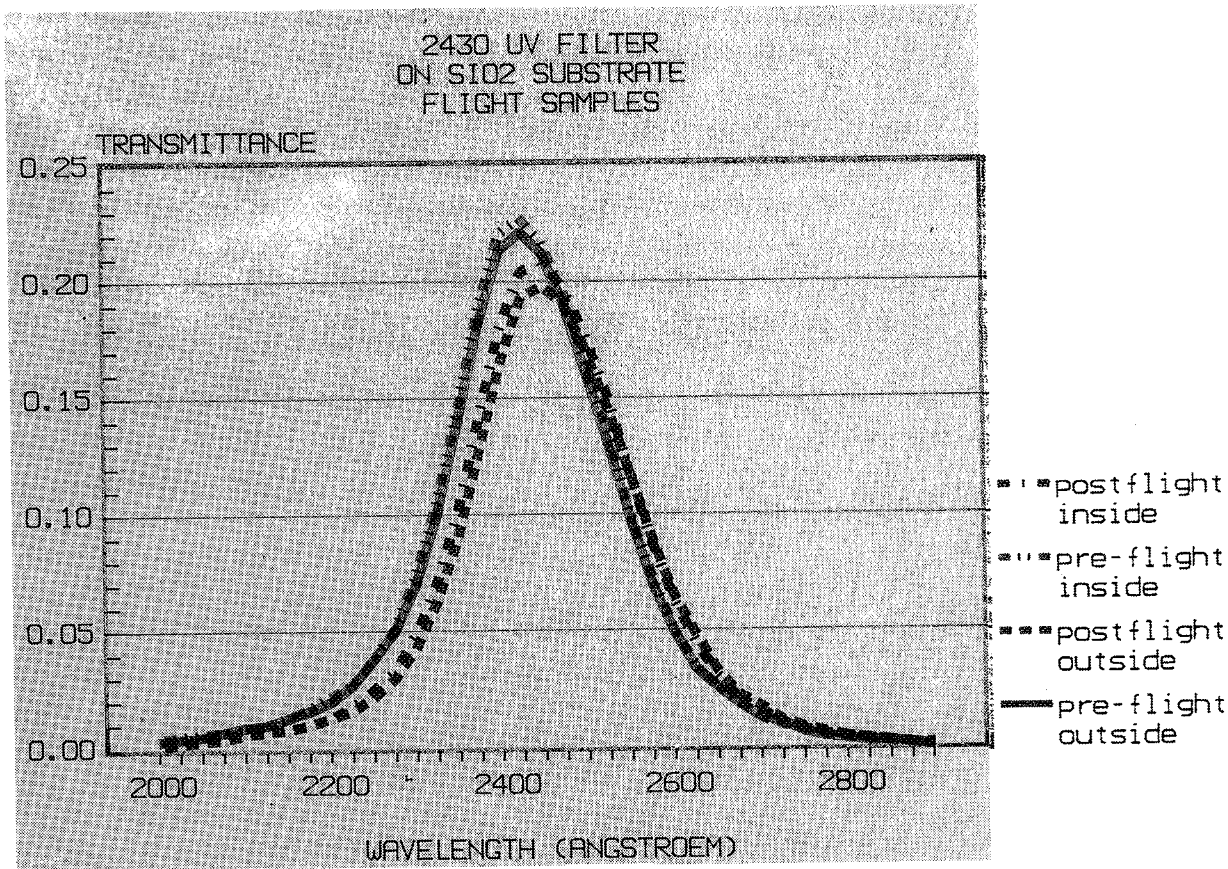

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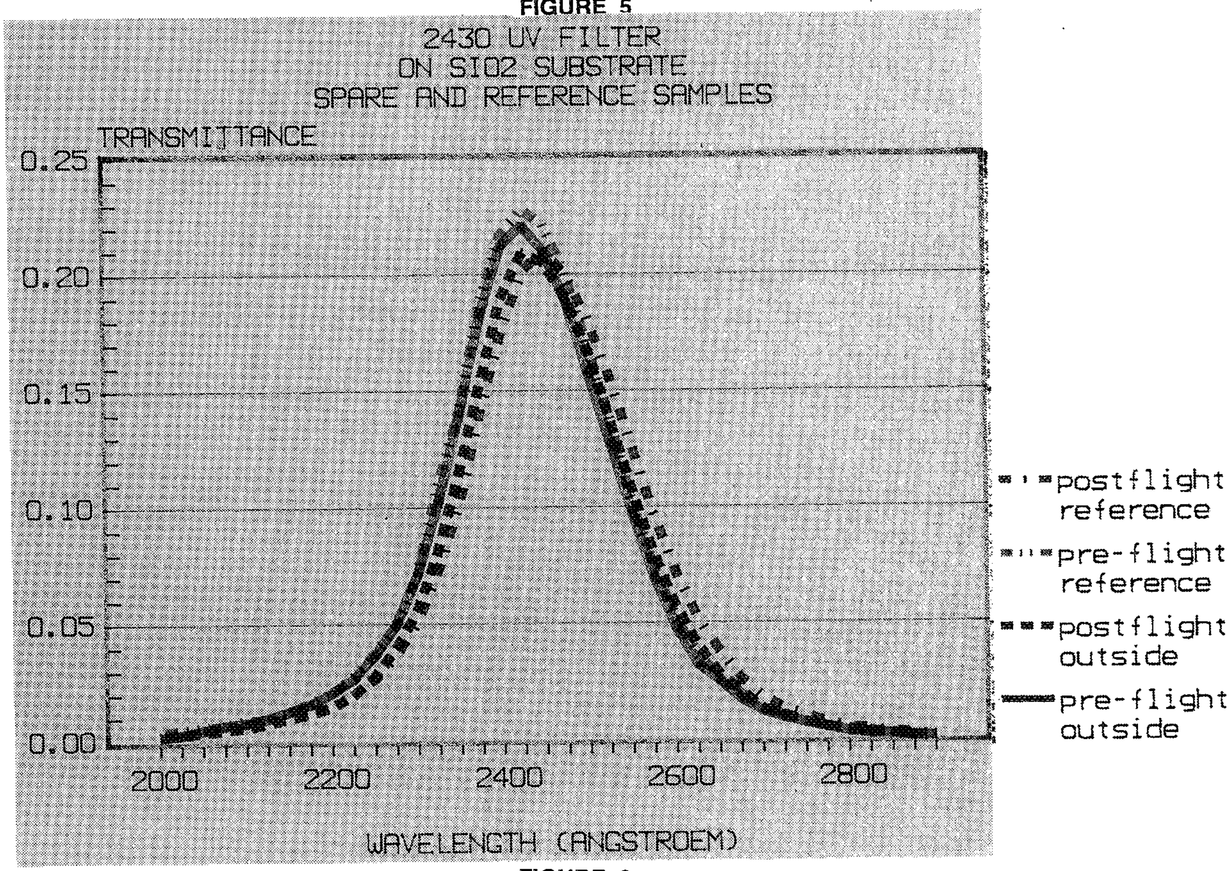

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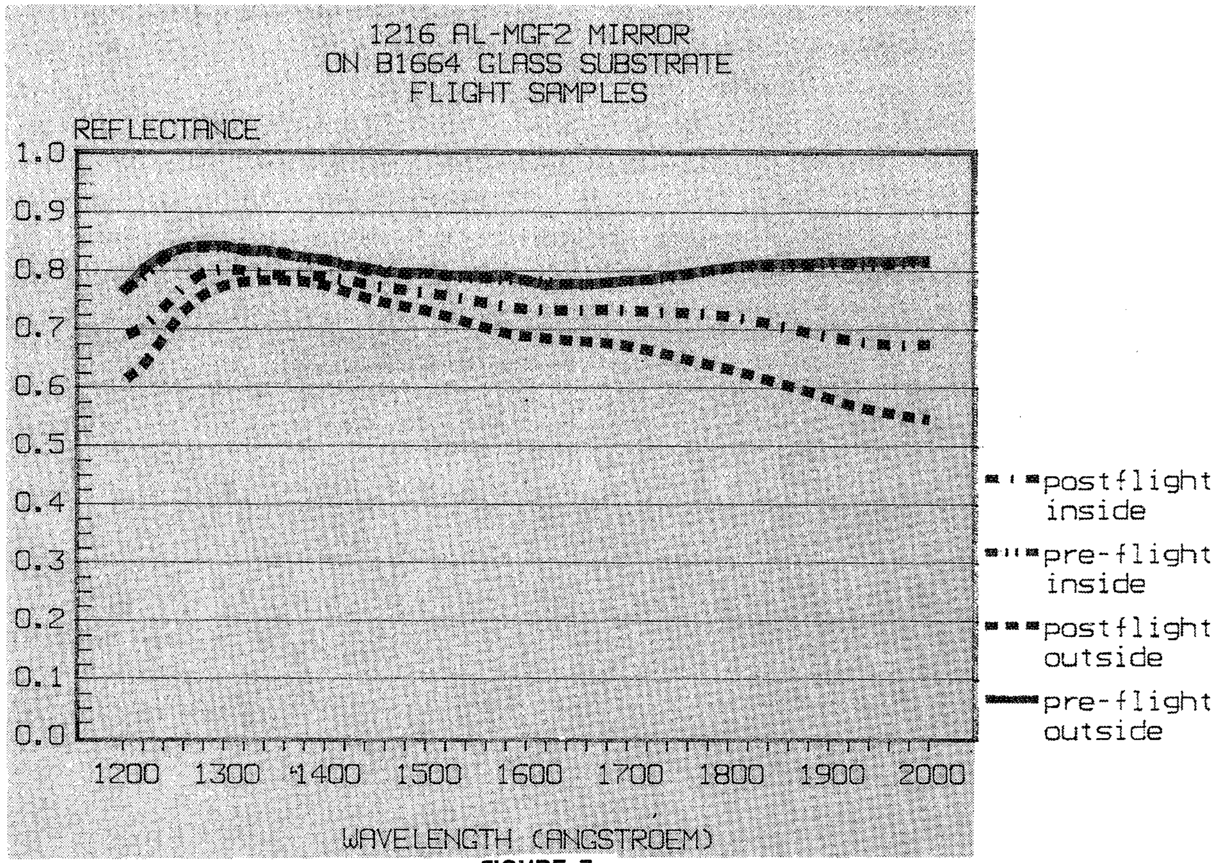

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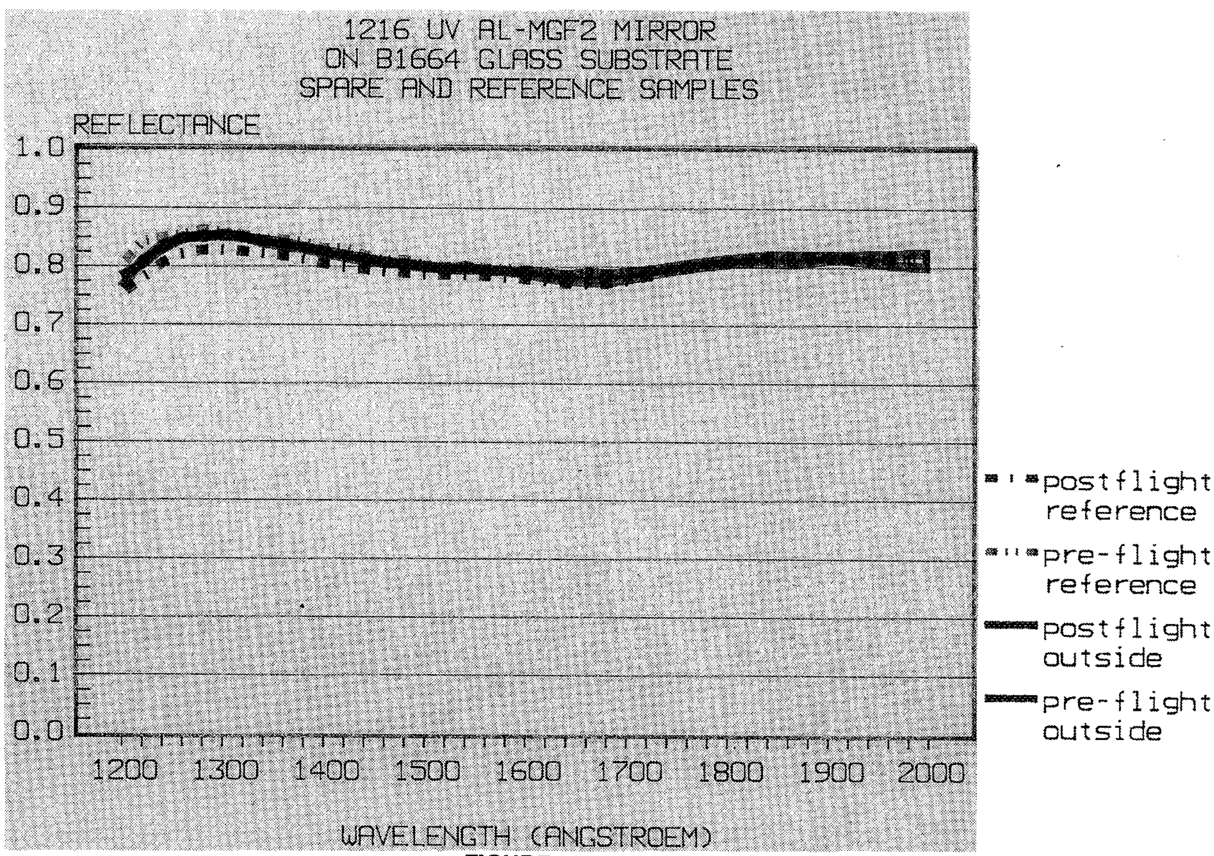

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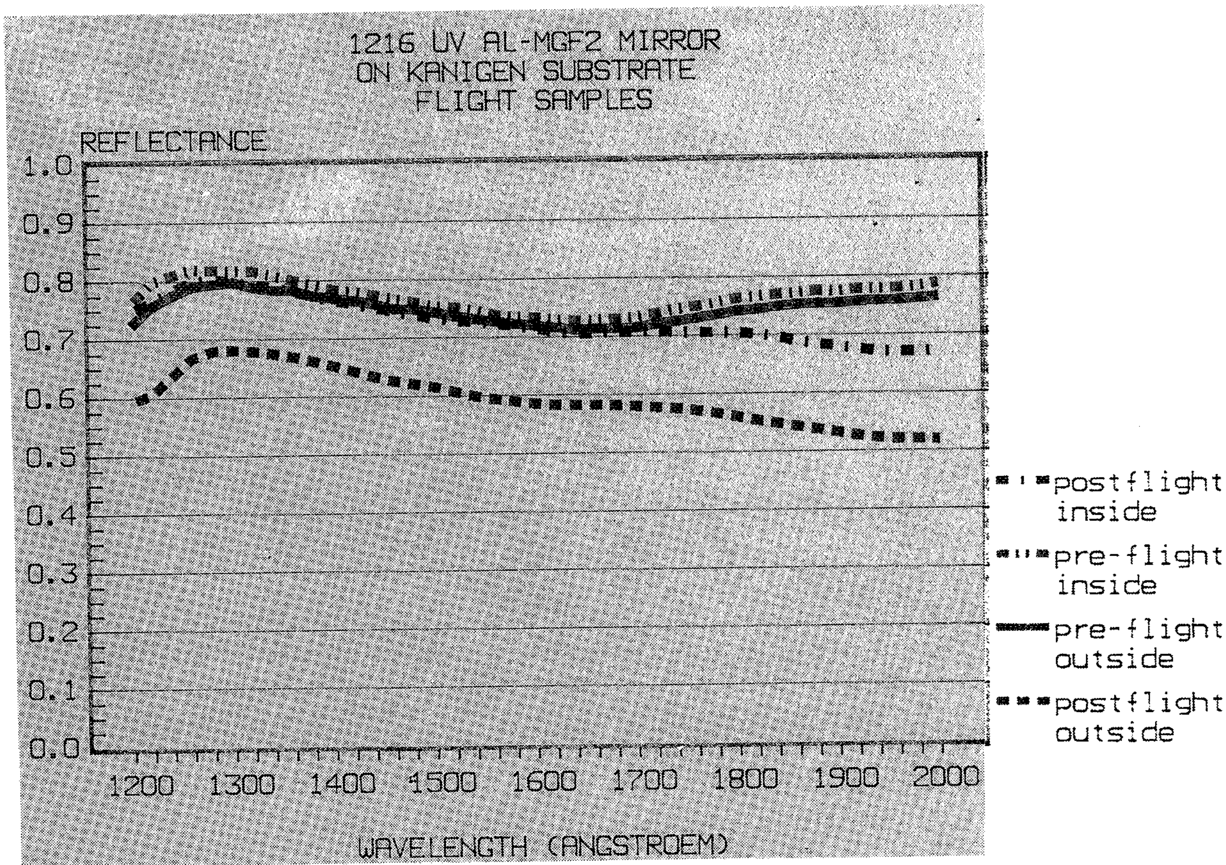

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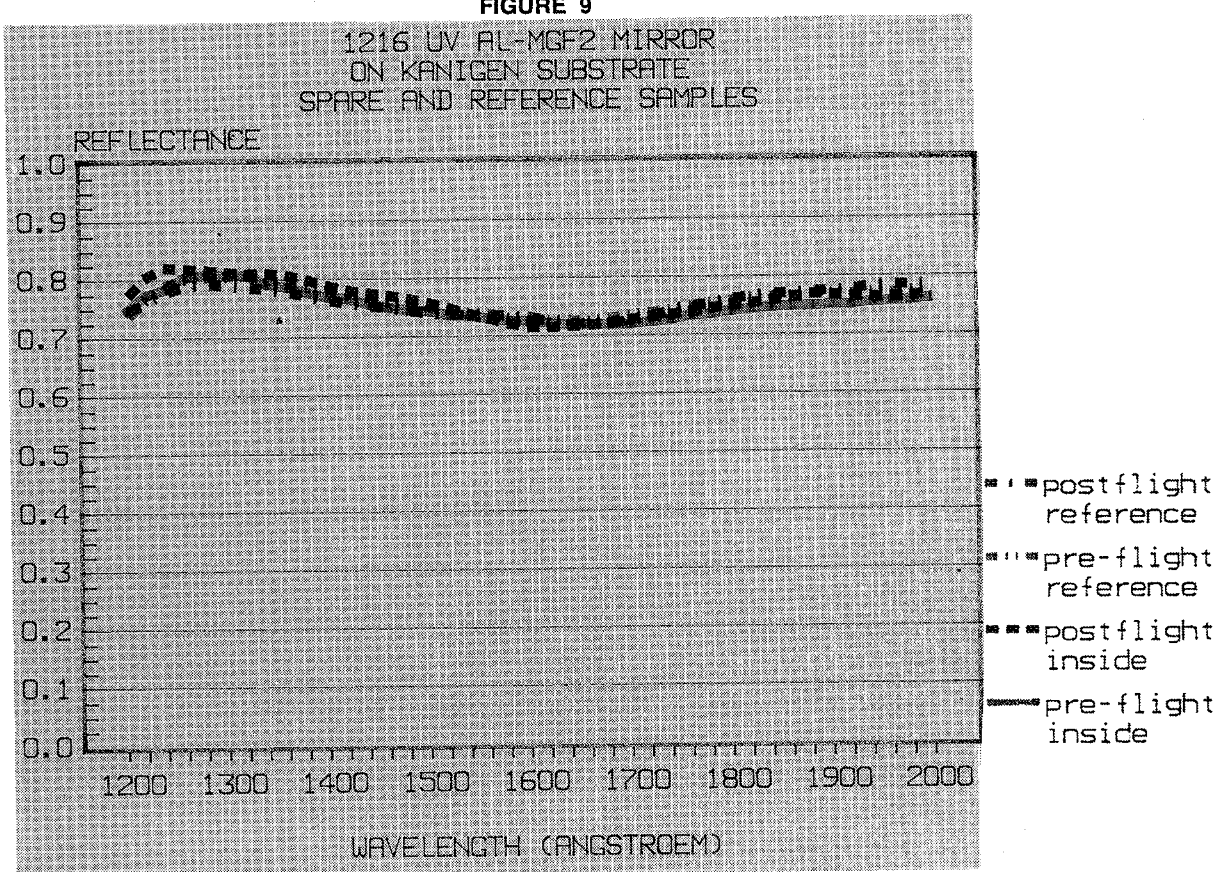

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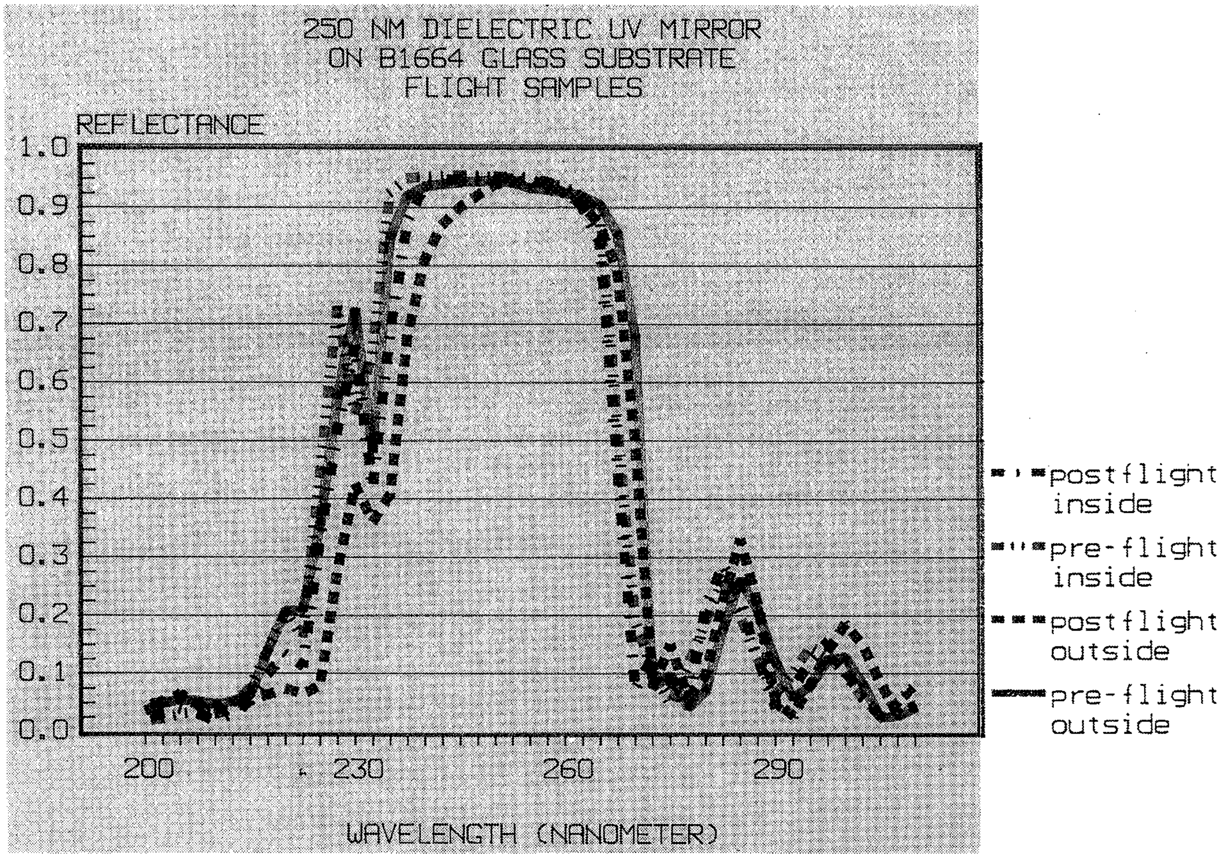

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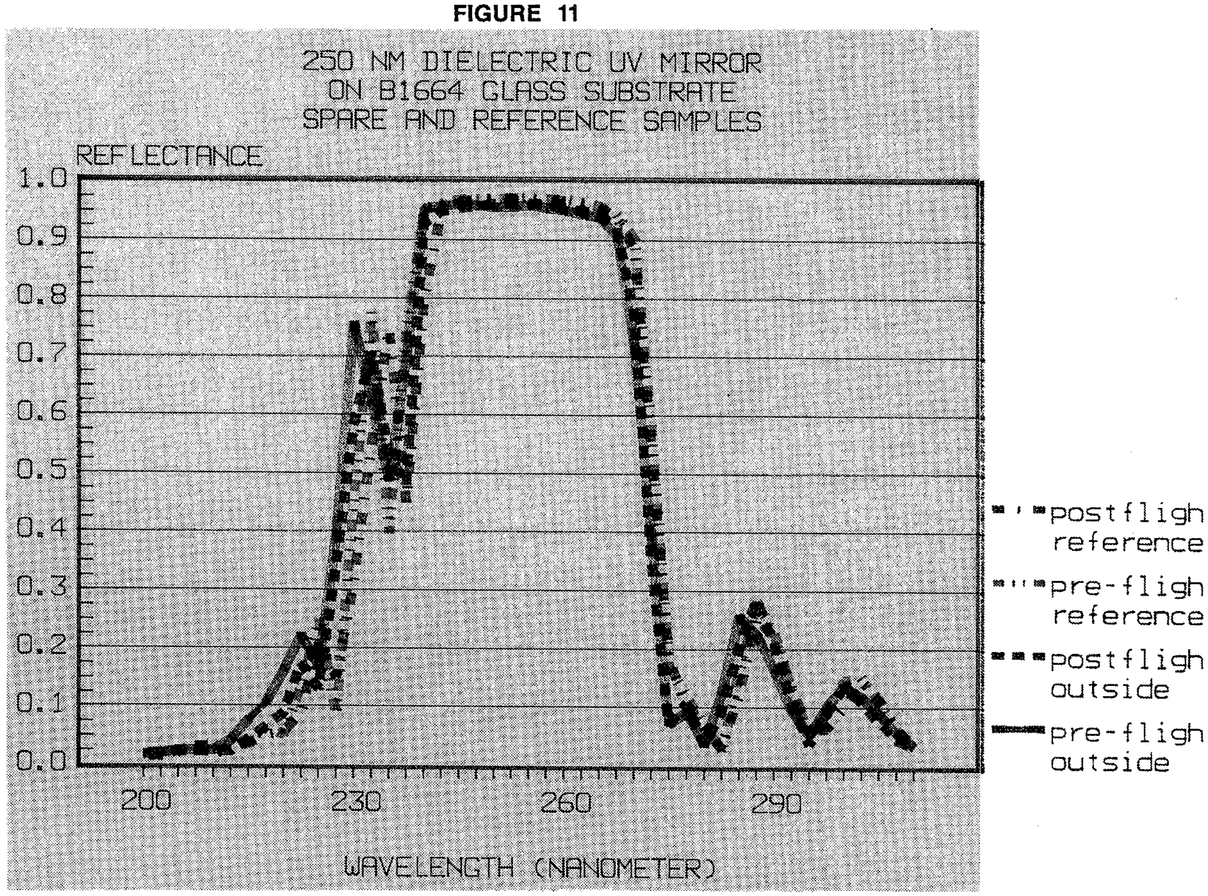

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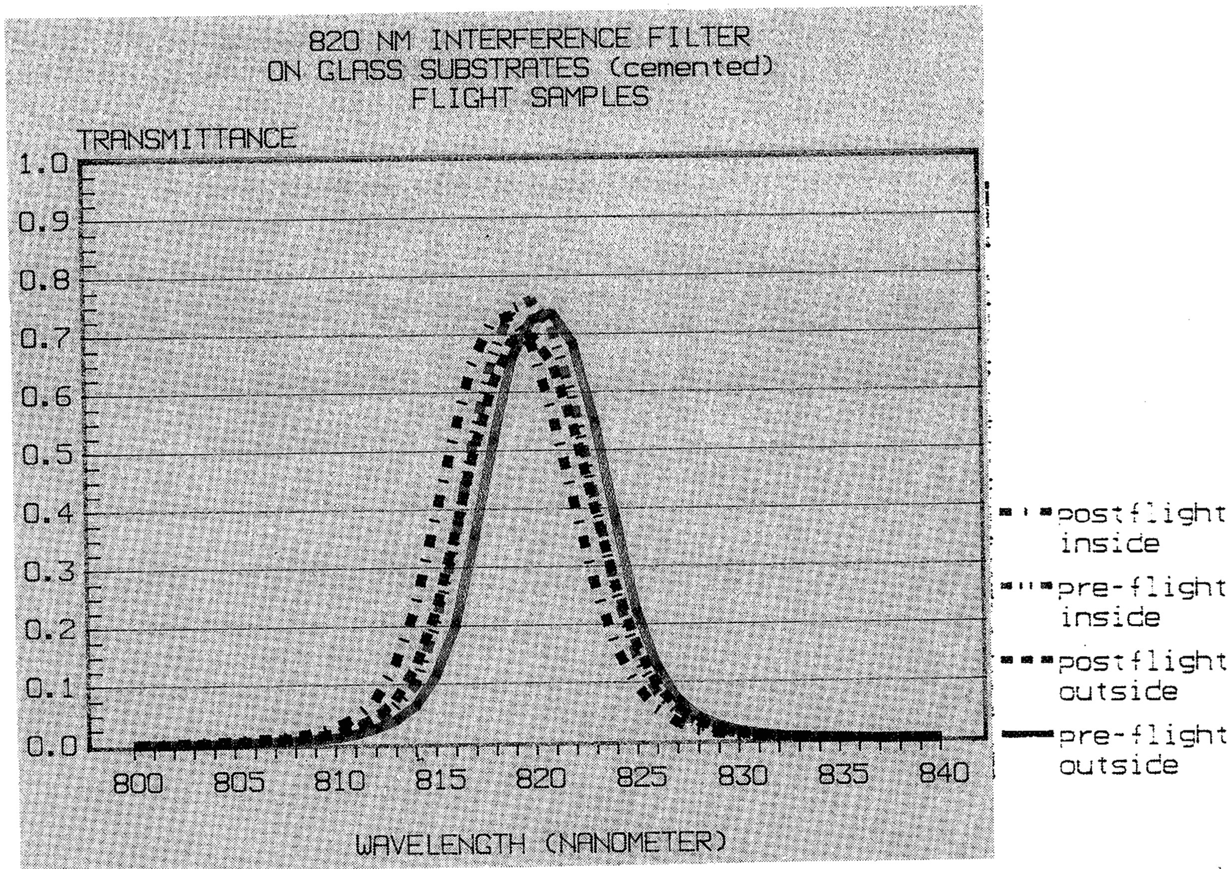

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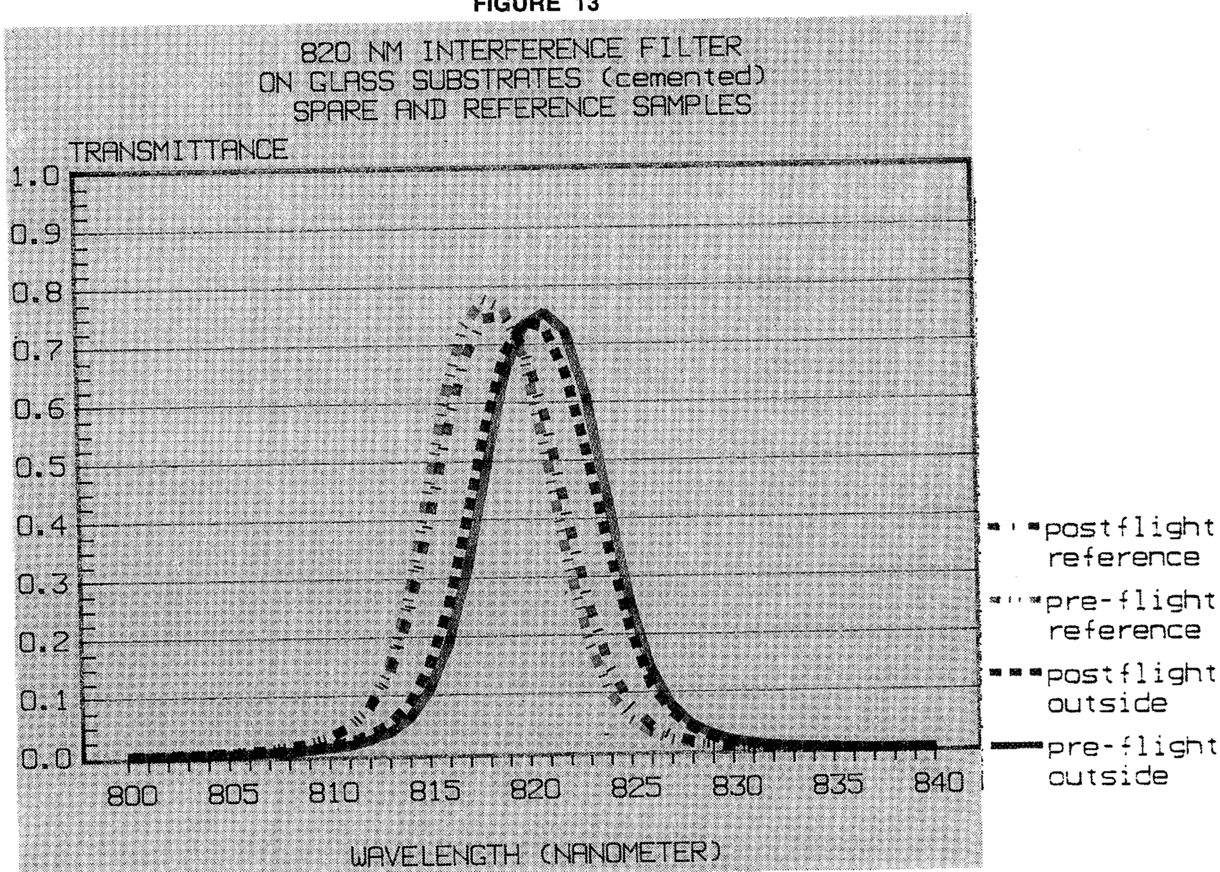

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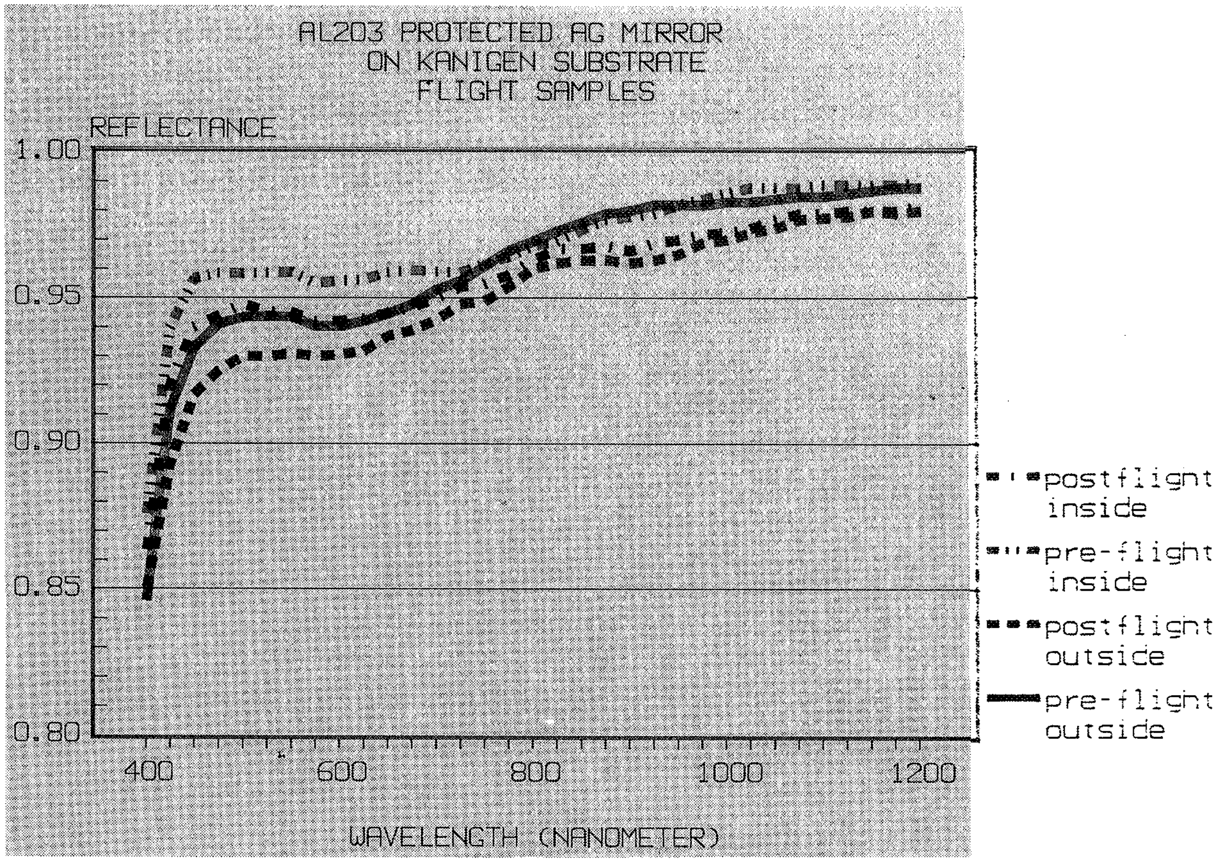

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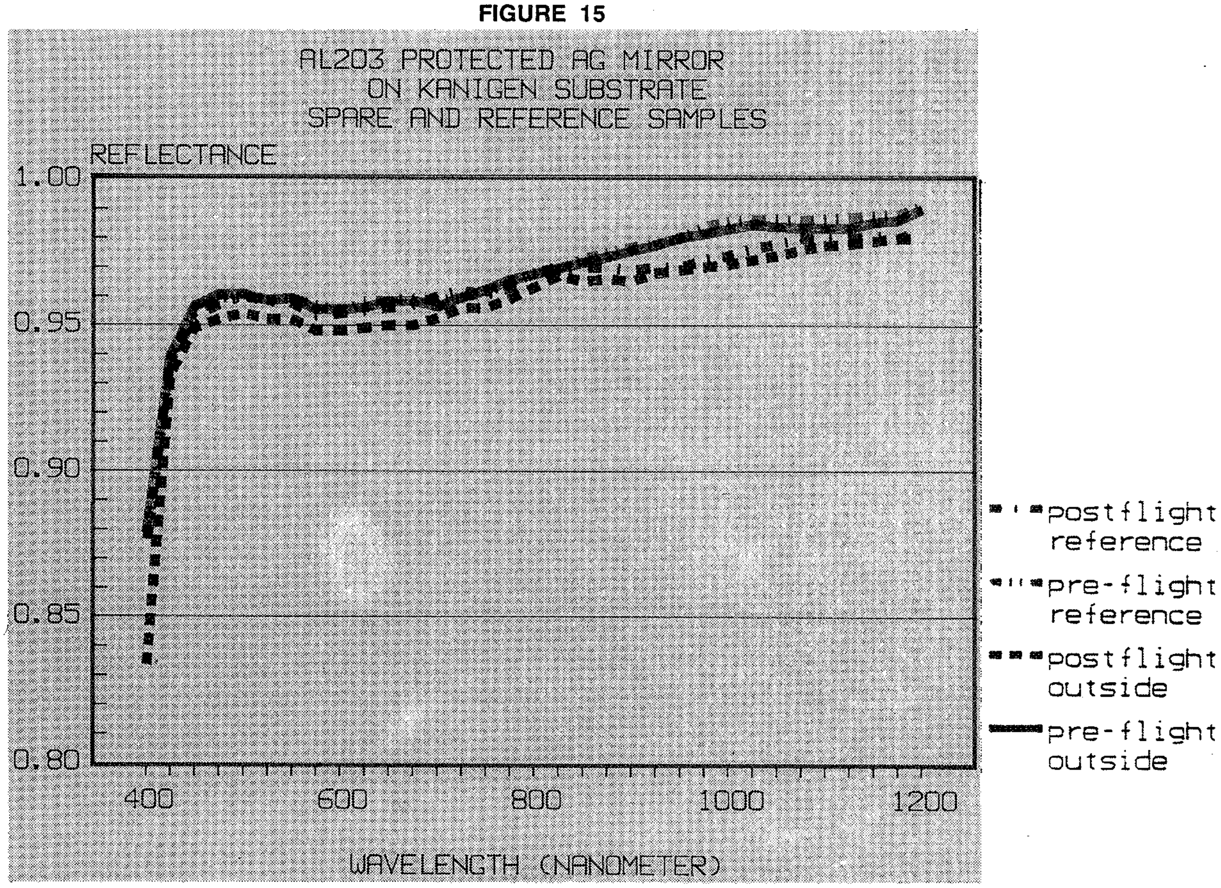

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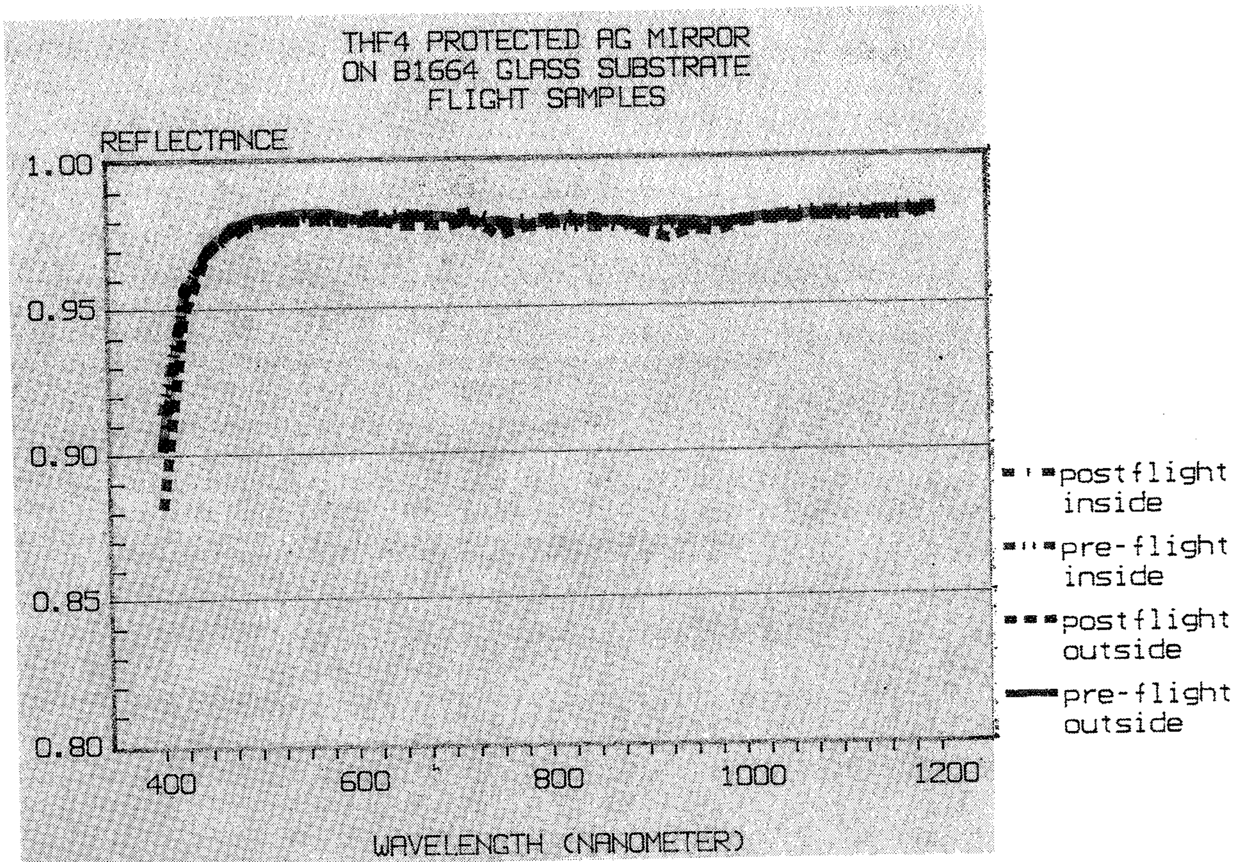

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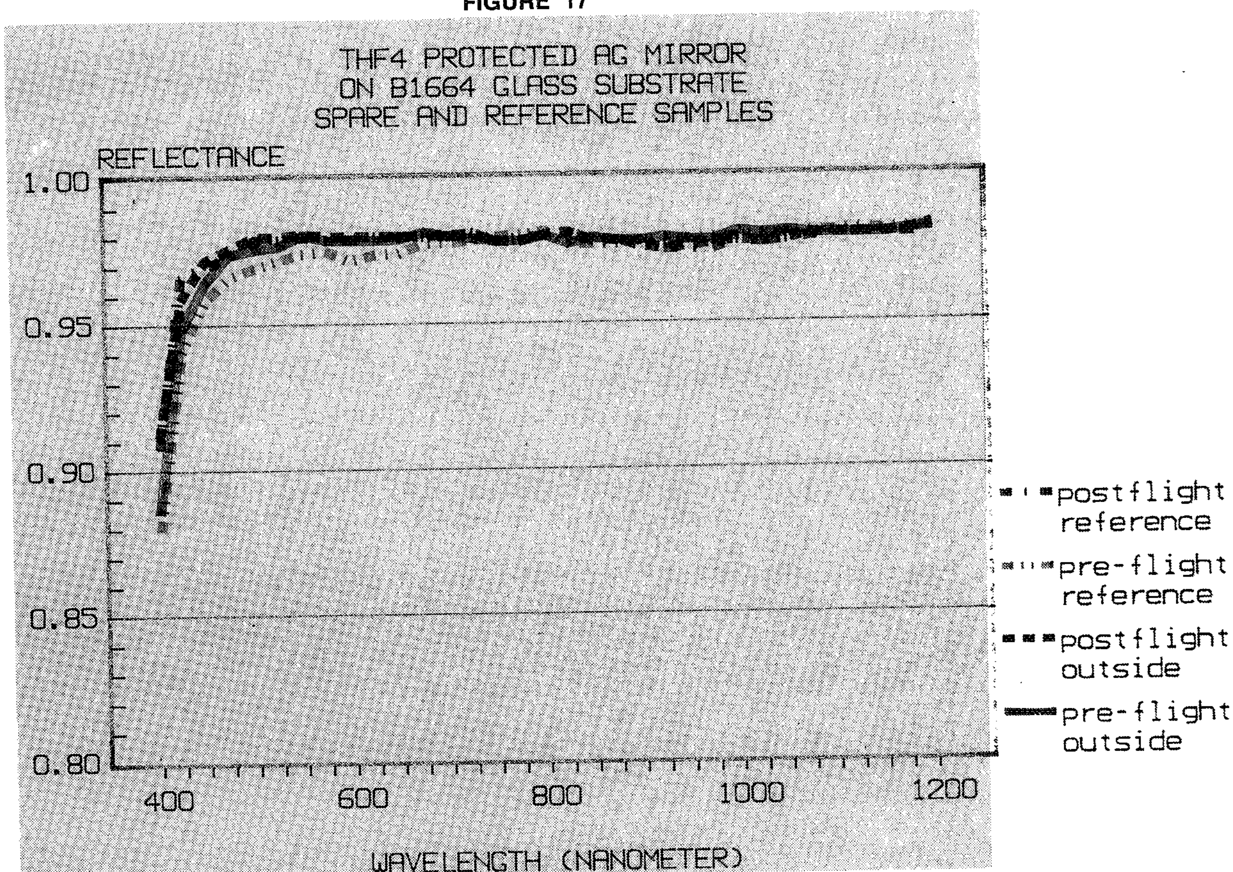

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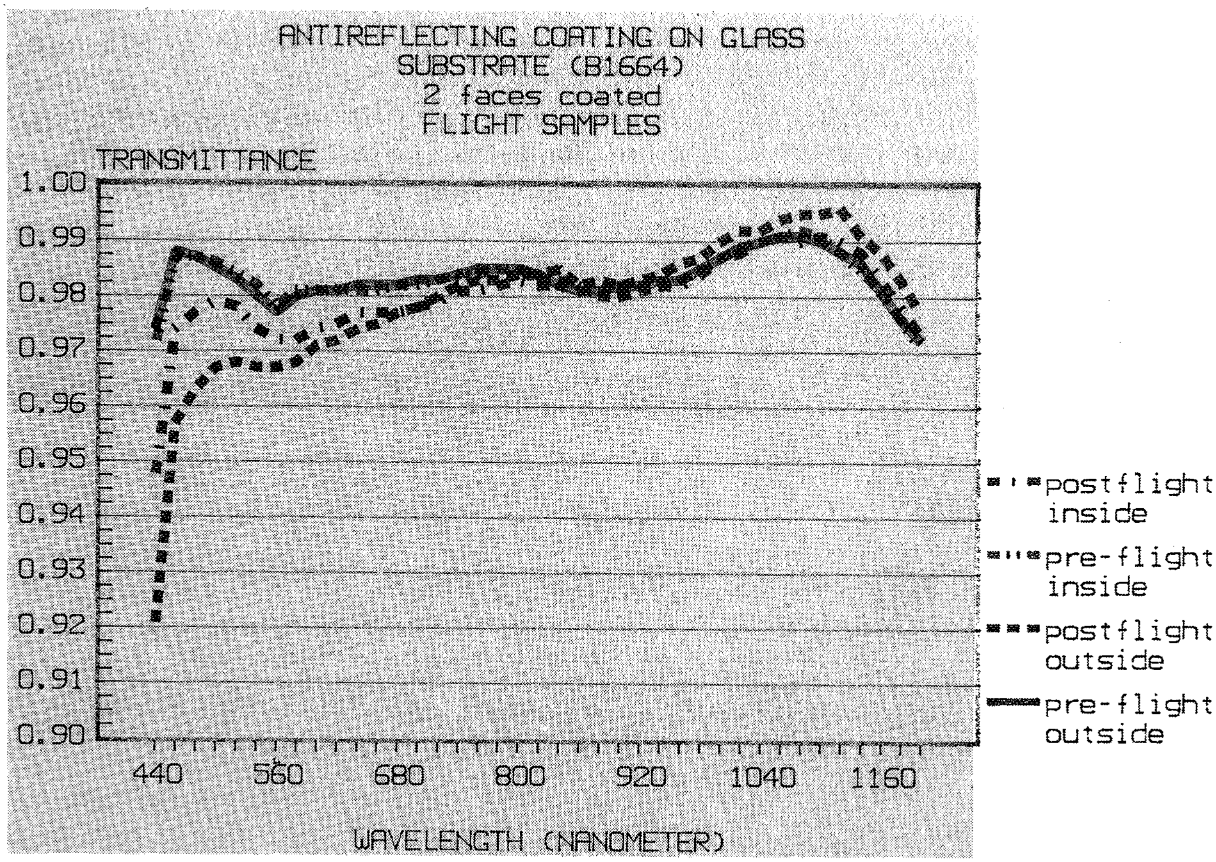

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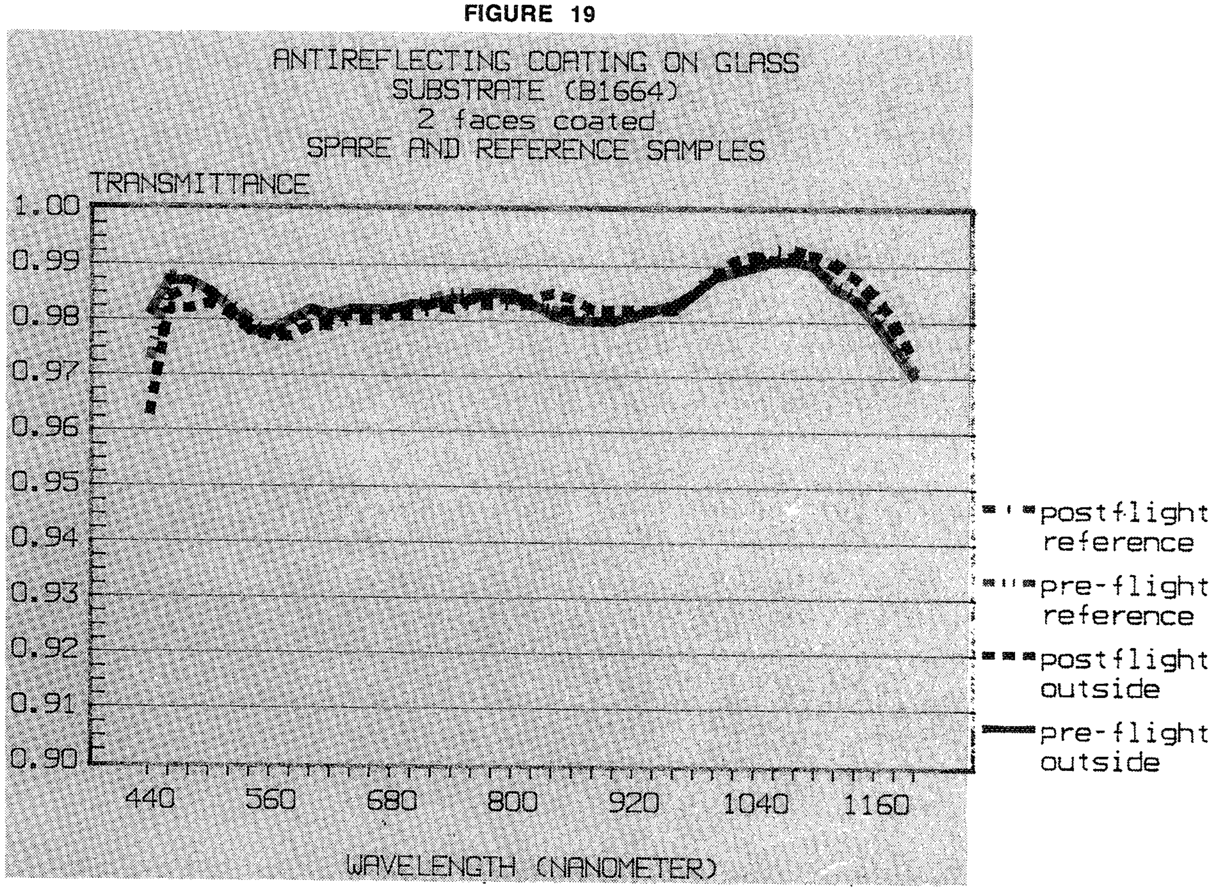

FIGURE 20