# STUDIES OF EFFECTS ON OPTICAL COMPONENTS AND SENSORS: LDEF EXPERIMENTS AO-147 (ERB COMPONENTS) AND S-0014 (APEX)

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## SUMMARY

Some additional results of testing of optical filters and window materials and thermopile sensors of the two experiments are included here. The APEX interference filters exhibited much greater degradation in space than the ERB filters. The adhesion of the Indium washers to the APEX interference filters is reported.

## INTRODUCTION

This paper is a continuation of a paper presented at the First LDEF Post-Retrieval Symposium (ref. 1). The Passive ERB experiment of the LDEF mission (AO147) was composed of sensors and components associated with the measurement of the Earth Radiation Budget from Nimbus satellites. The flight spare sensors from the Earth Radiation Budget (ERB) experiment which operated on the Nimbus 6 (ref. 2) and Nimbus 7 (ref. 3) satellites comprised the major part of experiment AO147. The Nimbus 7 instrument is still returning data as of this date (July 1992). The 10 solar sensors were mounted in LDEF tray B-8 along with 10 (non-ERB) interference filters supplied by Barr Associates (ref. 4). The 4 earth-flux sensors were mounted in LDEF tray G-12 on the earth facing end. A cavity radiometer, similar to channel 10C of Nimbus 7 was included as part of the Advanced Photovoltaic Experiment (APEX) which was mounted in LDEF tray E-9 (ref. 5). While PEERBEC was a passive experiment APEX was active. This presentation includes some results relative to the APEX experiment (S0014); notably information relative to the interference filters of the filter radiometer . Much of the background information regarding the 2 experiments is included in the

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references and other LDEF documentation. The association of the two is that the Eppley Laboratory was involved with the design and fabrication of both experiments in addition to the fact that the cavity radiometer related to the Nimbus experiment was mounted in the APEX to assure a position on the leading edge (RAM). The APEX was mainly a photovoltaic experiment. The solar cell results are discussed in the proceedings of the first symposium (ref. 5) and elsewhere in these proceedings (ref. 6). The cavity radiometer and the filter based spectral radiometer were intended as calibration reference instruments for the solar cell measurements.

In the following sections we present selected results from these experiments. A bibliography of recent references to the Nimbus ERB analysis and results is included.

## SUMMARY OF RESULTS: EXPERIMENT AO 147

The Examination and testing of the returned ERB components generally confirmed the earlier contention that contamination of optical surfaces caused the degradation of most of the Nimbus 6 and 7 ERB data with time. The cleaning of these same surfaces (Nimbus) by atomic oxygen (AO) was also confirmed. Those channels which showed no recovery, notably ERB channel 7, were determined to have deposited layer materials which are not suitable for space use with high UV exposure. Also, the Suprasil W windows on the total irradiance channels showed some degradation in the UV transmittance region due to UV exposure. Interior optical elements appeared to be free of contamination. Interference filter transmittance changes were minor for channels 6 and 9, confirming another interpretation of the ERB results.

Earth-Flux channels on the earth facing surface (tray G-12) showed contamination deposits on the outer filter hemispheres. After cleaning, the transmittance was relatively unaffected except for transmittance loss in the UV region (ref. 7). The open channels, 11 and 12, were unaffected.

The thermopile sensors in all 14 channels appear to be unchanged by the space environment, even those of channels 3, 11 and 12 which had no protecting optical components to shield them from contamination, AO exposure and UV exposure.

The most important result of this effort was the retrieval, and subsequent testing of the cavity radiometer which was mounted in the APEX experiment. The post-retrieval intercomparisons and reflectance tests have had a major impact on the interpretation of the low percentage changes in the total solar irradiance. Previously these changes were questioned because of possible instrument degradation.

Contamination is determined to be the major factor in the reliability of a well designed ERB type experiment. When the solar maximum, with the increase in AO flux, occurs after the deposition of the contamination there is a possibility of total cleansing of some components and partial cleansing of others. The Nimbus 7 ERB has experienced this sequence twice since its launch in November 1978. The second factor is the decrease in UV transmittance of the broad band window materials which are necessary to separate the short wave flux from the total flux in ERB experiments. Our results combined with the APEX and other LDEF investigations indicate that Corning 7940 has less degradation than the Suprasil W. However, the Suprasil W was purchased in the 1970's, and was chosen for ERB applications based on the absence

of water (OH) absorption bands at the near infrared end of the spectrum, which was felt to be more appropriate for radiometric measurement purposes.

## THE APEX (S 0014) FILTERS

There was some delay in removing and testing the filters of the APEX filter radiometer. This was because of the difficulty experienced in trying to remove the filters from their mounts. It was feared that the information on the transmittance would be lost if the filters were separated during the removal process. It was originally thought that the sticking was caused by a flow of the epoxy, which held the 2 filter substrates and spacer together. After carefully machining the outer surface of the mounting ring from one of the filter holders, it was found that the adhesion was caused by the Indium washers which were included for thermal transfer from the rear substrate to the holder. It was then decided to remove all 16 filters by machining as necessary. The following table is a summary of the condition of the filters after machining of the mounts (H blocks).

APEX PROJECT - FLIGHT FILTER CONDITION ON REMOVAL

| Filter Number | Nominal Wavelength Angstoms | NOTES ON CONDITION after removal from H block | back substrate (glass type) |
|---|---|---|---|
| 1 | 3250 | together - like ERB filter with spacer | clear |
| 2 | 3750 | together - like ERB filter with spacer | clear |
| 3 | 4250 | together - like ERB filter with spacer filter broke during milling | clear |
| 4 | 4750 | separated - front filter speckled | clear |
| 5 | 5250 | separated - front filter speckled and has pin holes | yellow |
| 6 | 5750 | separated - front filter speckled and has pin holes | yellow |
| 7 | 6250 | separated - epoxy ring on front of rear substrate | orange |
| 8 | 6750 | together - probably the best looking filter | red |
| 9 | 7250 | separated - glass ring: scratch on front deposit and haze | red |
| 10 | 7750 | separated - epoxy or glass ring (broken) | red |
| 11 | 8250 | separated - epoxy or glass ring | dark red |
| 12 | 8750 | separated - hit on front - glass ring between | |
| 13 | 9250 | separated | dark red |
| 14 | 9500 | separated - bubbled front coating | dark red |
| 15 | 11000 | separated | dark red |
| 16 | 12500 | together - crystallized chips loose inside between substrates | dark red |

An additional problem with the identification of the actual deposited layers and rear substrates was that the manufacturer could not locate the fabrication information and formulas because of the long time since manufacture and the death of the individual who specified the filters. The front substrates are believed to be Corning 7940. The

search for manufacturing information continues.

The post flight transmittance curves for the filters are given in figures 1 through 17. The first is a composite for the filters 1 through 13 on the same scale (60% transmittance full scale). The upper plots are all pre-flight transmittance and the lower are post-flight and after removal and/or separation as discussed above. It can be seen that all 13 filters suffered loss of transmittance. Some of the changes are drastic. It can also be seen that the wavelength band for each filter was retained to a high degree. There are no major band shifts apparent on this plot. Figures 2 through 17 are expanded transmittance plots for each filter showing the change from the original plots. Plots for the red end filters, 14, 15 and part of 16, are included in this group. Please note that the full scale ordinate value is not the same on all of the individual filter plots. Filter 14 appears to have experienced a band shift to the longwave.

It is apparent that the APEX filters experienced much greater changes than did the ERB filters (reported last year). Without the information on the layer materials, it is unlikely that the reason can be fully explained. From examination, it appears that the substrate materials were not a major contributor to the degradation. It is possible that a study of the first year flight data for the filter radiometer may help in identifying the onset of the experienced degradation.

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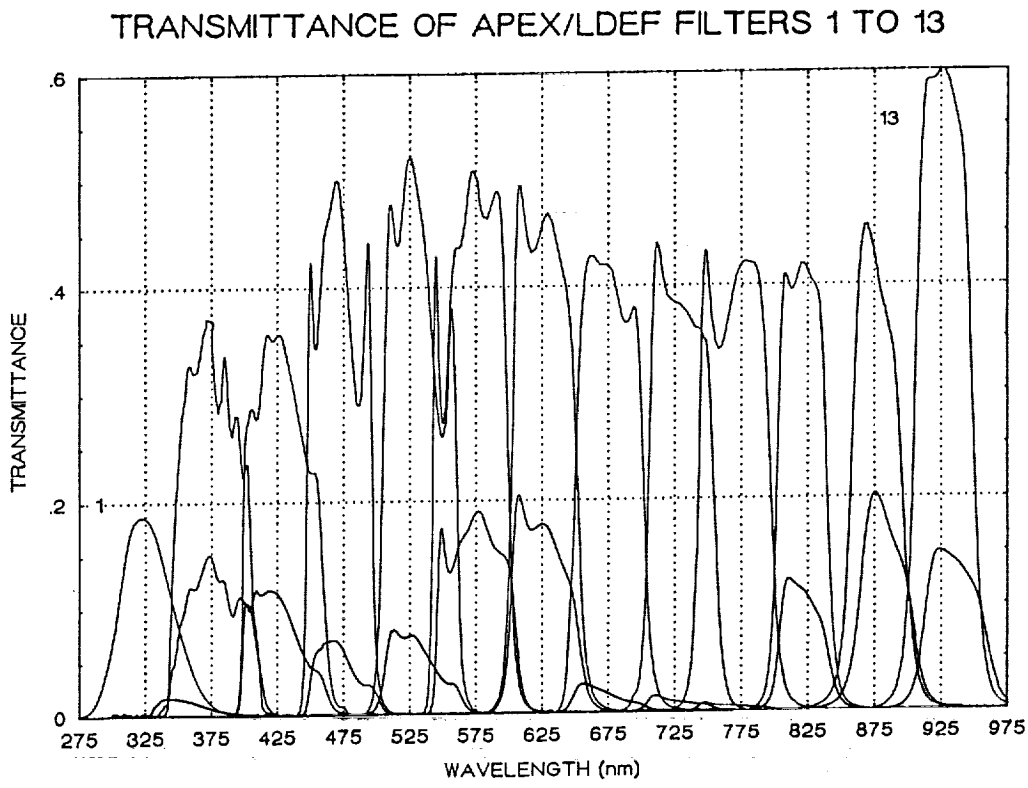


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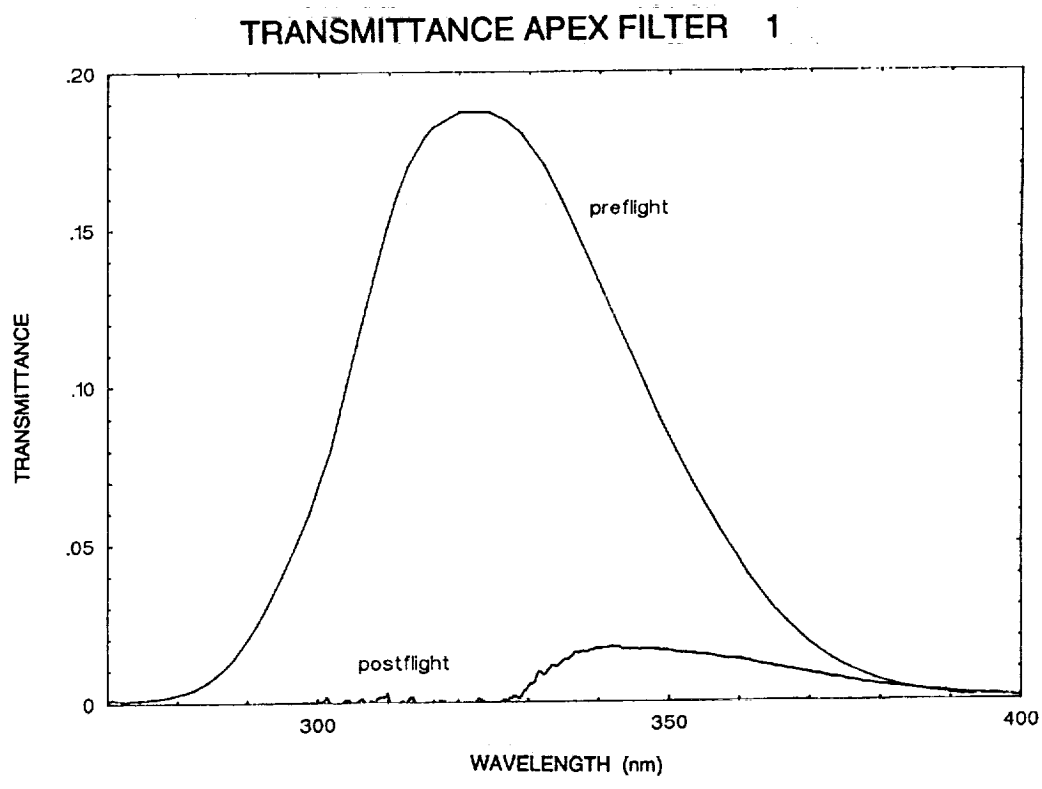


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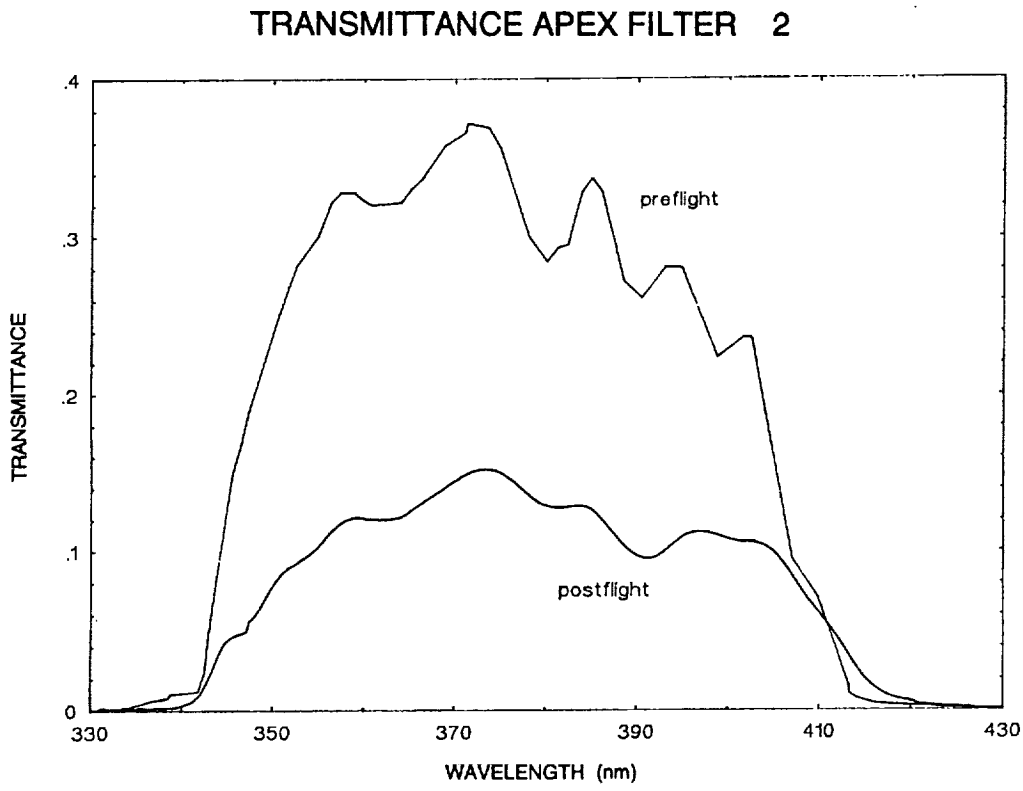


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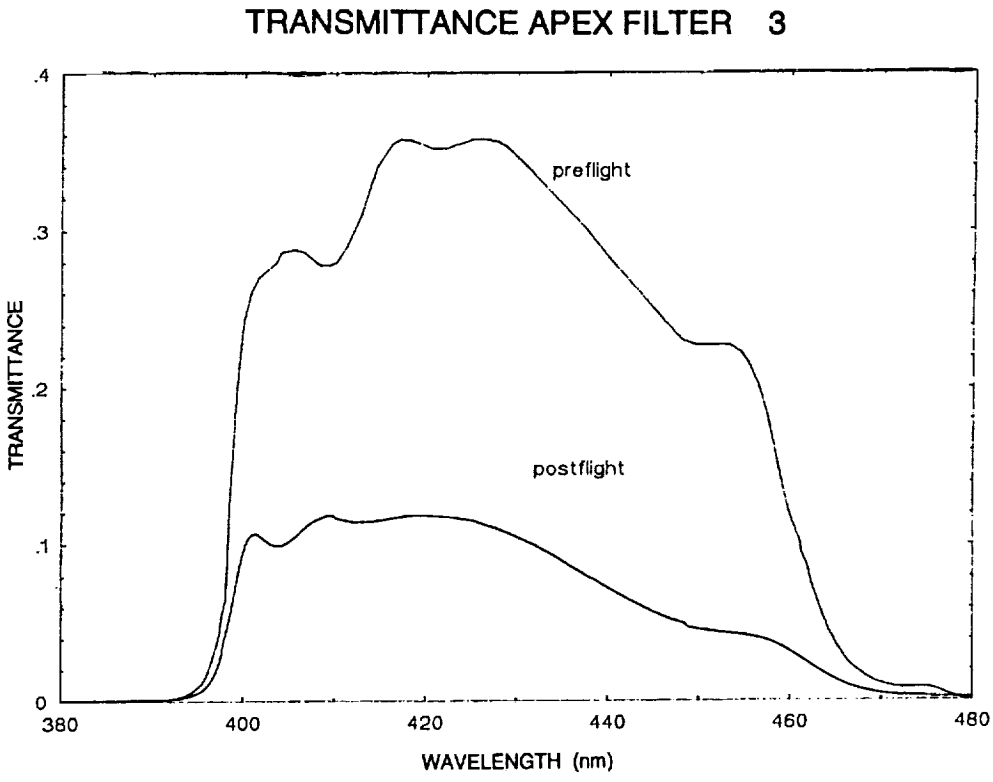


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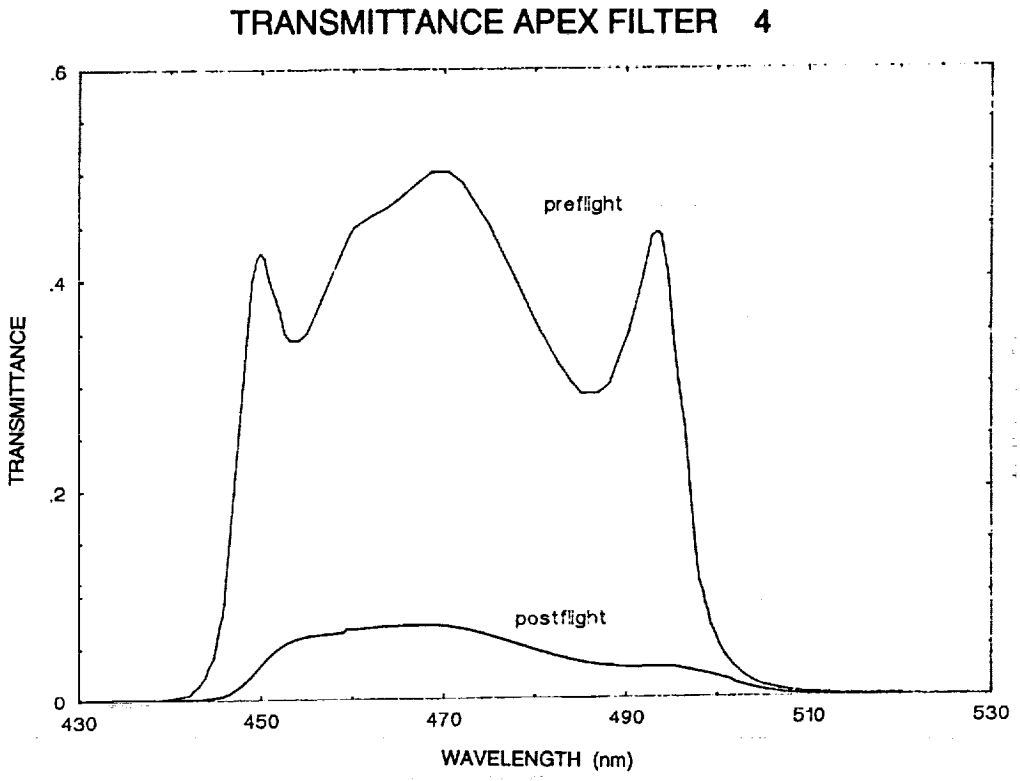


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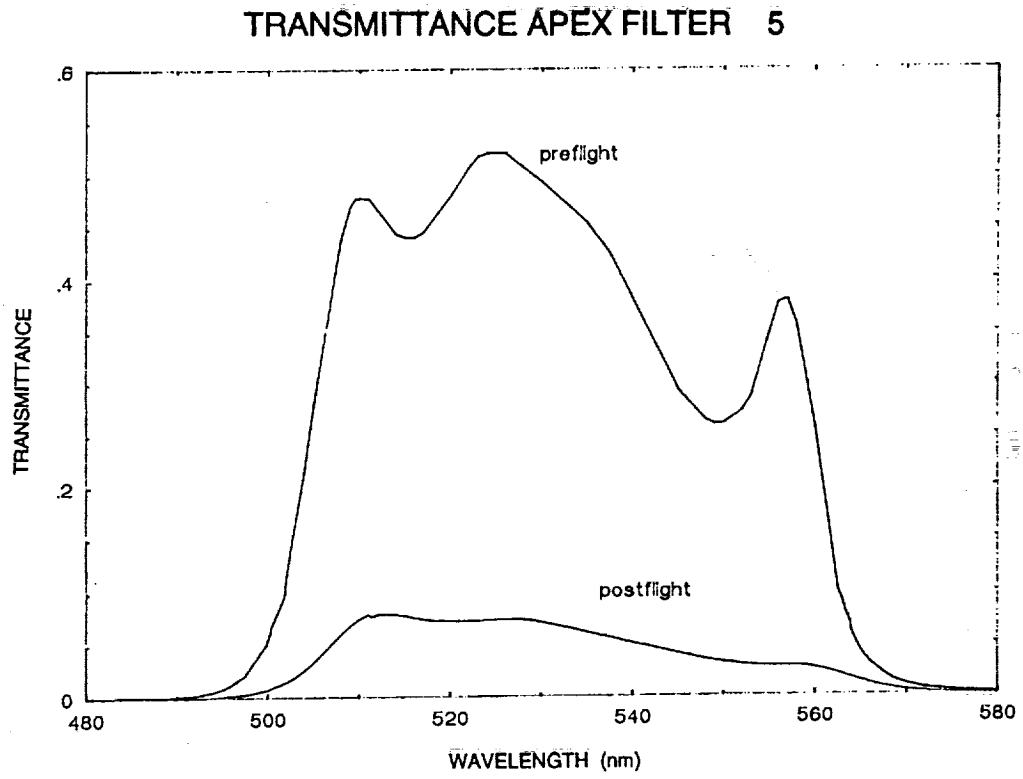


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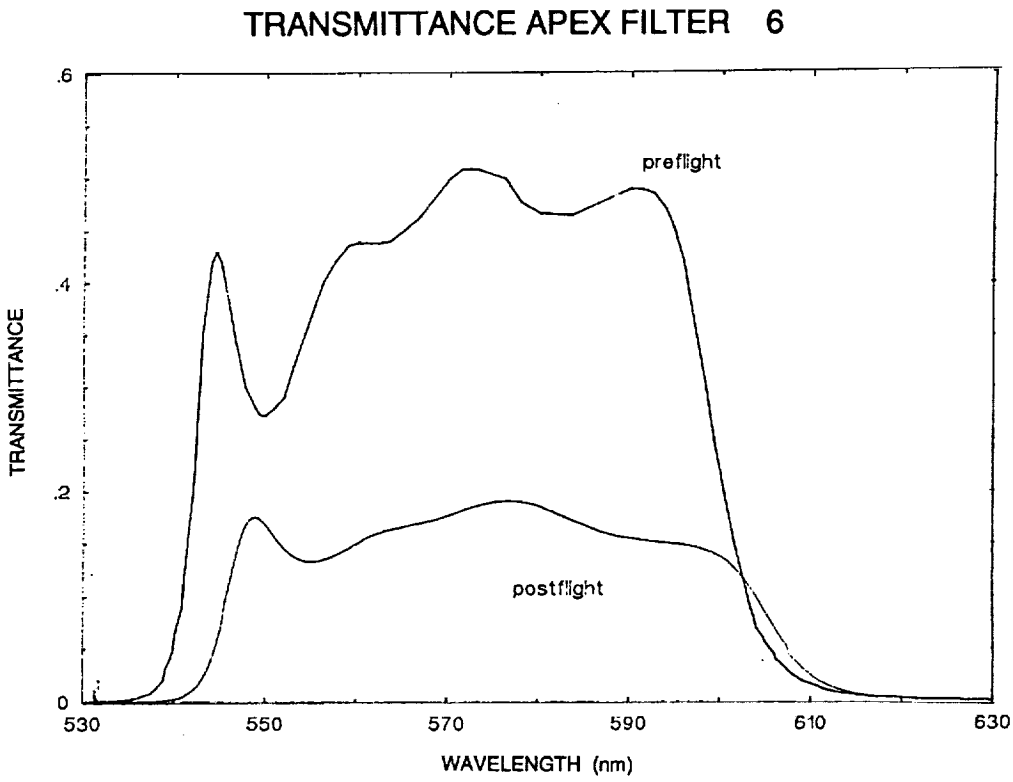


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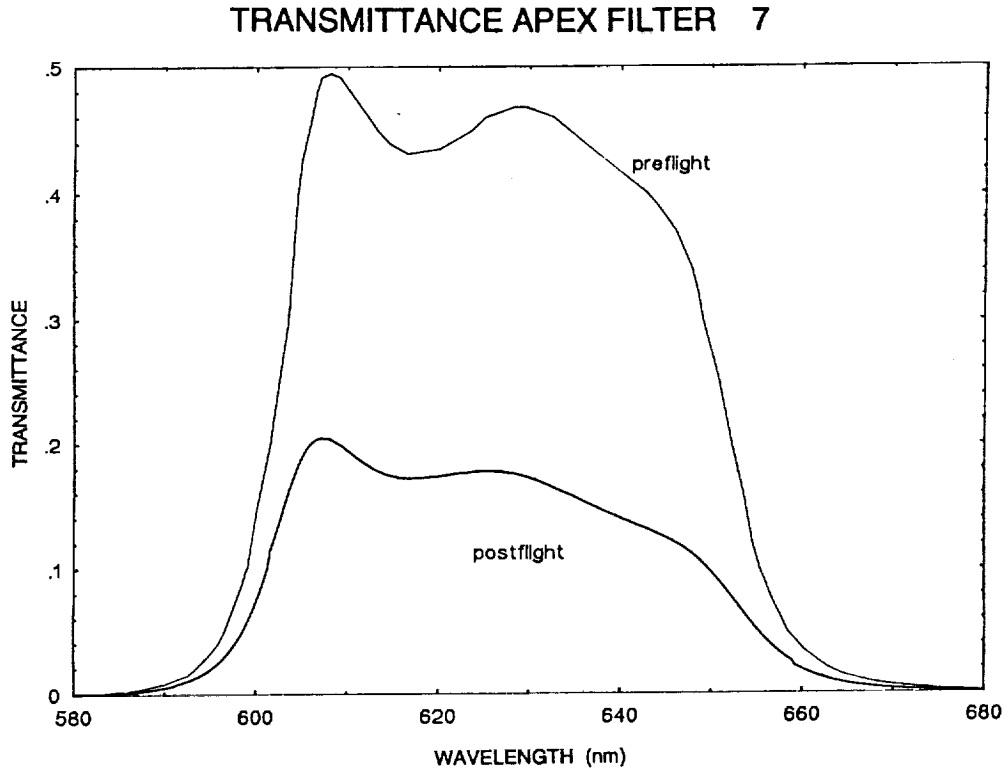


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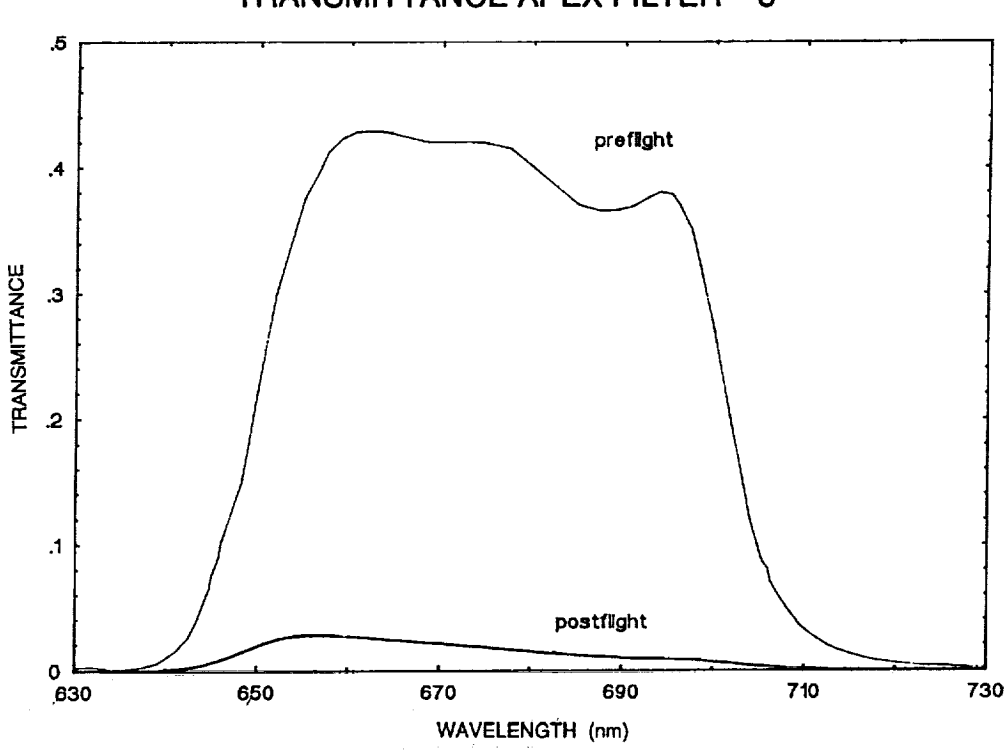


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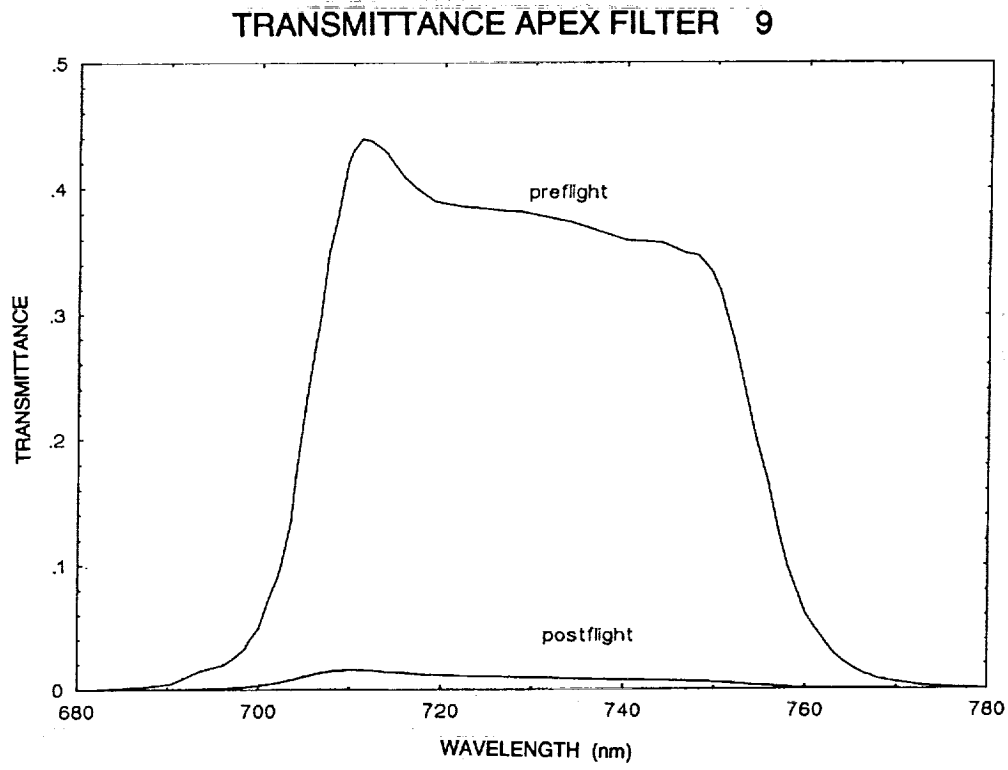


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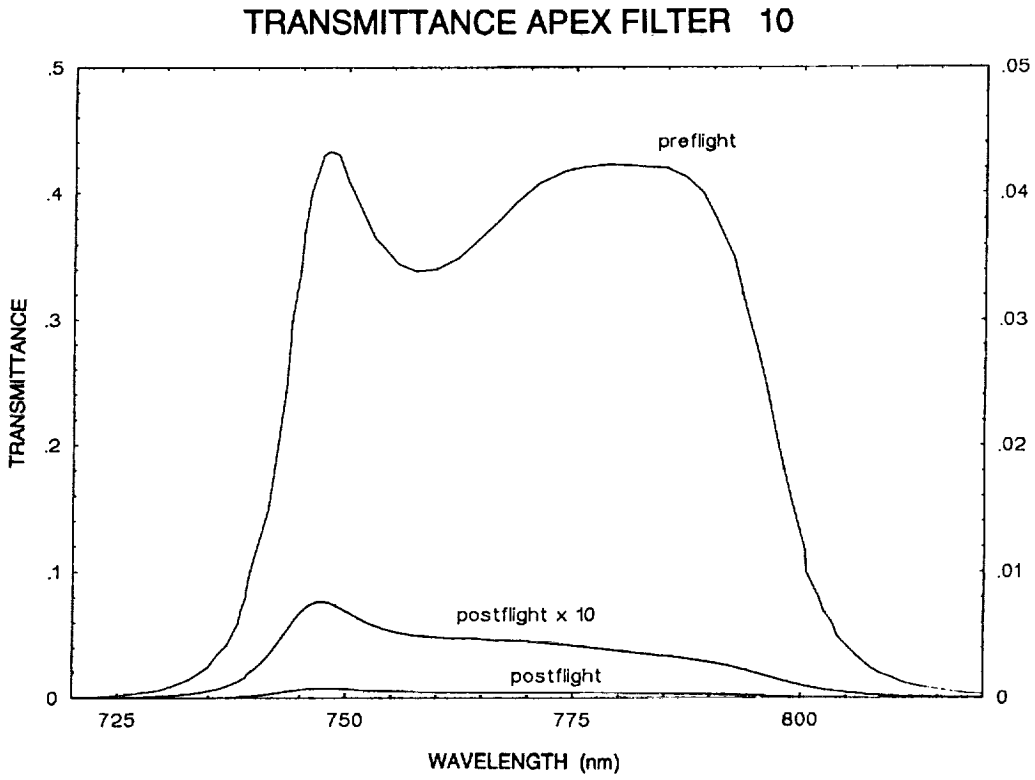


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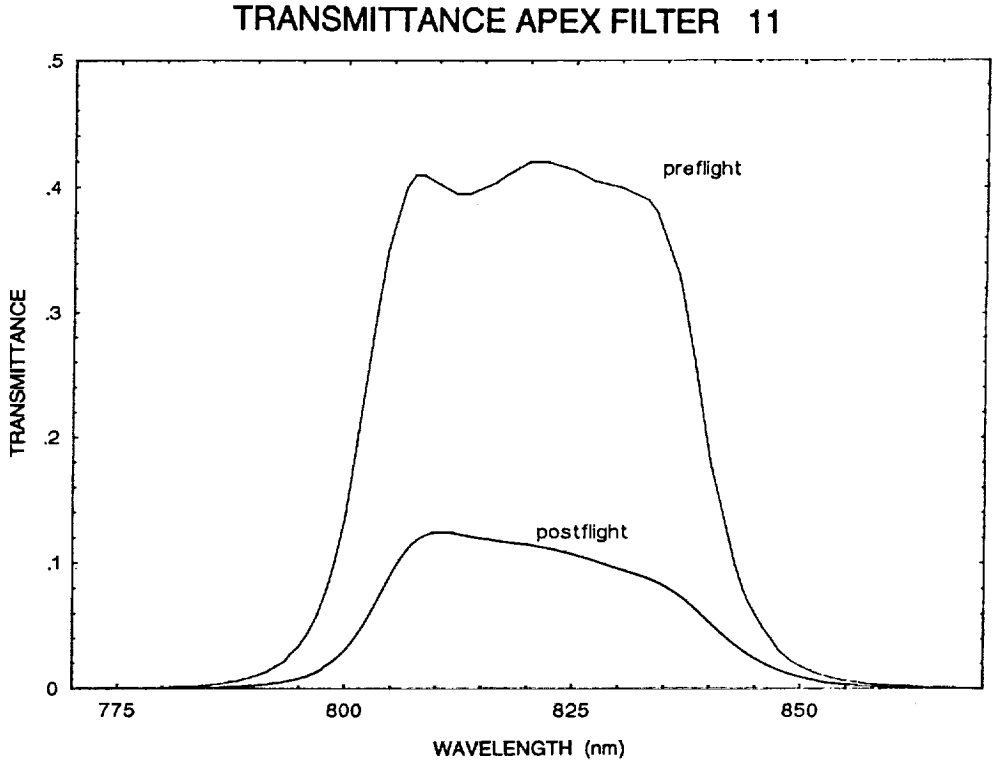


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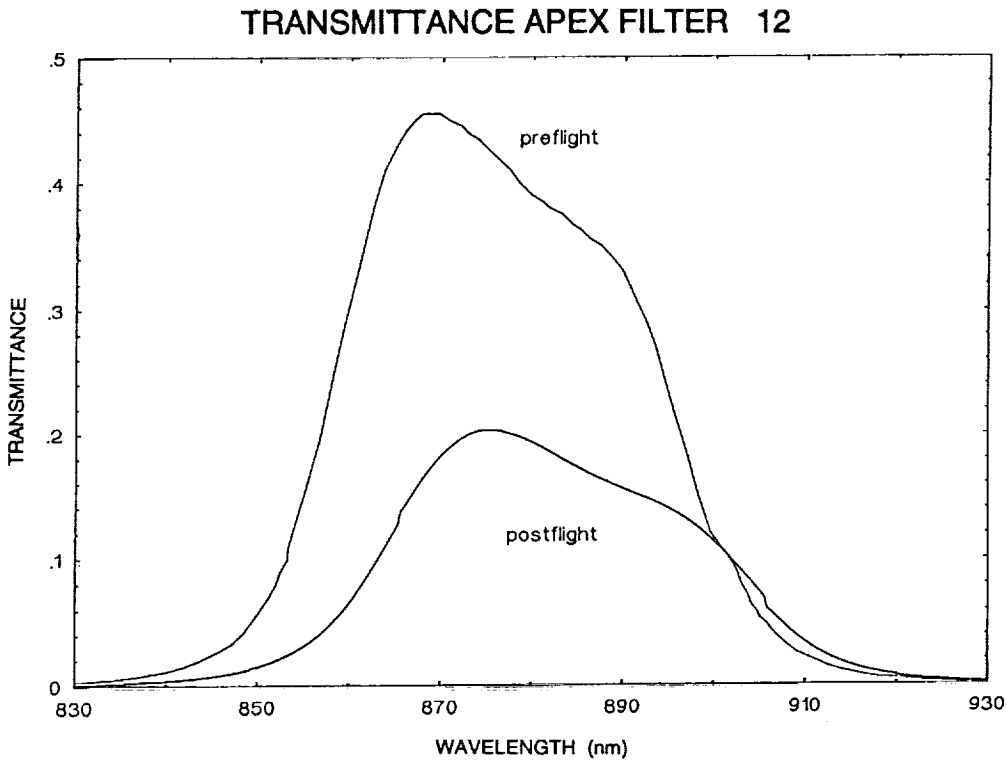


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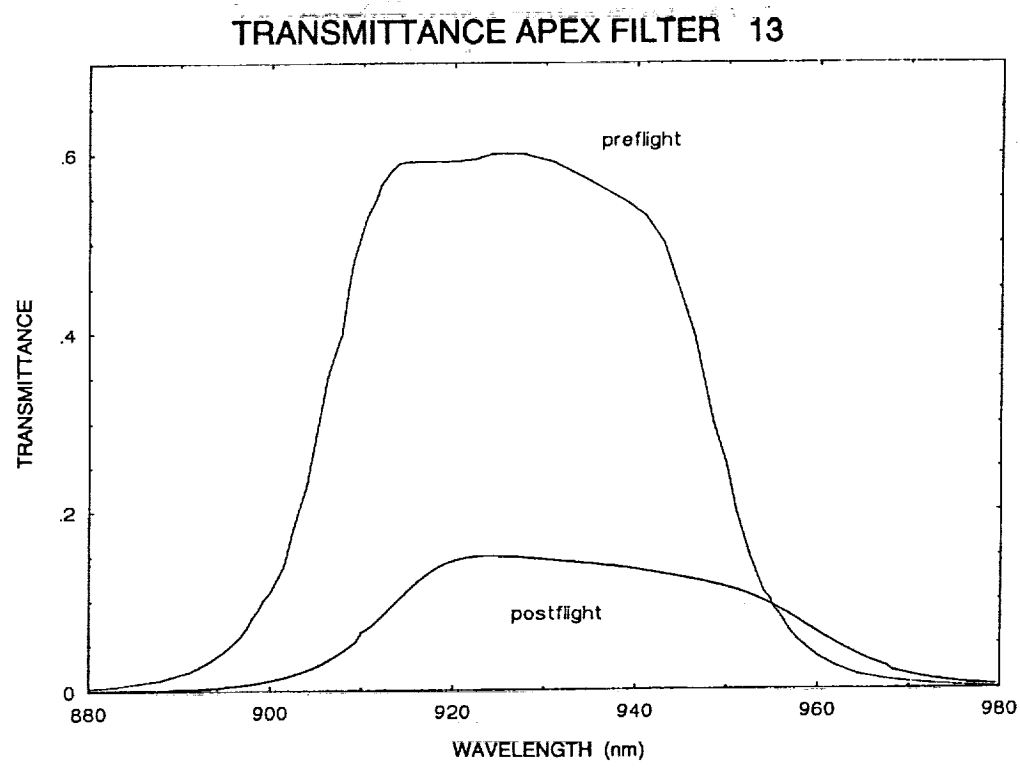


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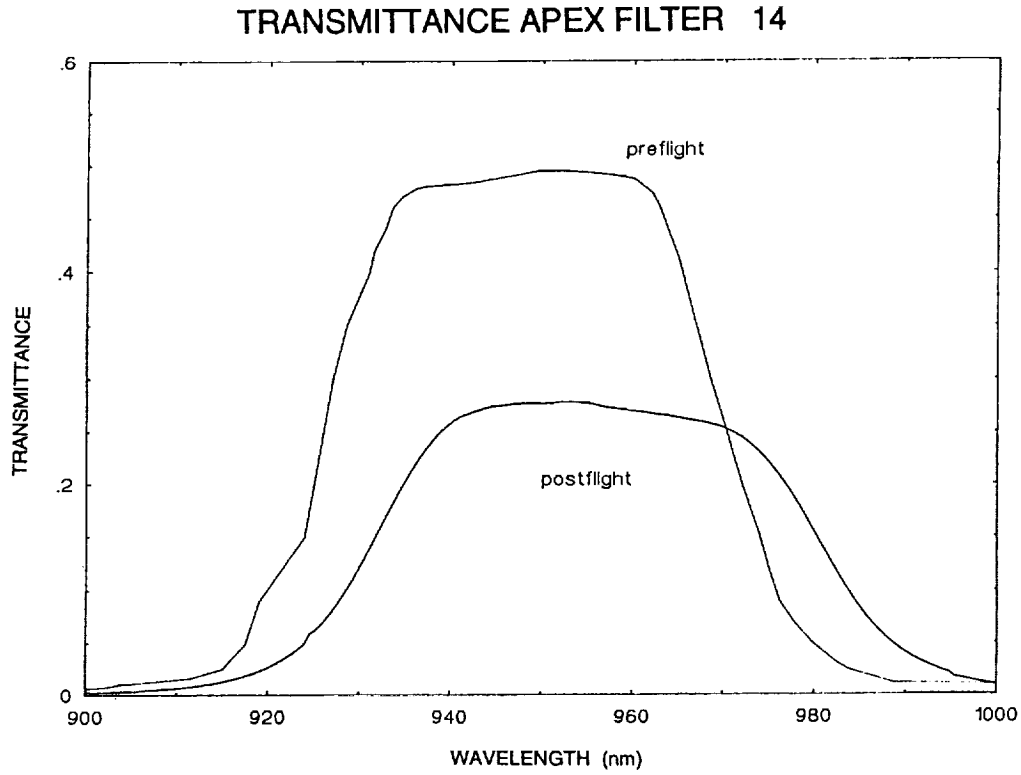


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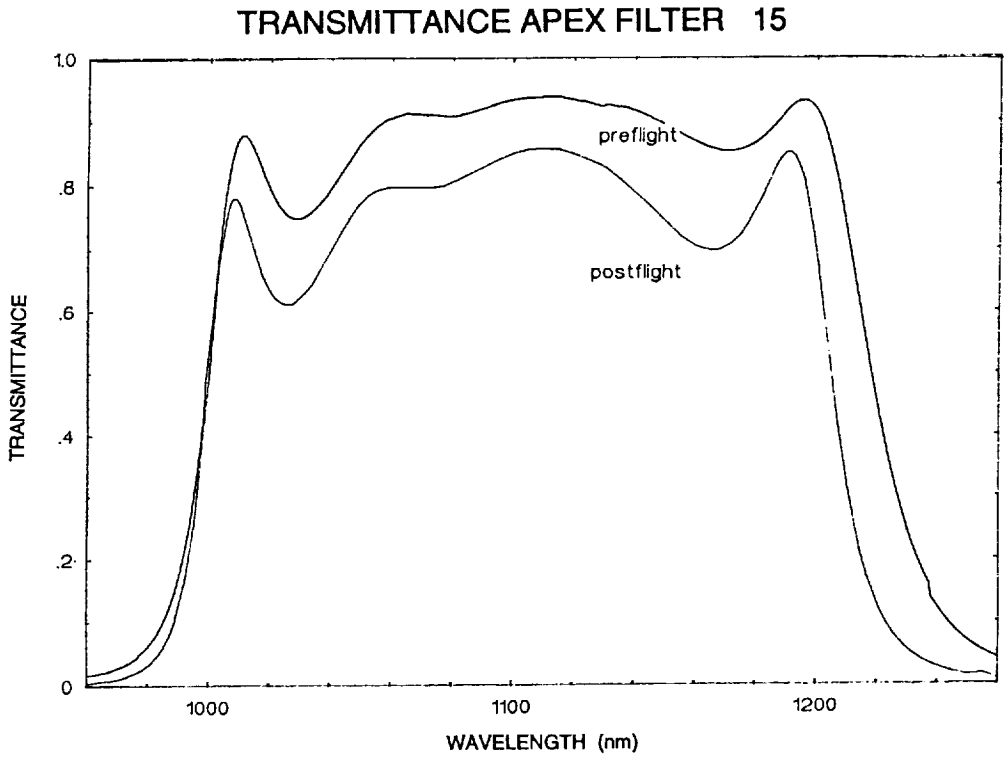


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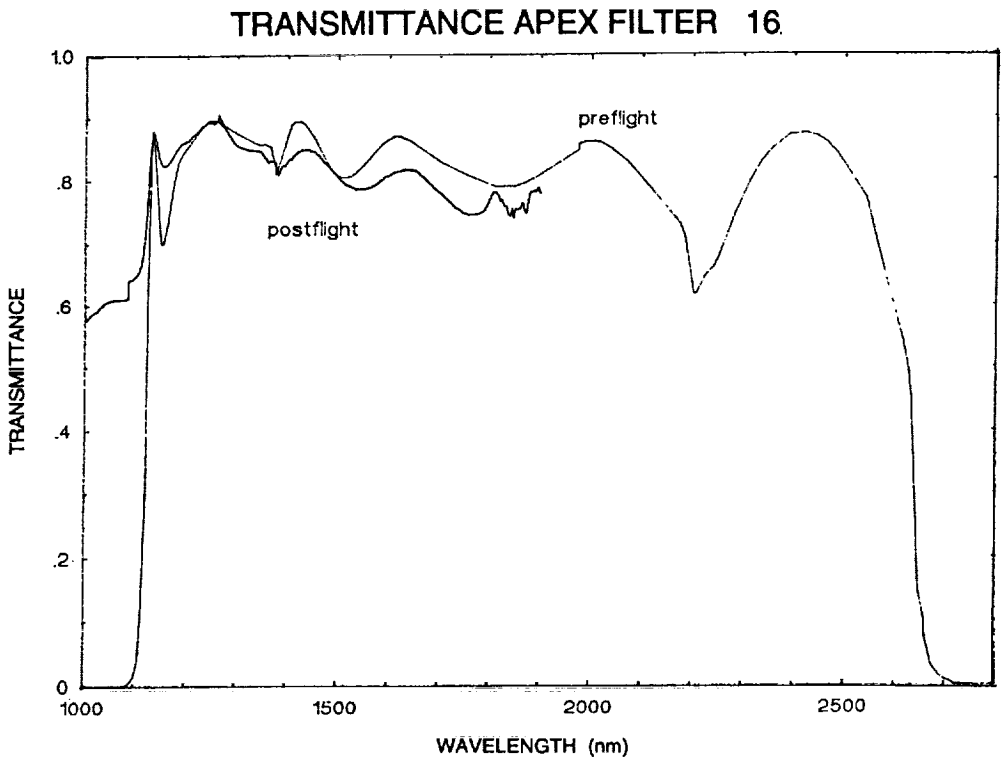
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Figure 17