NISTIR 4711

Optical Performance of Commercial Windows

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NIST
United States Department of Commerce
Technology Administration
National Institute of Standards and Technology

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January 1992
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U.S. Department of Commerce
Rockwell A. Schnabel, *Acting Secretary*
Technology Administration
Robert M. White, *Under Secretary for Technology*
National Institute of Standards and Technology
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Abstract

The role of window system characteristics on privacy-related issues was examined. The optical characteristics of various window materials were measured and compared to determine the best candidates for enhancing building occupant privacy. Strategies for inducing privacy are discussed, along with related performance characteristics of window systems.

Keywords: absorptance, contrast, glazing, privacy, visibility, windows

Executive Summary

This report examines the issue of optical privacy in buildings with windows. The influence of window characteristics and design on the potential for privacy, or conversely, the transmission of visible information through the window is investigated and discussed. Various window systems are characterized through measurement and compared on the basis of their privacy potential.

The key performance characteristic was found to be the ratio of window reflectance to transmittance, with high values indicating greater privacy. While this value varies with wavelength, average ratios of ten or greater were found to be available in certain current window materials. Specifically, both tinted and reflective films and coated glass were found to provide high reflective to transmittance ratios.

Other methods of enhancing privacy included angular (directional) shielding, diffusely transmitting materials, polarization and spectrally selective transmittance. In addition to these privacy issues, other related performance considerations discussed included RF shielding, physical security, durability, energy and daylighting. Future developments, such as switchable glazings and integrated envelope systems are also considered.

This report is intended for building designers or operators who are concerned about potential loss of visual information through the window system. It assumes a basic familiarity with the concepts of transmission and reflection of radiant energy in the UV, visible and IR spectrum. The report presents information which should be useful for specifying window systems to achieve optical privacy without seriously sacrificing other window functions, such as view out and admittance of daylight.

Acknowledgements

The authors acknowledge the support of the sponsor, the Security Evaluation Office, and its project managers, Mr. John Looney and Mr. John Churchill. They also would like to thank Mr. Willard Roberts and Mr. Eric Byrd of the Building Materials Group for their assistance in performing the spectral solar/optical property measurements.

Disclaimer

Certain trade names and/or manufacturers referred to in this report are for the purpose of identification only and do not imply any endorsement by NIST, or recommendation on their behalf.

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1. Introduction

The role of windows in buildings is a varied and important one, including admitting daylight into the building interior, allowing occupants a view of the outside world and enhancing the overall aesthetic qualities of the building. The appropriate use of windows can control building energy requirements for lighting, heating and cooling, and provide psychological benefits, resulting in greater efficiency and productivity. The selection of the appropriate window system for a building requires consideration of the tradeoffs between the various performance characteristics of different alternatives. This ultimately results in an optimization exercise conducted in accordance with occupant needs and priorities.

Typical window performance characteristics include solar-optical properties, such as transmittance and reflectance, thermal transmission, color, durability, first cost, maintenance requirements and security. Security concerns involve visual privacy, physical safety and non-visible electromagnetic radiation transmission. Visual privacy relates to the potential for undesirable view into the building from the outside. Physical safety is associated with penetration through the window, or window breakage, due to projectiles, explosions or geophysical activity. EMR transmission can be a significant issue for security of electronically processed and stored information, particularly computers and CRT displays.

In order to address these window security concerns, a research effort was conducted to evaluate the relevant performance characteristics of commercially available window systems. The primary focus of the project was on the optical performance of window systems as related to privacy and other optical security threats. The objective of the research was to identify and evaluate commercially available window systems relative to their ability to protect against optical security threats.

The project involved seven tasks:

Task 1 Identify the important relevant window performance characteristics and testing procedures

Task 2 Survey commercially available windows and window treatments

Task 3 Select the appropriate window candidates according to the desired performance characteristics

Task 4 Evaluate and test the window candidates to determine their complete performance characteristic profiles

Task 5 Compare and rate the performance of the window candidate

Task 6 Prepare a technical report summarizing the results

Task 7 Perform follow up testing to verify field performance and durability

This report summarizes the results of the research project, including the manufacturers survey, testing and evaluation procedures, and performance characteristics.

2. Visibility, Visual Privacy and Windows

2.1 Visual Information

The lack of visual privacy is best evidenced by the potential for obtaining visual information by way of the window system. Visual information encompasses a wide variety of categories, ranging from printed material, to video terminals to the identity or mere presence of building occupants. All visual information, however, shares a similar basic set of characteristics; namely, visual information is conveyed as a pattern of luminances, colors and shapes. The ability to distinguish visual information is dependent upon the luminance and color contrasts produced by interaction between light sources (both natural and artificial) and illuminated surfaces, and the capabilities of the observer. Visibility is influenced by contrast, light level, size and color, and the adaptation level of the observer. In the completely general case, the observer may have available the means to enhance visibility through optical and/or electronic processes involving magnification, amplification, polarization and image collection and processing. The transfer of visual information from the interior to the exterior of a building by way of the window occurs in two modes as shown in Figure 2.1. In one mode, the task is illuminated by the interior lighting system, causing light to be reflected from the task and out through the window. A CRT or other video display is a specialized case of this, where the task (in this case the screen) generates and emits its own light.

The second mode of information transfer involves light from an exterior source, usually the sun and sky, entering through the window and being reflected off of the task and back out of the window.

There are important differences between the two modes of information transfer as related to optical privacy. These differences center around the spectral composition of the light source, and the spectral reflectance characteristics of the tasks being illuminated. Natural light is relatively broadband in nature, containing energy from the ultra violet through the visible and the shortwave infrared wavelength regions. Clear glass will transmit most of this energy very efficiently. Electric light sources, on the other hand, produce light with different spectral power distribution than daylight. While incandescent lamps emit a broad spectrum of radiant energy peaking in the infrared, fluorescent and HID lamps emit light in much narrower wavelength bands. The luminances of various tasks will depend on the product of the spectral power distribution of the incident light and the spectral reflectance of the task. Thus, a task will look different when illuminated by daylight than when illuminated by electric light, because the spectral content of the reflected light will be different.

In the case of video displays, the visual information is produced by a combination of phosphors which emit light in narrow wavelength ranges (i.e. red, blue, green). The eye interprets various combinations of these phosphor intensities as different colors, although they are actually just combinations of three narrow spectral regions. This is important because it is easier to control narrow wavelength ranges than the entire spectrum.

2.2 Contrast

The most frequently used indicator of visibility is luminance contrast (C), defined as the ratio of the difference in luminance (L) between the background$_B$ and the detail$_D$ to the luminance of the background:

$$C = \frac{L_B - L_D}{L_B} = 1 - \frac{L_D}{L_B}$$

A simple example of this would be a dark circle on a piece of white paper, as shown in figure 2.2. The visibility of the circle would be determined primarily by its contrast with the paper, the size of the circle, and the level of illumination on the paper (or the luminance of the paper). The apparent size of the circle would vary with the distance of the observer, and any optical magnification. For any fixed circle size, however, visibility varies with contrast and background luminance according to a typical relation, as shown in figure 2.3. At low light levels, or low background luminance levels (the luminance of the white paper is the background), higher contrast is needed for equal visibility. As background luminance increases, so does visibility of a fixed contrast target. Conversely, if contrast is decreased, visibility does likewise.

Setting aside for the moment, the potential for enhancing visibility through the use of optical, photographic or other related methods, visibility through a window is dependent on the relative amounts of light reflected from and transmitted through the window, and any physical screening. An observer outside of a building attempting to look through a window will see a combination of light from the building interior attenuated by the transmittance of the window material plus light reflected from the exterior window surface, as shown in figure 2.4. The transmitted light contains the useful information, while the reflected light is noise. In general, privacy is enhanced by controlling or degrading the light transmitted through the window and increasing the light reflected from the window. This can be accomplished by increasing window absorptance, increasing window exterior surface reflectance, as well as various other methods.
The effect of a window on the contrast of a task as viewed from the outside of a building looking in through a window is a function of the window characteristics and the interior and exterior light levels. Applying equation 1, the ratio of contrast from the exterior (C_E) to the contrast from the interior (C_I) can be expressed as:

$$\frac{C_E}{C_I} = \frac{1}{1 + \frac{\rho L_E}{\tau L_B}}$$

where: ρ = window exterior surface reflectance
τ = window transmittance
L_E = exterior luminance
L_B = task background luminance

Exterior luminance is related to exterior light level, while task background luminance is a function of interior light level. The ratio in the denominator of equation 2 summarizes the effect of window characteristics on privacy. When the ratio is large, contrast viewed through the windows is significantly degraded. The ratio can be conveniently separated into two terms, one related to the window, ρ/τ, and one related to the light levels, L_E/L_B. Privacy is enhanced when the ratio of window reflectance to transmittance (ρ/τ) is high, or when the ratio of exterior to interior light level (L_E/L_B) is high.

Window ρ and τ can be selected through a fairly wide range. L_E and L_B can be controlled somewhat, but L_E varies strongly with exterior daylight levels. Exterior light levels can be increased by illuminating the window exterior with electric lights.

Figure 2.5 demonstrates how contrast is reduced due to a window for a range of ρ/τ and L_E/L_B values. Each curve represents a different ratio of exterior to interior light level, while the abscissa corresponds to the ratio of window reflectance to transmittance. The ordinate is the contrast reduction expressed as the ratio of contrast through the window to contrast inside.

At one extreme, when the exterior luminance is 100 times the interior luminance, such as in bright daylight, contrast is reduced to less than 10 percent even for low values of ρ/τ (i.e. clear glass). Under such conditions, a window reflectance of twice the transmittance practically washes out all interior contrasts as viewed through the window.

At the other extreme, when interior luminance is 10 times exterior luminance, such as at dusk, the contrast ratio remains above 50 percent even if the window ρ/τ ratio reaches 10. Of course, the amount of light transmitted would be low for such a window, since tranmittance would probably be less than 10 percent. However, the task contrast would still be there and could be enhanced photographically. After nightfall, contrast reduction by the window would be even less, unless exterior lighting were used.

The importance of window ρ/τ is most apparent at intermediate L_E/L_B values, such as on overcast days or other low daylight conditions. When interior and exterior light levels are equal ($L_E/L_B = 1$), a ρ/τ value of 10 will provide a contrast ratio of about 15%, a significant reduction. At higher light levels the contrast ratio reduction improves. A ρ/τ value of 6 or greater provides a contrast reduction ratio of 20% or less as long as the exterior light level is at least equal to the interior light level.

The ratio of window reflectance to window transmittance will be used later to compare and rate the different window systems. Since the magnitude of this ratio correlates with privacy, it is convenient to refer to it as the privacy index. For complete accuracy, it should be pointed out that ρ/τ varies with wavelength for a particular window system. Thus, contrast reduction will also vary with the spectral composition of light from the task versus the window spectral ρ/τ. Figure 2.6 demonstrates several of the concepts related to spectral transmittance characteristics throughout the ultraviolet (UV), visible (Vis) and infrared (IR) regions, or from 190 to 25,000 nm. Clear glass typically transmits radiant energy from 300 to 5000 nm only, with a maximum transmittance in the spectral range of 380 to 2000 nm. A plastic film will transmit radiant energy beyond 5000 nm. However, if it is installed on a glass surface the combined transmittance will be determined by the product of the individual transmittance. Thus, plastic film on glass will not transmit energy beyond 5000 nm.

A narrow bandpass filter will transmit radiant energy only in a narrow wavelength range, as shown in the figure. If this range does not match the range of the incident radiation, little transmission will occur.

2.3 Enhancing Visual Privacy

Optical privacy can be enhanced in a number of ways, taking advantage of different physical mechanisms, as listed in the following eight general categories:

1. Alter absorptive characteristics
2. Alter reflective characteristics
3. Provide angularly selective transmittance
4. Induce diffuse transmittance
5. Induce polarization
6. Provide spectrally selective transmittance
7. Induce optical noise
8. Provide physical shielding

The potential applicability and effectiveness of these options are discussed below. Inherent in this discussion is the assumption that the window is expected to provide all of the usual benefits associated with its use, including view of the exterior and admission of daylight. Otherwise, it would be a simple matter to achieve privacy by blocking off the window with an opaque material or surface.

3. Mechanisms for Enhancing Window Privacy

3.1 Alter Absorptive Characteristics

Increasing the absorption of light in the window causes a corresponding decrease in the amount of transmitted light, and thus a decrease in transmission of visual information. However, the absorption effect has two important considerations. Lowering window transmittance by increasing absorptance does not alter transmitted contrast. The various interior luminances are reduced in proportion to the absorptance, and since contrast is a function of luminance ratios, it remains unchanged. Also, increasing window absorptance will cause a corresponding decrease in daylight transmission through the window. This may produce a gloomy or otherwise less attractive interior working condition. It should be noted, however, that low-transmittance glazings are routinely used quite successfully, particularly for solar heat gain control.

A characteristic feature of light-absorbing glazing is that the absorption occurs within the material, as opposed to at the glazing surfaces (which is the case for reflectance). The implication is that non-reflective, high-absorptance glazing is identical in appearance from both sides. Such glazings are available in various tints and colors, primarily greys and browns.

3.2 Alter Reflective Characteristics

Increasing window reflectance provides two benefits. First, the window transmittance is reduced, as interior light is reflected back into the room. Second, the amount of light reflected from the window exterior surface is increased, inducing a corresponding increase in the masking effect. This is a very important characteristic because as opposed to the absorptive effect, the reflective effect reduces the contrast of the transmitted light. This occurs because light reflected from the exterior window surface adds an equal amount of luminance to each luminance transmitted through the window. As the reflected luminance increases, such as would occur for high exterior light levels and high window reflectances, the reflected light almost completely obliterates the transmitted light. This is shown in figure 2.4.

An important characteristic of the reflectance effect is that the reflectances of the interior and exterior window surfaces need not be equal. This has important consequences both for privacy and occupant acceptability. One of the drawbacks of high reflectance is that building occupants see themselves and the building interior reflected from the inside window surface. This obstructs their view of the outside. However, if a high reflectance surface is applied to the exterior of a high absorptance glazing, the interior reflectance will be less than the exterior reflectance, due to the absorption of light in the glazing. This effect is demonstrated in figure 2.4. Thus, when it is bright outside, such as during the day, building occupants will see a strong transmitted image of the exterior with a weak reflected image of the interior, while someone outside of the building will see a strong reflected image of the exterior with a weak transmitted image of the interior.

3.3 Provide Angularly Selective Transmittance

Angularly selective transmittance refers to the use of a physical device such as a screen or louver which has a transmittance which varies with incident angle. This is shown schematically in figure 3.1. Such screens are available at various angles, with a range 10 to 20 louvers per inch. They have been widely used for solar control. Their main advantage is that they completely prevent view into a building above a certain cut-off angle. This would prevent, for example, any view of desktops or low-lying objects. However, this also prevents building occupants from being able to see the sky.

3.4 Induce Diffuse Transmittance

Introducing diffuse transmittance to the window system dramatically enhances privacy, while at the same time greatly degrading the ability of the occupants to see out of the window. Daylight transmission, however, is not significantly reduced, and its distribution is improved. One potential compromise between privacy, daylight and view would be to provide a small area of non-diffuse glazing together with larger areas of diffuse glazing.

3.5 Induce Polarization

Incorporation of polarizing filters in the window system may have some potential for enhancing privacy. While light from the interior could be polarized upon passing through the window, it would still be visible to an external observer. However, if the interior light, including sources and reflections, could be cross-polarized to the window, a significant reduction in transmittance could be achieved. It is possible that room light could be somewhat polarized through the use of radially polarizing lenses, which are commercially available, in combination with a positioning of interior reflecting surfaces to maintain proper cross-polarization with the window.

One promising use of polarization would involve polarizing filters on CRT display screens. If these were cross-polarized with the windows, transmittance of images on the CRT screen would be significantly reduced.

3.6 Provide Spectrally Selective Transmittance

This technique is based on the concept that light from the exterior consists of a broad-band spectrum, while interior light sources can be designed and selected to emit in narrow bands. Thus, for example, the window system could be designed not to transmit the wavelengths emitted by the light sources, but still transmit the other wavelengths. This would significantly reduce the ability of an exterior observer to see inside the building, while still allowing the building occupant to see out.

It would still be possible for some light to pass through the window, since light from the exterior could illuminate interior objects and be reflected back out of the window. This would only be a concern during daylight hours. In fact, a major advantage of this technique is that it would work very well at night, when it is otherwise difficult to achieve visual privacy. When the light in the room is due solely to the lighting system, the room would appear nearly dark from the exterior.

This technique would work equally well with the lighting system and CRT displays. Both fluorescent lamps and CRT screens depend on phosphorescent materials to generate light. These phosphors usually emit in narrow wavelength bands. It should be possible to develop window materials, coatings or films to absorb or reflect preferentially in wavelengths being emitted by the phosphors, thus reducing the transmittance of visual information in those wavelengths. The lamps, CRT's and windows would need to be tailored as a combination to achieve this effect. Figure 3.2 demonstrates the technique, where the light source emits in narrow band, while the window transmits in other regions.

The selective transmittance of the window system would have some affect on the color appearance of the exterior as seen from the interior. The significance of these effects would need to be investigated, but in general the blocking of a few wavelength bands should not create an objectional view of the outside.

3.7 Induce Optical Noise

This technique is very promising and is based on the principle of increasing the amount of light being reflected from the exterior surface of the window by artificially boosting the amount of light falling on the exterior building surface. A simple example of this technique would be to floodlight the building. Since the reflected light tends to obscure the transmitted light, it can be termed optical noise.

A variation on this technique would be to floodlight adjacent buildings, which would have the effect of creating more reflections in the windows of the building of interest. Since windows are specular reflectors, meaning that they reflect in a mirror-like fashion, the exterior light sources should be positioned throughout a range of incident angles so that the resulting reflected light will not be confined to a narrow angular region. This would be the case if the exterior lights were positioned only at the base of the building and oriented to wash the building facade. Under such conditions, most of the reflected light would be reflected upwards rather than towards any potential viewing sites.

3.8 Provide Physical Shielding

Physical shielding is the simplest and least flexible privacy options. Examples would be fins, overhangs, ledges and shutters. While having significant privacy potential, they also inhibit the view of the exterior by the building occupants. Combining physical shielding with optical noise could provide an acceptable compromise, since light could be diffusely reflected from exterior window ledges and fins to enhance privacy.

4. Window Product Survey

A survey of commercially available window systems was conducted, to determine the scope of product availability. Manufacturers were contacted and product literature was obtained. Relevant manufacturers were determined from the appropriate registers, industry contacts and consultations with other researchers. Approximately 100 manufacturers and distributors were contacted.

Appendix A contains a listing of window system sources. This list includes those sources for window products determined to be useful for optical privacy. Also included on this list are products primarily marketed for physical security, but which also have beneficial optical privacy characteristics.

The product literature from the manufacturers and distributors was reviewed with the intent to select the best candidates for optical privacy. The original plan was to select about a dozen candidates for detailed measurements. However, the limited nature of the product literature and the large number of products encouraged a revision of this plan to include a larger number of samples for laboratory measurement and evaluation. In this manner, a larger range of products and characteristics could be evaluated.

A number of material samples were obtained for laboratory measurements. These included both products believed to possess desirable characteristics, and others for comparison. Product samples included glass, plastic films, screens and fabrics.

4.1 Scope and Range of Available Products

A number of different window systems are available, but they can be divided into four categories:

- glass or coated glass
- glass with plastic film
- glass with screen
- glass with blind or drape

Each window system has unique characteristics, features and applications. As shown in figure 4.1, glass or coated glass is durable. It is available in various transmittances (τ), reflectances (ρ) and absorptances (α). Its

properties are fixed (i.e. can't be changed routinely). If coated with a metallic layer, it can control RF transmission.

Glass with film, as shown in figure 4.2, is similar to coated glass in that τ, ρ and α can be selected. While the plastic film is not as durable as glass, it can last over 10 years, and makes the glass shatter resistant. It can help reduce UV damage from sunlight and control RF transmission. An attractive feature of plastic film is that it can be installed on existing windows at less cost than window replacement. It can also be removed, although with some effort.

Figure 4.3 shows glass with screen. Exterior screens are usually fixed and frequently louvered or woven mesh. They can be used to retrofit a window and can be removed. They shield the window from impacts, but do not prevent glass from shattering.

Figure 4.4 shows glass with blind or drape. Their key feature is that they are operable, can provide nearly complete privacy, at the expense of blocking view and light. They are very flexible in application and operation.

4.2 Typical Product Information

Manufacturers typically provide visible and solar transmittance data for their products. Reflectance values may also be available, along with energy-related characteristics such as thermal transmittance (U-value) and shading coefficient.

5. Laboratory Measurements

A detailed series of measurements was conducted on each material sample. The measurement variables were transmittance, reflectance and absorptance as functions of wavelength in the ultra-violet (UV), visible (VIS) and infrared (IR) wavelength regions. Three different measurement systems were used to cover the total wavelength range of interest. Figure 2.6 shows the wavelength ranges of the measurement systems, and a typical spectral transmittance curve.

5.1 Ultra-violet measurements

Total (diffuse and direct) transmittance was measured in the range of 190 to 750 nm. The wavelength range includes both ultraviolet and the shorter visible wavelengths.

5.2 Visible Measurements

Specular transmittance and reflectance were measured in the range of 300 to 2150 nm, which covers the entire visible spectrum. This measurement overlaps the UV-visible instrument data, but differs in that it is directional in nature rather than total. Since most glazing materials are primarily specular transmitters and reflectors, total and specular transmittance will be similar. If a material is substantially inhomogeneous or anisotropic (such as a mesh or louver) specular and total optical characteristics will differ.

5.3 Infrared Measurements

Specular infrared transmittance was measured over the range of 2040 to 25,000 nm. This slightly overlaps the upper part of the visible region, and includes both the short and long-wave infrared.

6. Evaluation of Laboratory Measurement Results

The results of the laboratory measurements of spectral transmittance and reflectance are presented in a series of figures. Each sample is represented by four figures, covering a different spectral range (wavelength) or, in the case of the solar spectrum measurements, separate plots for transmittance and reflectance.

The material samples are identified by a two letter code for reference purposes. Table 1 lists the material sample code, material description, and the figure numbers for the results for each material. The various materials are grouped according to general type, first the screen and shade materials, followed by the clear glass sample, the plastic film and the coated glass materials.

Table 1

ID Code	Material Description	Figure Numbers
AA	louvered solar screen	6.1 a,b,c,d
AB	louvered solar screen	6.2 a,b,c,d
AC	woven screen, white	6.3 a,b,c,d
AD	woven screen, gray	6.4 a,b,c,d
AE	woven screen, gray	6.5 a,b,c,d
AF	clear iron glass	6.6 a,b,c,d
AG	plastic film, smoke	6.7 a,b,c,d
AH	plastic film, silver	6.8 a,b,c,d
AI	plastic film, silver	6.9 a,b,c,d
AJ	plastic film, bronze	6.10 a,b,c,d
AK	plastic film, smoke	6.11 a,b,c,d
AE	plastic film, gold	6.12 a,b,c,d
AM	plastic film, bronze	6.13 a,b,c,d
AN	plastic film, bronze	6.14 a,b,c,d
AO	plastic film, silver	6.15 a,b,c,d
AP	plastic film, gray	6.16 a,b,c,d
AQ	plastic film, smoke	6.17 a,b,c,d
AR	plastic film, bronze	6.18 a,b,c,d
AS	plastic film, smoke, ribbed	6.19 a,b,c,d
AI	plastic film, clear, ribbed	6.20 a,b,c,d
AU	plastic film, smoke	6.21 a,b,c,d
AV	plastic film, tan, diffuse	6.22 a,b,c,d
AW	plastic film, gray, diffuse	6.23 a,b,c,d
AX	plastic film, bronze	6.24 a,b,c,d
AY	plastic film, silver	6.25 a,b,c,d
AZ	plastic film, silver	6.26 a,b,c,d
BA	plastic film, bronze	6.27 a,b,c,d
BB	plastic film, silver	6.28 a,b,c,d

BC	plastic film, silver	6.29	a,b,c,d
BD	plastic film, bronze	6.30	a,b,c,d
BE	coated glass, bronze	6.31	a,b,c,d
BF	coated glass, silver	6.32	a,b,c,d
BG	coated glass, silver	6.33	a,b,c,d
BH	coated glass, silver	6.34	a,b,c,d
BI	coated glass, bronze	6.35	a,b,c,d
BJ	coated glass, bronze	6.36	a,b,c,d
BK	coated glass, bronze	6.37	a,b,c,d

A detailed description of the measurement results is difficult due to the large amount of data. Rather than trying to proceed with a sample-by-sample description of the measurement results, the significant results will be highlighted in the following sections. Particular emphasis will be given to the material characteristics which have beneficial privacy aspects, and to the comparison of different window products.

6.1 Potential for Enhancing Privacy

The starting point for privacy evaluation is clear glass (sample AF). As can be seen in figures 6.6 a through d, clear glass is highly transparent from about 300 to 3000 nm. This wavelength range extends from the upper UV through the near infrared. Between 3000 and 5000 nm, clear glass gradually becomes opaque and remain so up to 25,000 nm. Thus, if the window system includes at least a single glass pane, as nearly all windows do, radiation can only be transmitted in the wavelength range between 300 and 5000 nm. Of course, glass may be transparent to EM radiation outside of the range measured, such as microwaves, radio waves and x-rays etc., but these are not of concern for optical privacy. If two or more window materials are combined, the overall transmittance at any wavelength will be the product of the individual transmittance at that wavelength. The spectral transmittance of the window composite will be the product of the individual material spectral transmittance.

Clear glass has a very low reflectance, less than ten percent, and a fairly consistent spectral transmittance of about 85 percent in the visible region, and about 70 percent for the shortwave spectrum.

The screen materials, identified by codes AA through AE, generally have low reflectances, and moderate to low transmittance depending on the density of the weave and color. Screens AA and AB are miniature louvers. These provide total shielding of view for angles greater than about 20° above the horizontal. Sample AC is a dense, nearly translucent woven material, which appears to be opaque from a distance, but actually preserves an image of the exterior when viewed from a short distance. Samples AD and AE are more loosely woven materials.

A number of plastic films were tested, covering a wide range of characteristics. The films, which are designed to be adhered to glass, can consist of clear or tinted layers with reflective coatings. Laminated films are available, consisting of multiple layers with different properties. Materials can be obtained in different colors, and with different solar/optical properties. The absorptance of a film is determined by the amount of tint, while the reflectance is controlled by the nature of the metallic coating.

As far as the effect on transmittance, a tinted film will have a low-transmittance at visible wavelengths, but not in the shortwave IR region. A metallic coating will cause the opposite effect. A combination of the two will provide for the lowest overall transmittance. A number of films were found to exhibit these characteristics. Samples AI, AJ, AL, AO, AR, AY, and BB had the lowest transmittances. The spectral transmittance signature of each sample differed as a function of their tint, color and metallic coating. Keep in mind that each film was tested without being mounted on glass, so that the film properties alone could be determined. However, in an actual installation, the film on glass transmittance would be lower than the film only, in proportion to the glass transmittance. In particular, the presence of the glass would significantly reduce UV and IR transmittance.

Regarding the coated glass samples, most of these were found to have low transmittances, as they were selected for that reason. Samples BE, BH, BJ and BK showed the best performance.

A few special samples are worth mentioning. Samples AV and AW are diffusing plastic films which transmit light but do not preserve an image (similar to frosted glass). Samples AS and AT are ribbed for extra strength. These materials may be useful for special applications.

6.2 Intercomparison of Products

As was shown previously in equation 2, a primary indicator of optical privacy potential is the ratio of window reflectance to transmittance, or privacy index. Based on the measurement results, this ratio was computed for each of the sheet materials (i.e. not the screens or shades) as a function of wavelength. The average ρ/τ was calculated for each material both over the wavelength range of 300 to 2150 nm, and over the visible wavelength range. Since most optical information is visible in nature, the value of average visible privacy index is probably the best metric to use to compare the different samples.

Table 2 summarizes the ρ/τ results, and lists the spectral ρ/τ plot figure numbers for each sample. The plots are found in figures 6.38 through 6.69. The samples are ranked according to their average visible privacy index values. It should be noted that the privacy index values for the films would be higher if they had been mounted on glass. However, even without that consideration, plastic film samples AY and AL had the highest visible privacy index, followed by coated glass samples BJ and BK, ranging from about 7.5 to 10.7. In all, seven samples had visible privacy index greater than 5, which indicates good privacy potential. By comparison, clear glass has a visible privacy index of 0.1. The coated glass materials had the highest total privacy index values, ranging almost up to 60. This is due to their low UV and IR transmittances, so the film on glass performance would be similar.

Table 2					
Code	Figure #	Visible Privacy Index	Ranking	Total Privacy Index	Ranking
AY	6.57	10.66	1	16.07	5
AL	6.40	10.[illegible]7	7	11.37	18
BI	6.40	8.219	3	36.92	2
BA	6.40	7.484	4	59.63	1
AJ	6.40	7.055	5	13.16	16
BE	6.63	6.713	6	17.00	4
AI	6.40	6.467	7	12.64	11
BI	6.62	5.207	7	15.26	7
AO	6.40	4.503	8	13.65	9
AR	6.50	4.396	8	15.45	9
BE	6.40	[illegible].74[illegible]	10	14.58	8
BH	6.66	3.681	10	21.43	3
BF	6.64	3.592	12	6.694	21
AH	6.40	3.312	18	10.44	16
AW	6.55	3.127	16	8.740	16
BC	6.61	2.970	15	5.693	23
BA	6.62	2.782	16	7.691	20
AZ	6.57	2.366	12	10.75	15
BA	6.63	2.354	18	8.895	18
AX	6.66	2.329	10	11.10	14
AG	6.39	1.635	28	11.57	12
BG	6.65	1.593	21	3.048	27
AN	6.40	1.381	22	3.168	20
AM	6.40	1.326	23	9.628	12
AK	6.43	1.309	24	3.476	25
AS	6.51	1.285	25	6.245	22
AU	6.53	1.132	26	7.950	11

AP	6.48	1.066	27	4.388	24
AV	6.54	0.3760	28	2.209	28
AQ	6.49	0.3255	29	1.178	30
AT	6.52	0.1757	30	1.495	29
AF	6.38	0.1053	31	0.2446	31

7. Selection of Most Favorable Candidates

The window characteristics which enhance privacy can be obtained in a number of different products. The basic beneficial properties of low transmittance and high exterior surface reflectance can be embodied in tinted and/or coated glazings and plastic films. The choice of a particular window system will depend in a large part on the specific application, particularly whether for new construction or retrofit of existing windows.

Before proceeding with the discussion of the most favorable candidates for window privacy, the performance of shades, blinds, drapes and other similar products should be mentioned. It is obvious that fully drawn, opaque products such as these provide a great deal of privacy. Even a clear window will provide privacy when the blinds are closed. Such products have the advantage that they are operable and can be controlled and deployed by the occupants when required. The following discussion is based on the best way to obtain privacy <u>without</u> necessarily having to cover the window. It is understood that shades, blinds and drapes might be available and be deployed when needed.

The situation is similar for exterior fixed screens and louvers, although they are not operable. These products prevent a view into the building from certain exterior locations, typically above a particular angle relative to the horizon. Window transmittance is zero above a certain angle, and increases to a maximum when looking into the building at the same angle as the louvers. This has the advantage of preventing the view of desk type, for example, but still affords a view of occupants and other objects. It also restricts the view of the sky for building occupants. Fixed devices such as these might be combined with privacy glazing to provide an extra measure of optical privacy.

7.1 New or Replacement Windows

In the case of a new building, or an existing building which is going to have the windows totally replaced, a great deal of flexibility is available for window system selection. The main limitations are integration with the architectural scheme of the building. Coated and tinted glazings are the most favorable candidates for this application, since they provide both privacy and durability. Examples of these would include samples BJ, BK, BE and BI. All of these glazings have very low transmittances and high exterior surface reflectances. Glazings with similar characteristics are available from other manufacturers.

7.2 Retrofit of Existing Windows

Options are more limited when dealing with retrofit applications. If the glazing is not being replaced, the characteristics of the existing glazing can be altered by installing a window film. Examples of effective privacy plastic films are samples AY, AL, AJ and AI, all exhibiting low transmittance and high exterior side reflectance.

There are some additional considerations involving the installation of tinted or highly absorbing films on existing windows. Clear glass does not absorb much solar energy, thus does not experience a large rise in temperature when irradiated?. Tinted films, however, absorb solar radiation and transfer a great deal of the heat to the glass to which they are adhered. This can result in significant thermal expansion. If the window frame cannot accommodate such expansion, glass breakage can occur in some instances. This issue should be investigated before installing heat absorbing film on existing windows.

There is also the slight possibility of glass cracking when a shadow line falls on the window, leaving part of the glazing in shade and part in the sun. The resulting thermal stresses have, on rare occasions, caused cracking of the glass. This is a difficult problem to predict, and the original window manufacturer should be consulted before installing the window film, if possible.

8. Related Window Performance Considerations

In addition to the window performance characteristics already discussed, a number of other window attributes are of interest. These other attributes are related to the transmittance of wavelength outside of the UV-Visible-IR range, physical properties, durability and energy factors. Even if privacy is the major criterion for selecting a window system, other performance characteristics should be considered to avoid any unacceptable side effects associated with the window. These other performance considerations are described below.

8.1 RF Shielding

The possibility of the transmittance of radio frequency (RF) radiation is a privacy and security issue. Electronic equipment, such as computers, CRT displays printers and communication devices, may emit radiation, radio or other wavelengths. The potential exists for information to be obtained from outside the building through reception and subsequent processing of these signals. Some window systems can significantly reduce the level of RF transmission. This capability is implemented through the use of a conductive metallic layer covering the entire window. The metallic layer must be in electrical contact with a similar barrier enclosing the entire room.

Normally available window systems will not totally block all RF radiation. Metallic coatings on glass or films have been shown to attenuate RF radiation by 20 to 60 dB over a frequency range of 100 KHz to 1 GHz. By comparison, a dense wire mesh can provide an attenuation of 60 to 80 dB over the same frequency range.

The electrical conductance of the metallic layer is the critical factor in determining shielding effectiveness, with higher conductance being better. Higher conductance is achieved by using thicker metallic coatings or metals with higher intrinsic conductances.

8.2 Physical Security

This performance characteristic is related to the ability of the window system to resist breakage due to projectiles or other means. Physical security can be enhanced through the use of strengthened or extra-thick glass, plastic films, exterior screens or shielding.

Strengthened glass is available with low visible transmittance, typically for special security applications, such as jails or guard houses. However, it is expensive, heavy and may not be adaptable to typical building envelope applications.

Plastic films on glass can reduce the chance of breakage and eliminate shattering. While not as strong as security glass, the plastic film or glass does not add significantly to the weight of the window, and is relatively inexpensive.

Services mounted on the window exterior, such as screens or louvers, can deflect projectiles, but will not prevent the window glass from shuttering once the screen is penetrated. They are usually more costly than plastic films, and harder to install.

8.3 Durability

Durability is always a concern with building components both from the perspective of performance degradation and cost of failure and replacement. Exposure to solar radiation, temperature extremes, wind and weather will eventually degrade most materials. While clear glass is relatively durable and does not suffer from serious aging problems, coatings, plastic films and fabric screens may be more susceptible to durability problems.

Another aspect of durability is related to scratch resistance of films and coatings during cleaning operations or other occupant activities. If a material, such as a film, is susceptible to scratching or abrasions, special care or cleansing instructions are provided and should be followed.

In general, plastic films on glass will last from five to ten years, with a number of installations still providing good service for longer periods. These materials are, however, usually warranted for three to five years. Advances in materials science has produced more durable films, but their long term performance is difficult to predict for the wide range of environmental conditions which are found in the various building installations.

The question of durability and weathering is being investigated in a subsequent phase of this project and will be reported on in the future.

8.4 Energy and Daylighting

Energy considerations are frequently of great interest when selecting building window systems. Windows allow heat transfer due to interior-exterior temperature differences, adding to building cooling and heating loads. Windows also admit sunlight, which adds to cooling loads and reduces heating loads, and daylight, which reduces lighting energy requirements.

When privacy is the major concern the energy implications of the window system are not so important. The low transmittance windows which provide privacy will not allow a great deal of solar heat or daylight gain. Thermal heat transfer, however, is not a function of transmittance but rather a function of thermal conductance. Lower thermal conductance is almost always beneficial for a window, since thermal heat transfer through the windows is usually undesirable. Window thermal conductance can be lowered by using multi-paned or gas filled glazings. Low emittance coatings also reduce thermal heat transfer. The metallic coatings used to provide privacy can also function as low emittance surfaces, providing a dual benefit.

The selection of the optimum window characteristics from an energy performance standpoint is a complex problem, usually solved by detailed computer simulations. Geographical location, building type, occupant factors and energy sources all must be considered in such an evaluation. When privacy is the major concern, if two window systems are nearly equivalent, the one with the lower thermal conductance should be selected.

9. Future Developments and Considerations

The development of new and improved materials is having a significant impact on window systems. This is particularly true for materials which possess the capability of changing their optical properties in response to external stimuli. Also, window systems can be controlled as part of an integrated building envelope system. Both of these concepts could enhance privacy by allowing adjustment of window characteristics to suit the situation.

9.1 Switchable Glazings

At the leading edge of window technology are the switchable glazings. these materials change their optical properties in response to external conditions. For window privacy applications, electrochromic materials are most promising. These are essentially large area liquid crystals which transmit light diffusely unless an electric field is applied, in which case they become nearly clear. They have a slight tint of gray or yellow when energized, but completely block image transmission when not energized. When privacy was desired, they could be switched off allowing only diffuse transmission of light.

The main drawbacks of electrochromic windows are their price, currently about $15 per square foot, and the fact that they can only be manufactured in small sizes. Also, the control equipment is an additional expense. Thus a typical large office window might cost as much as one thousand dollars to obtain and install.

Another switchable glazing type is photochromic. This type of glazing turns darker in bright light. The privacy benefits of photochromic windows are limited since transmittance increases with lower exterior light levels. This would cause the interior light transmitted through the window to increase relative to the exterior light reflected from the window. As has been discussed previously, privacy is enhanced when the opposite occurs, namely, low transmittance and high reflectance.

9.2 Integrated Envelope Systems

This concept is based on operable window systems with controls. The control system could sense the exterior and interior conditions and adjust the window system to meet user requirements. Examples of this type of technology would include motorized shades or drapes, adjustable blinds or louvers and automatic shutters.

While these techniques are particularly effective, they do require complex control equipment and mechanisms. Their main drawbacks are cost and maintenance considerations.

10. Conclusions

A survey and evaluation of currently available commercial window systems revealed a number of products which can be used to enhance privacy. For a fixed system, low transmittance and high exterior surface reflectance is the best basic system. Tailoring the spectral transmittance to attenuate wavelengths emitted by interior lights and equipment provides additional privacy. Physical shielding and angularly sensitive transmittance is particularly effective for preventing a view of the building interior from specific exterior locations.

The best optical characteristics can be obtained from either coated glass or plastic films.

In the case of new construction, coated glazings can be used to provide privacy. For existing buildings, windows can be retrofitted with plastic films or coated glazings can be used at a greater expense. A coating or film with high electrical conductance, if properly installed, can be an effective shield for RF and microwave transmission, attenuating such radiation by 20 to 60 dB.

Switchable or operable window systems can provide even greater privacy, but are costly to obtain, install and maintain.

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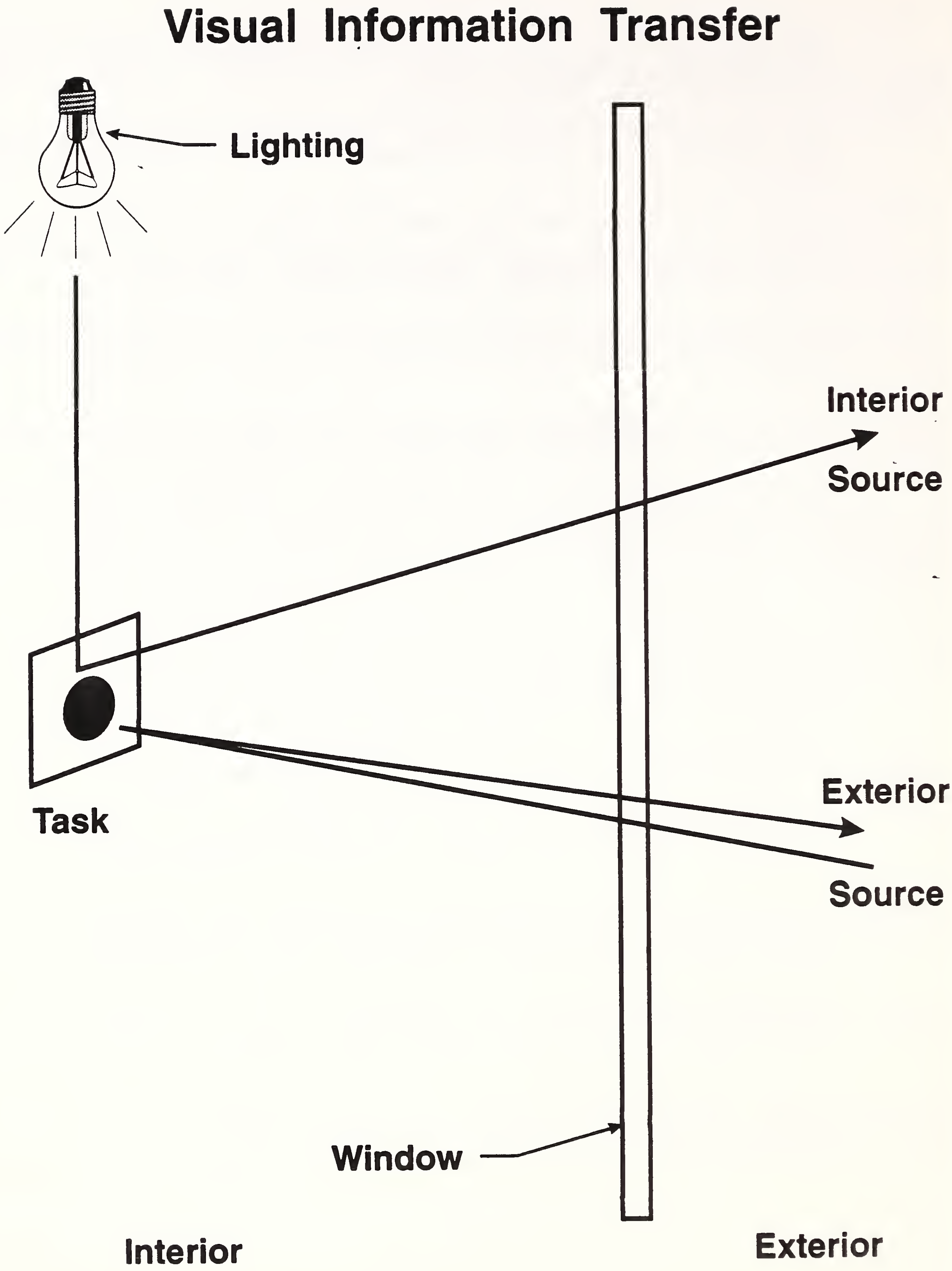
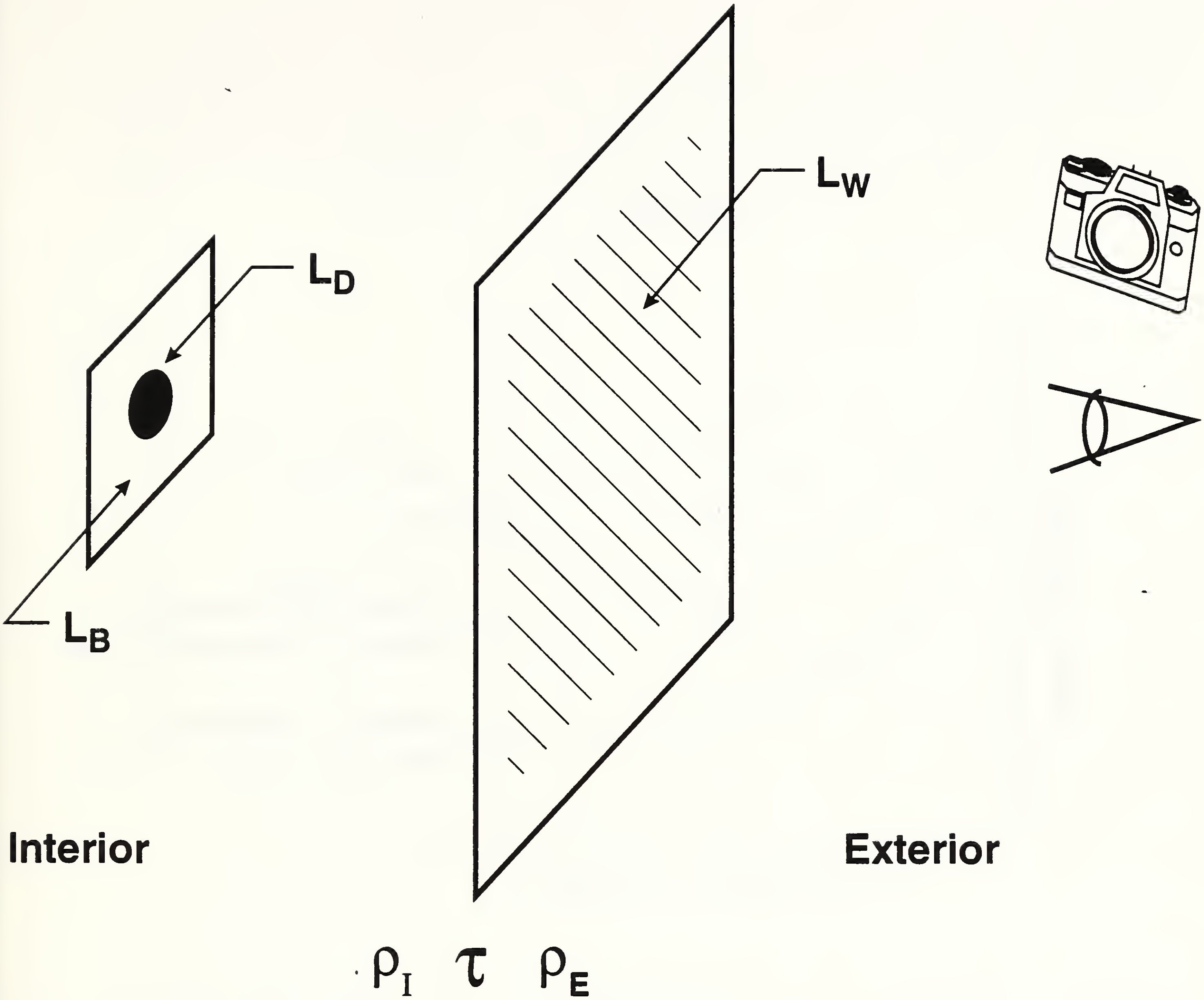


Figure 2.1 Modes of visual information transfer



ρ_I - interior window surface reflectance

ρ_E - exterior window surface reflectance

τ - window transmittance

L_B - task background luminance

L_D - task detail luminance

L_W - window luminance

Figure 2.2 Task and window luminance

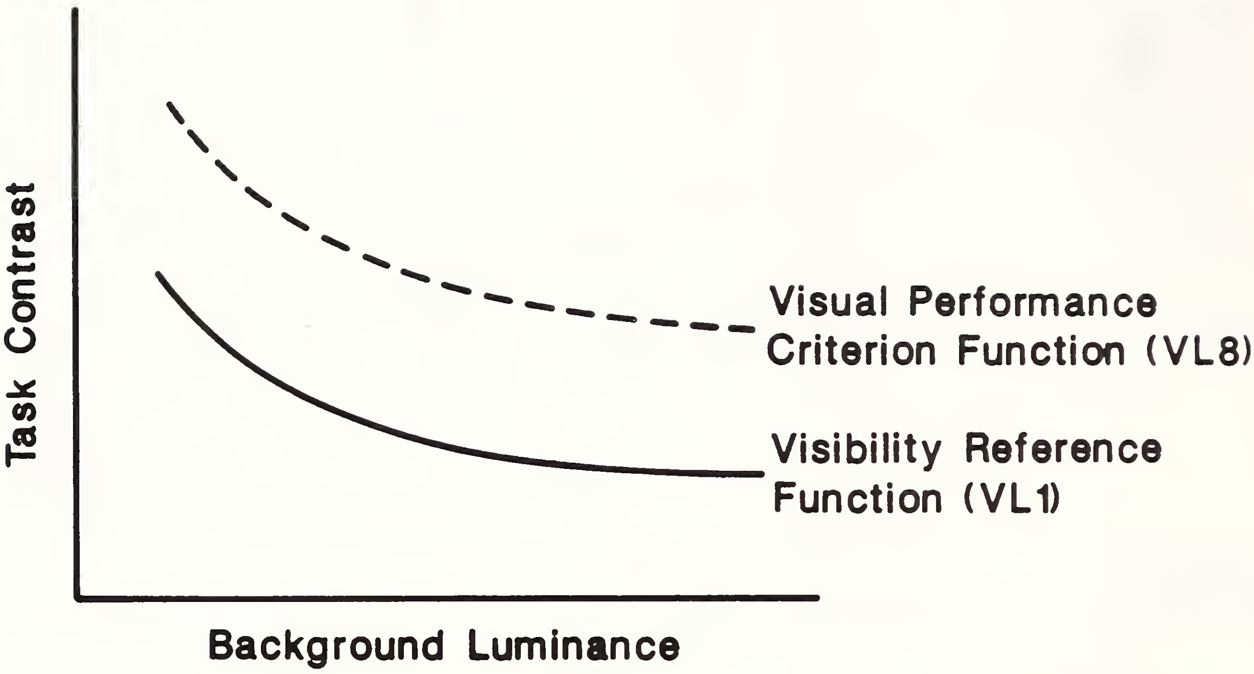
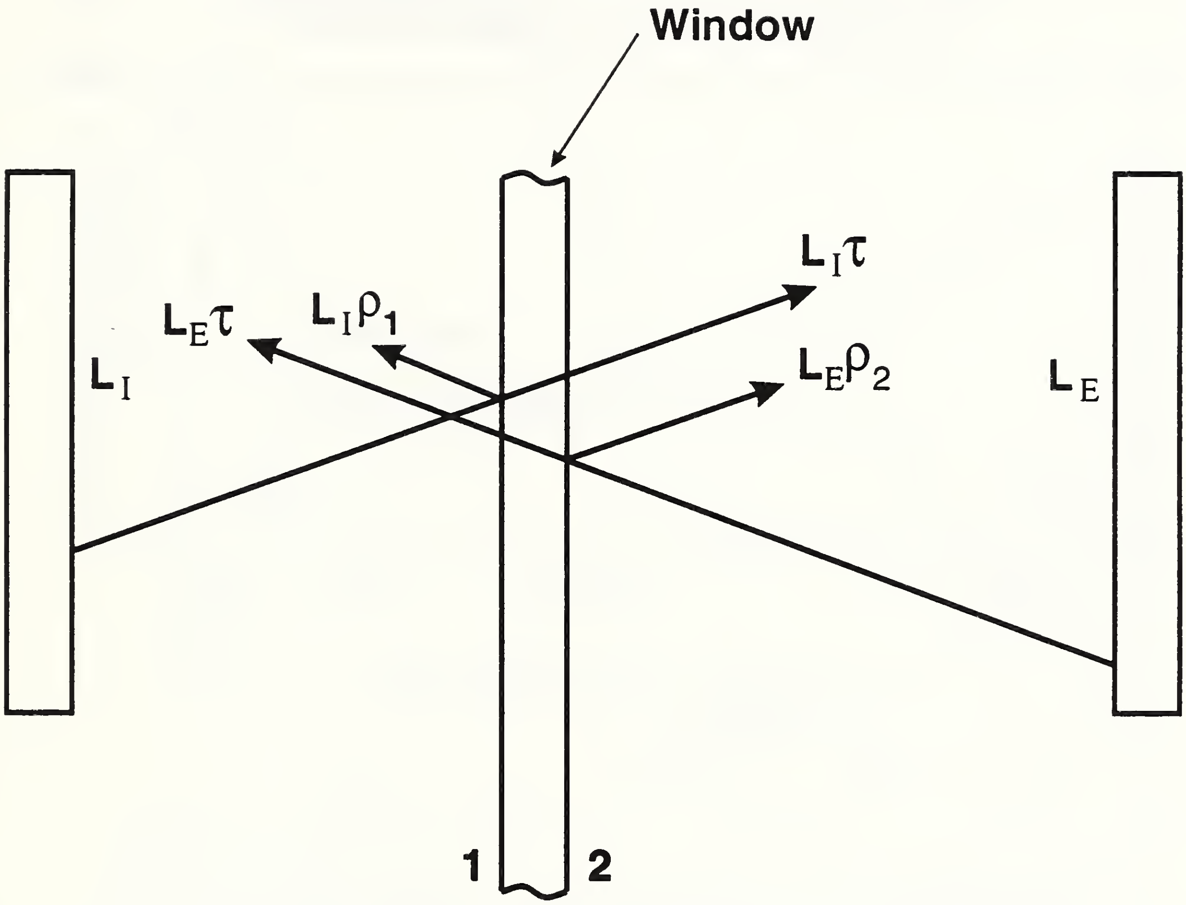


Figure 2.3 The effect of contrast and luminance on visibility



L_I - interior luminance τ - transmittance L_E - exterior luminance

ρ - reflectance

α - absorptance

Figure 2.4 The effect of a window on transmitted and reflected light

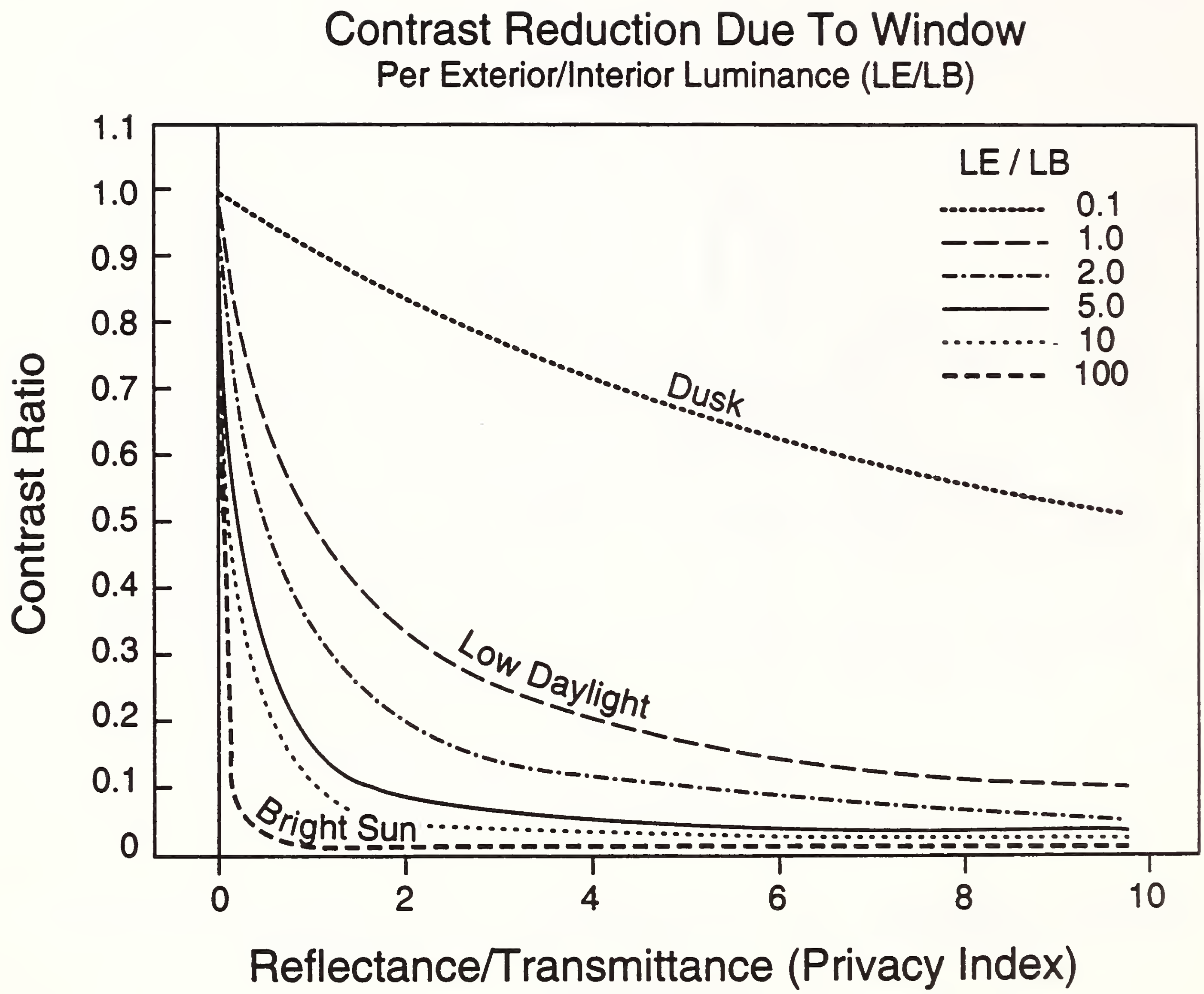


Figure 2.5 Contrast reduction due to a window

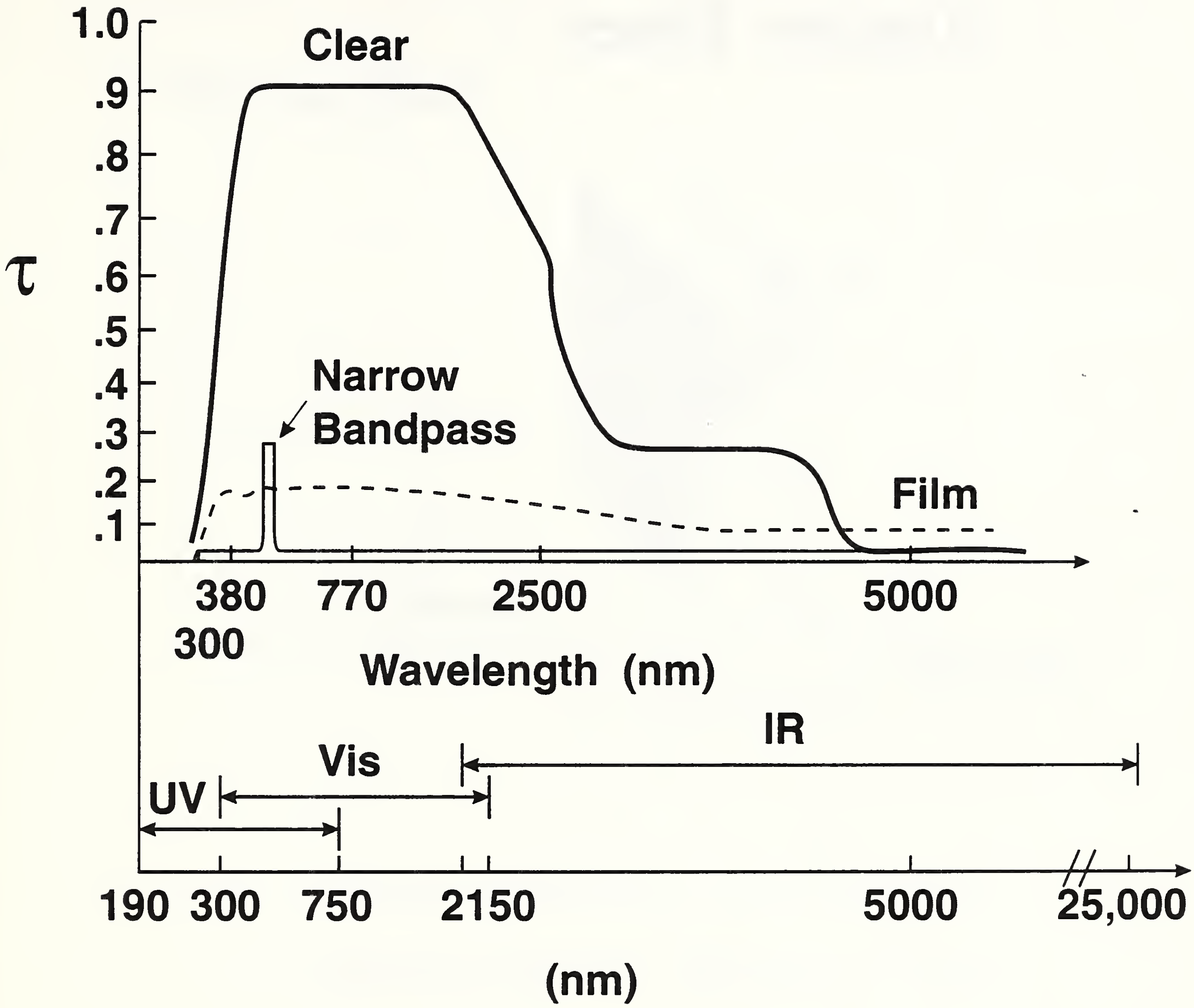


Figure 2.6 Spectral transmittance and wavelength ranges

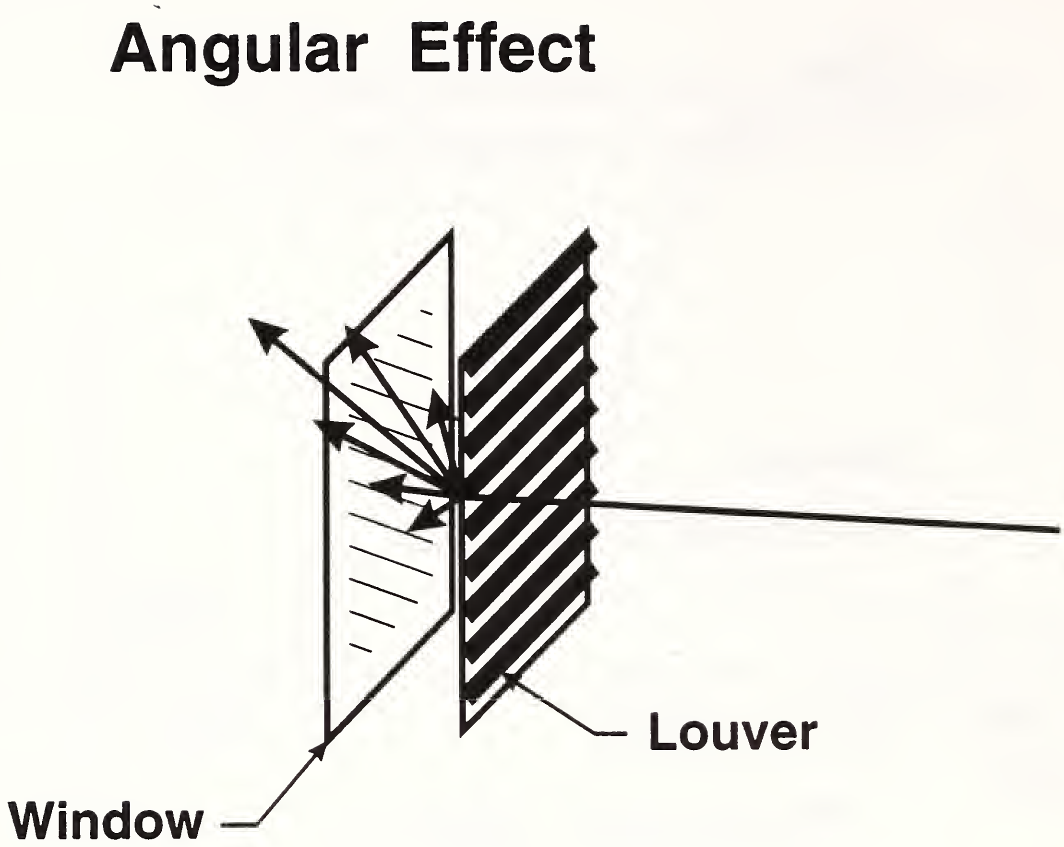


Figure 3.1 The effect of angularly selective window systems

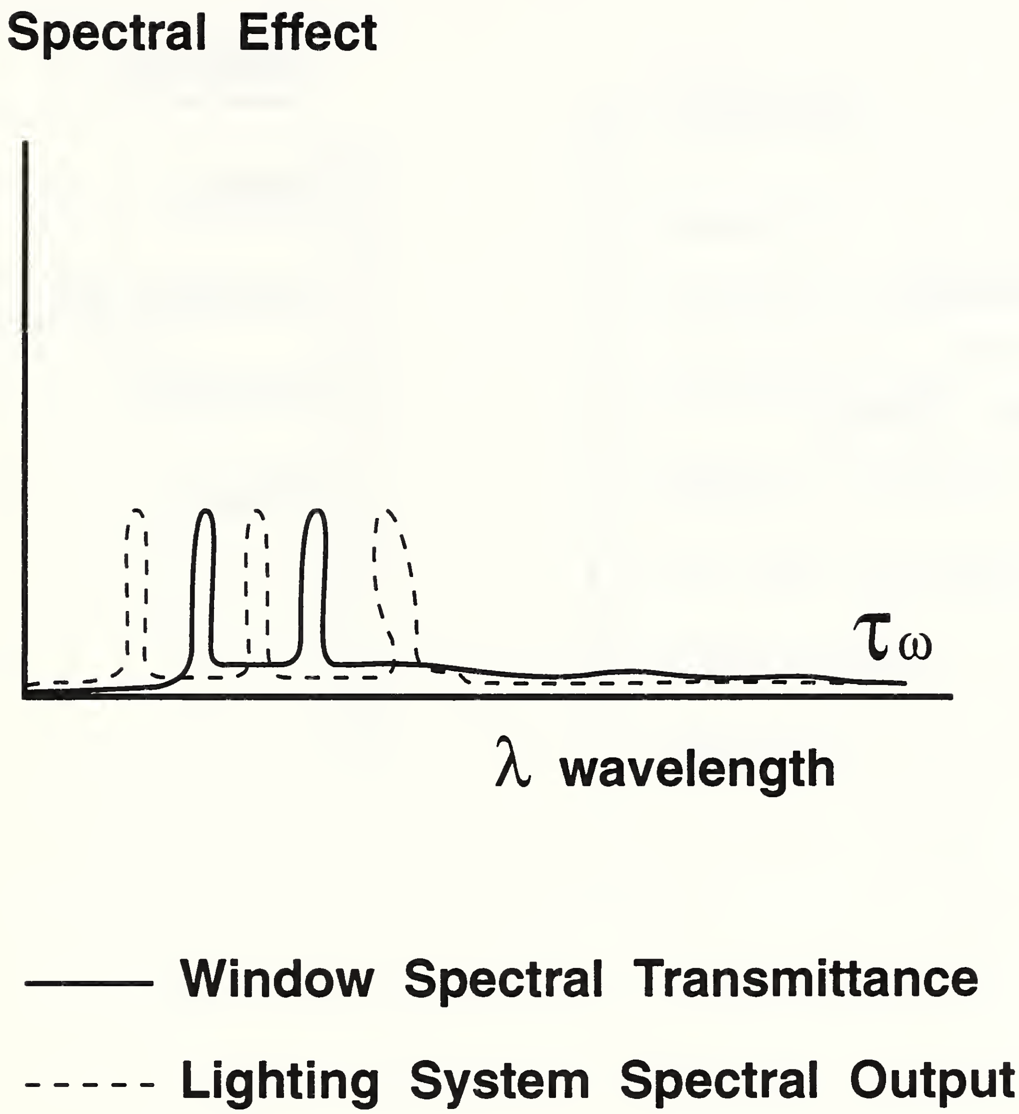


Figure 3.2 Inducing privacy via the spectral effect

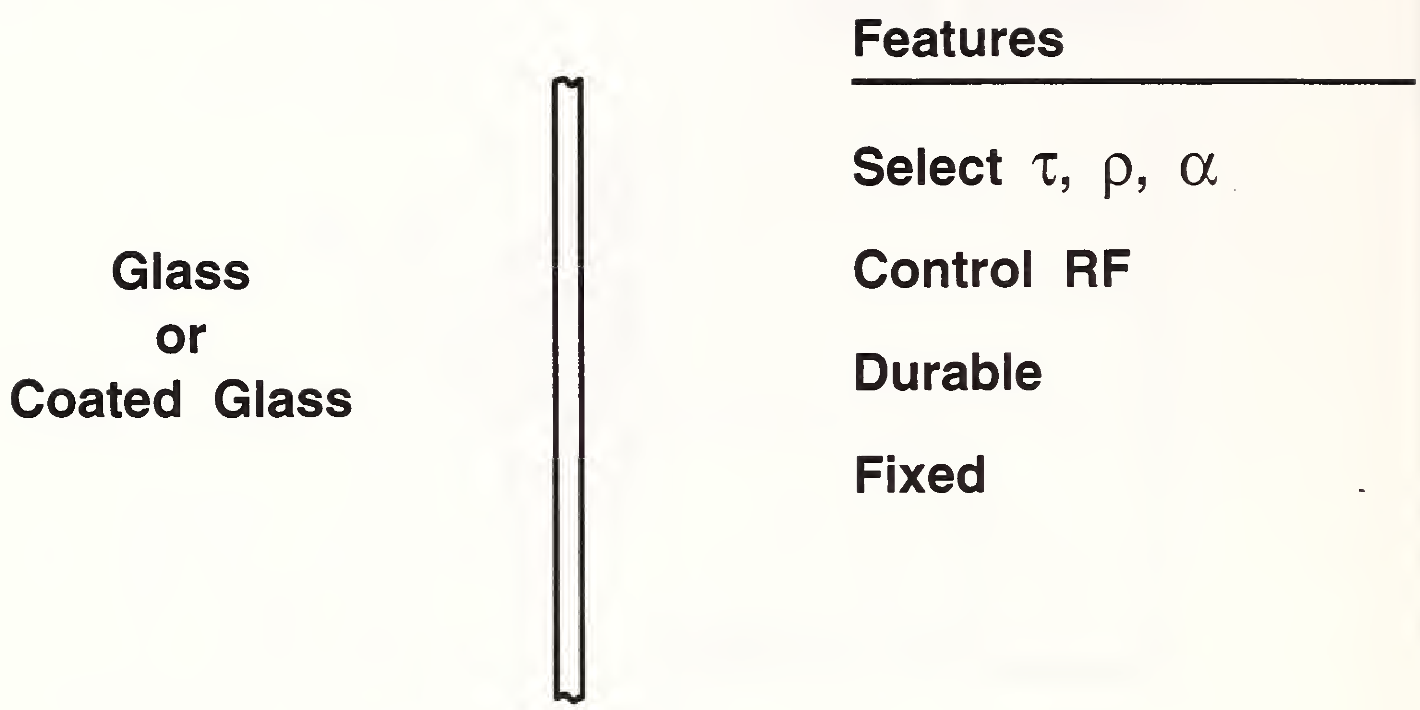


Figure 4.1 Features of glass and coated glass

Glass with film

Features

Select τ, ρ, α

Control RF

Control UV

Safety (shatter resist.)

Not as durable

Removable

Retrofit

Figure 4.2 Features of glass with film

Glass with screen

Features

Angularly selective

Fixed

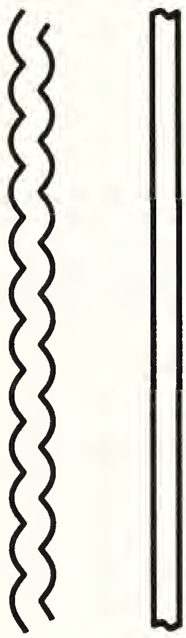
Impact resistant

Removable

Retrofit

Figure 4.3 Features of glass with screen

Glass with blind or drape



Features

Operable

Complete Privacy

Removable

Retrofit

Block view and light

Figure 4.4 Features of glass with blind or drape

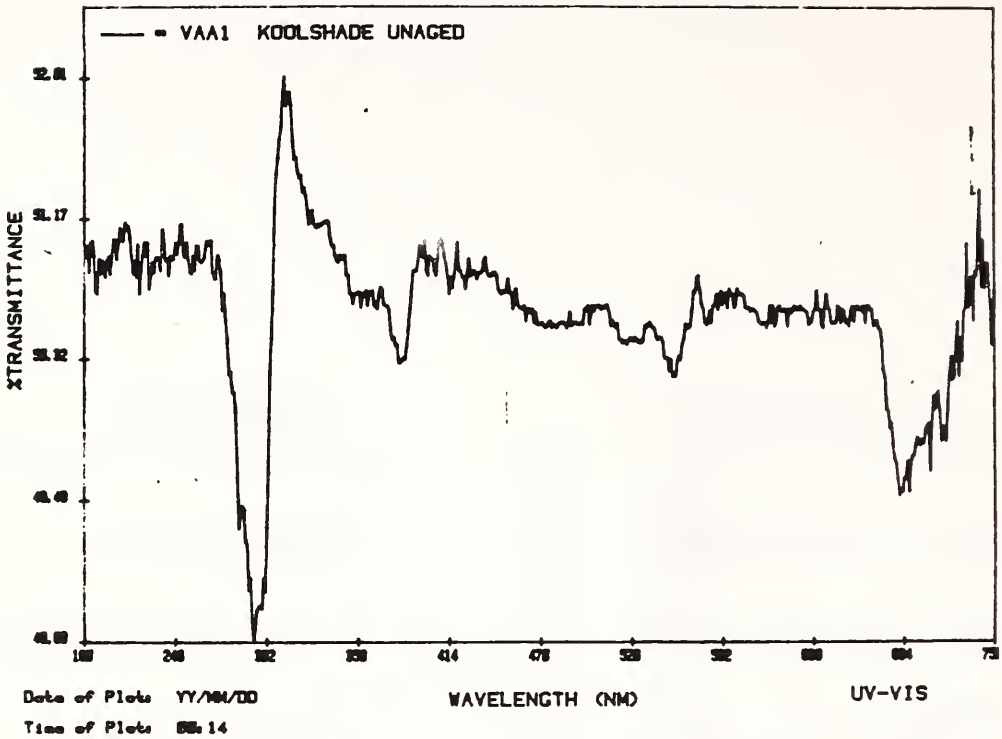


Figure 6.1a Sample AA, UV-visible total transmittance

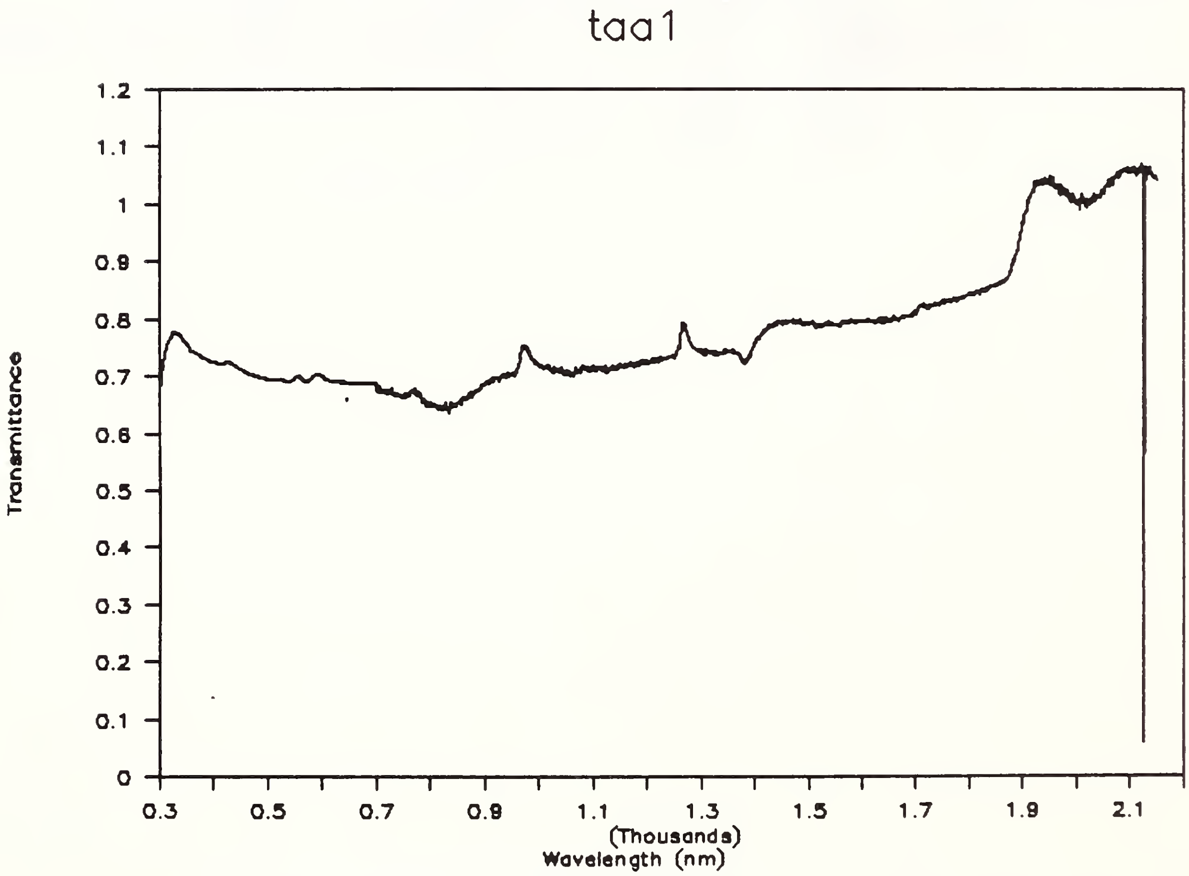


Figure 6.1b Sample AA, Visible specular transmittance

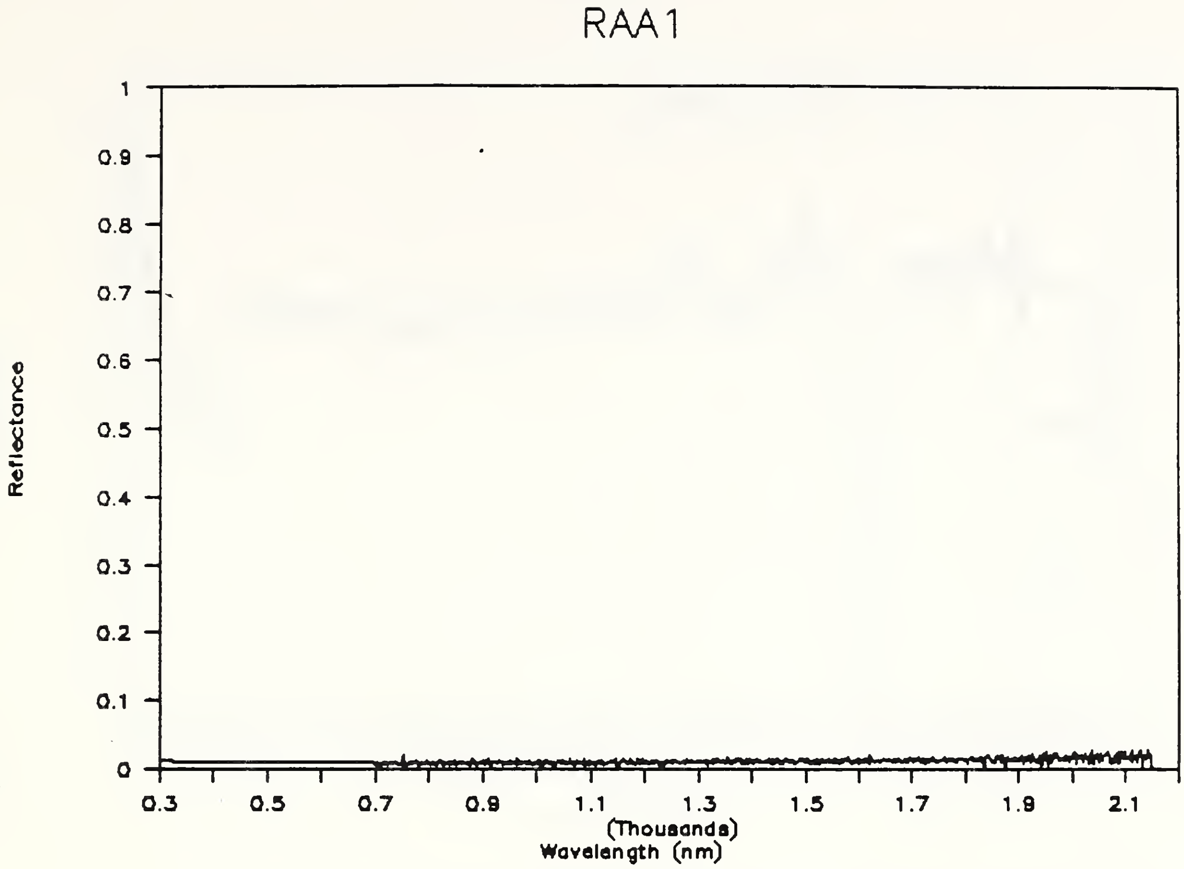


Figure 6.1c Sample AA, Visible specular reflectance

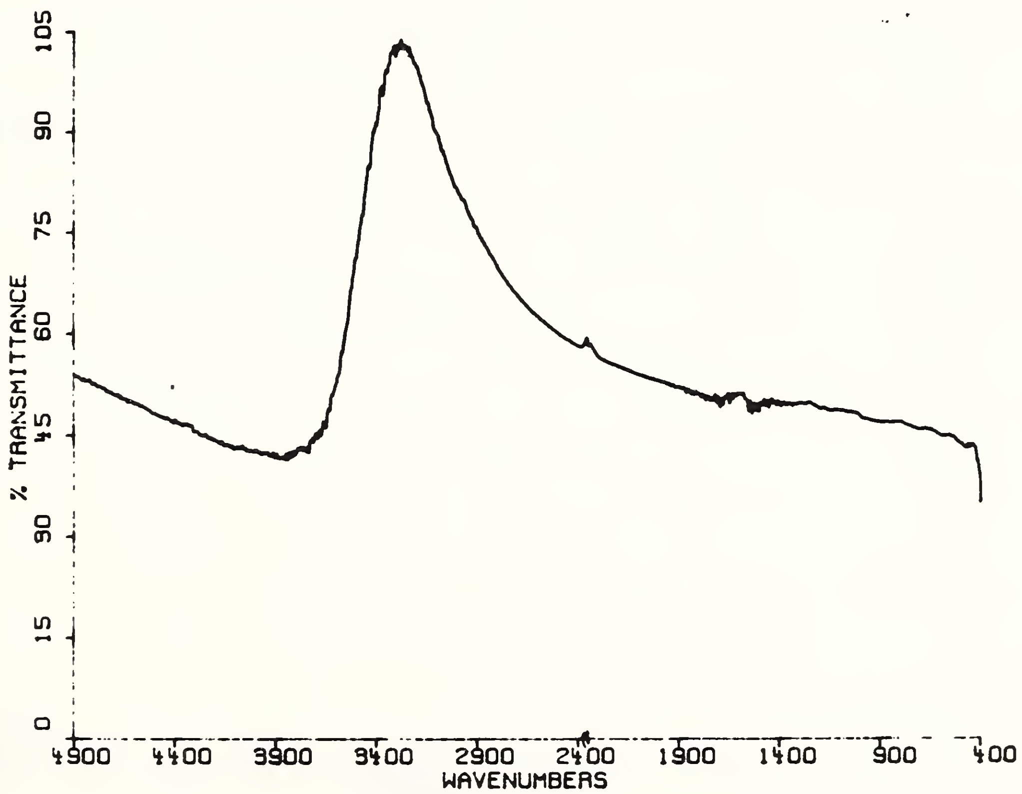


Figure 6.1d Sample AA, IR specular transmittance

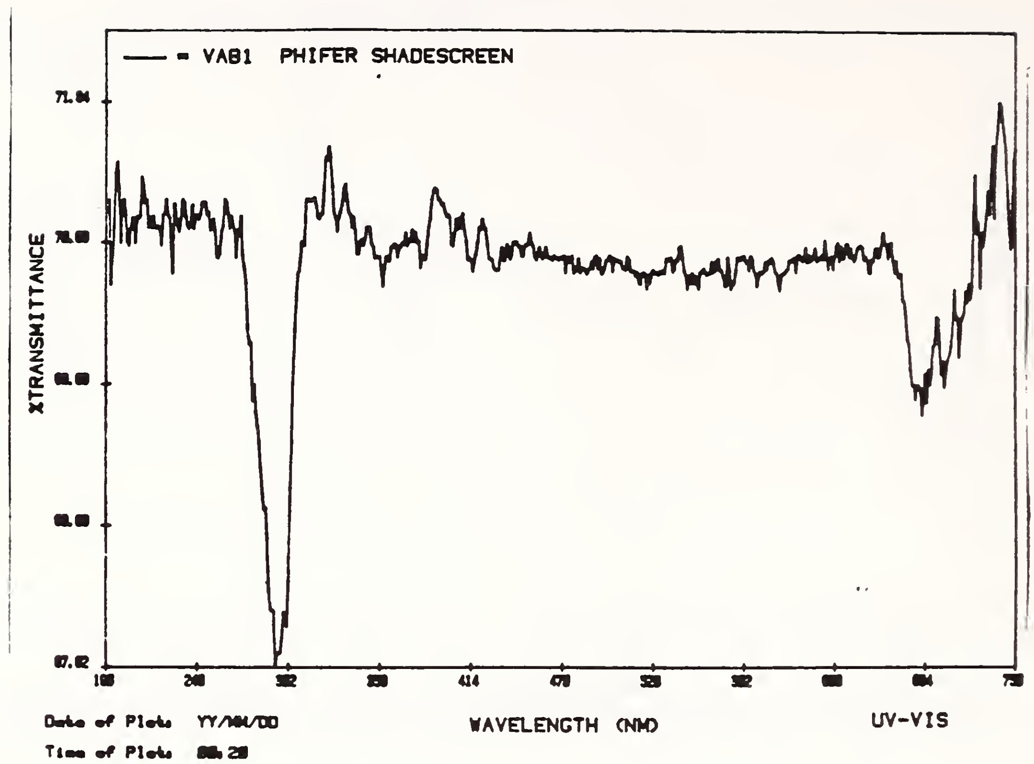


Figure 6.2a Sample AB, UV-visible total transmittance

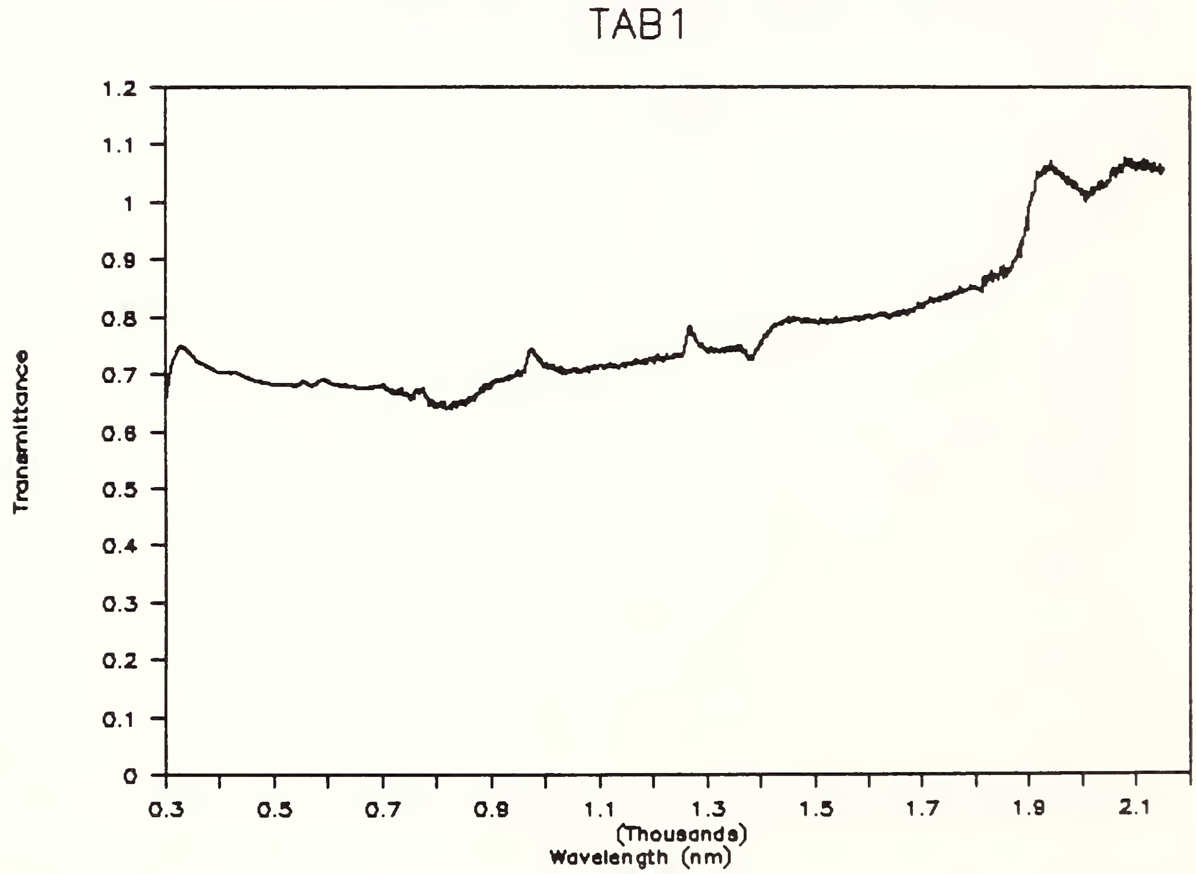


Figure 6.2b Sample AB, Visible specular transmittance

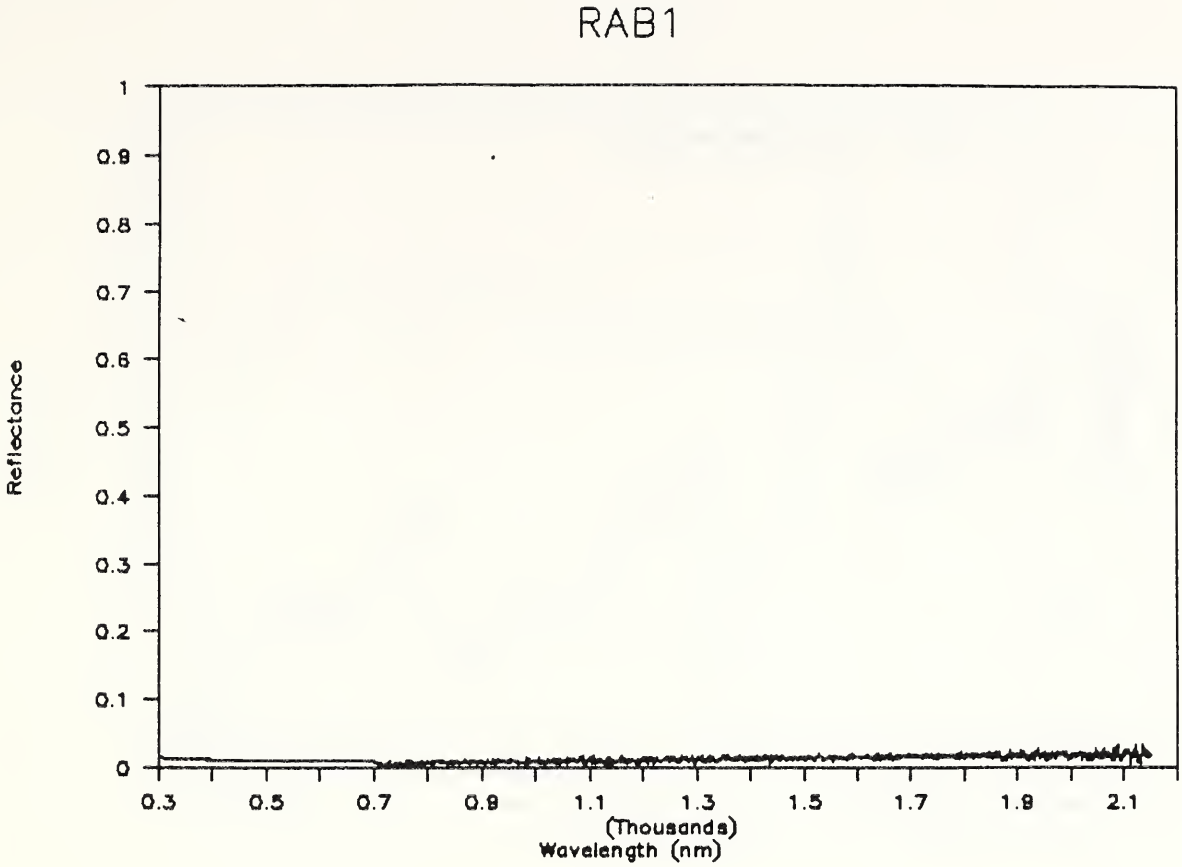


Figure 6.2c Sample AB, Visible specular reflectance

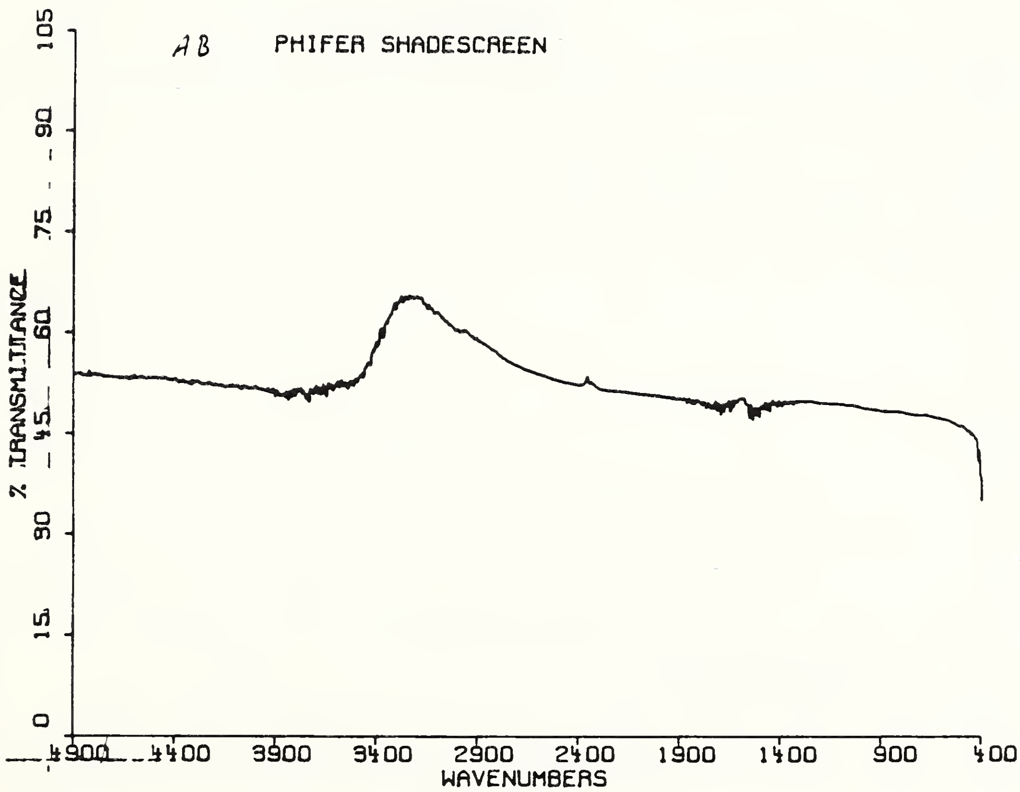


Figure 6.2d Sample AB, IR specular transmittance

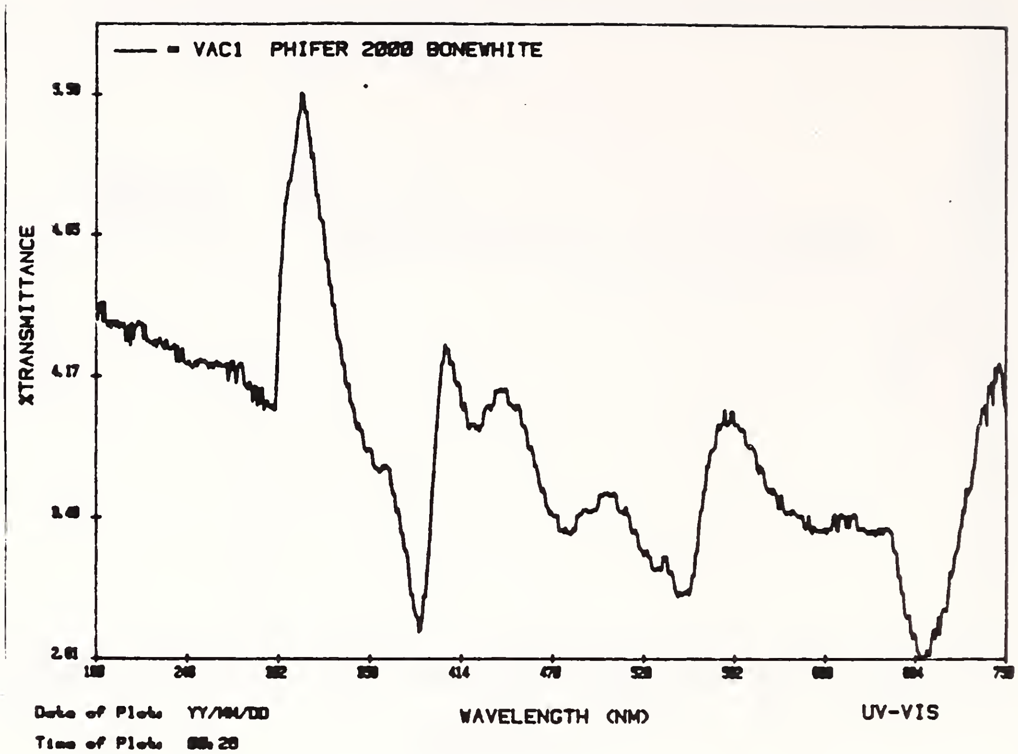


Figure 6.3a Sample AC, UV-visible total transmittance

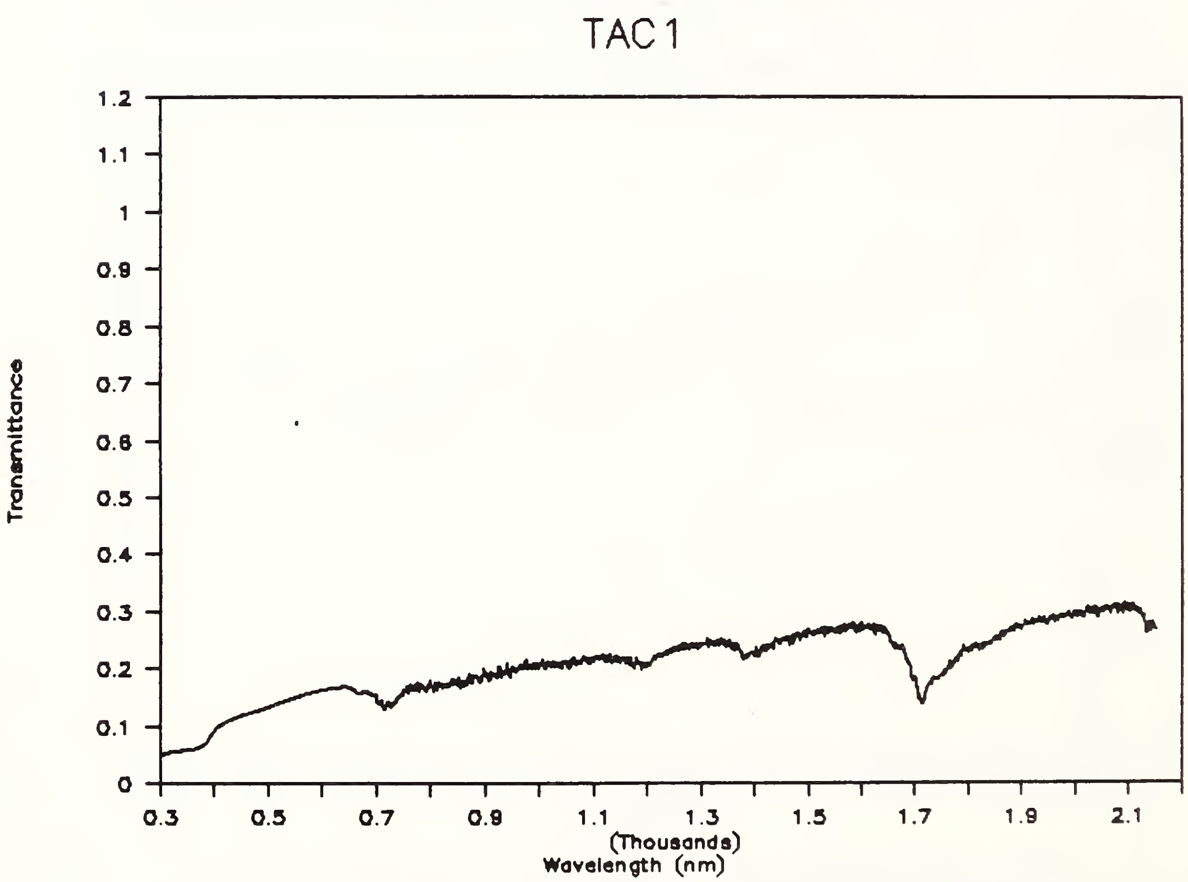


Figure 6.3b Sample AC, Visible specular transmittance

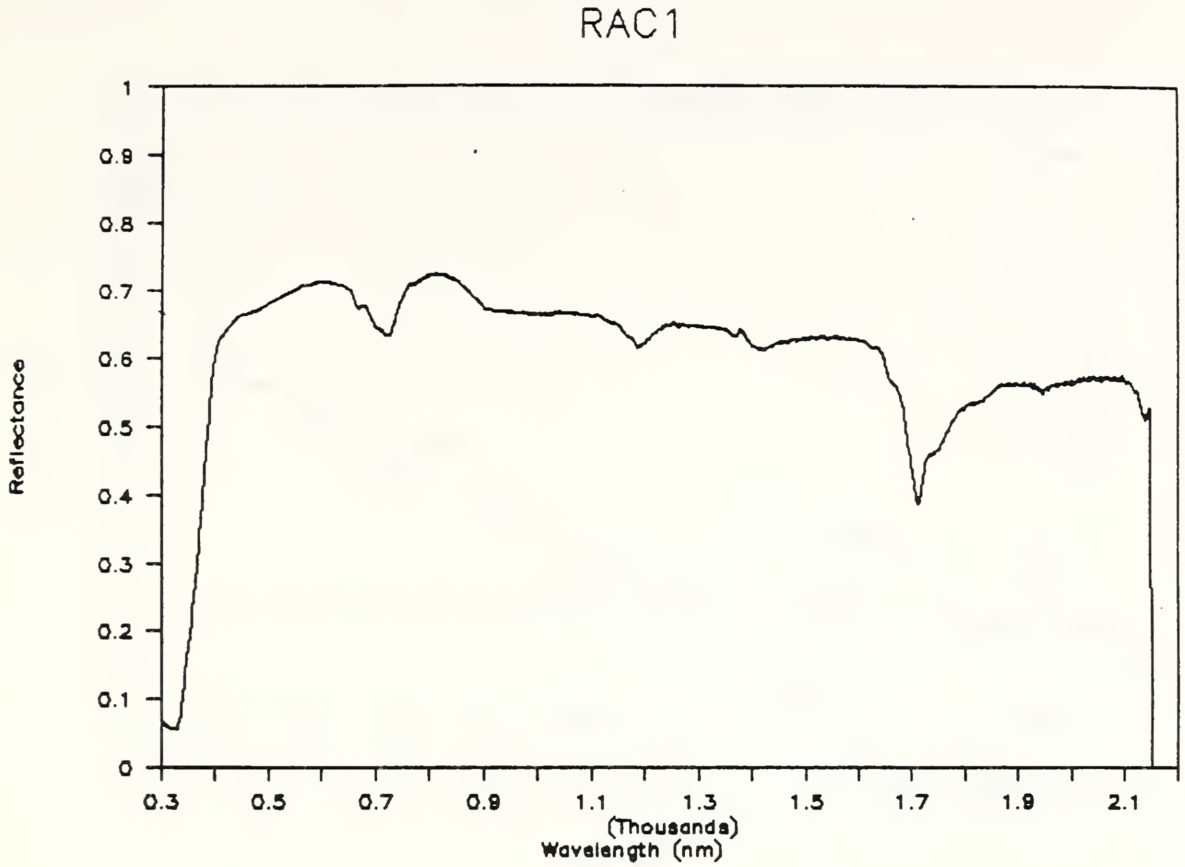


Figure 6.3c Sample AC, Visible specular reflectance

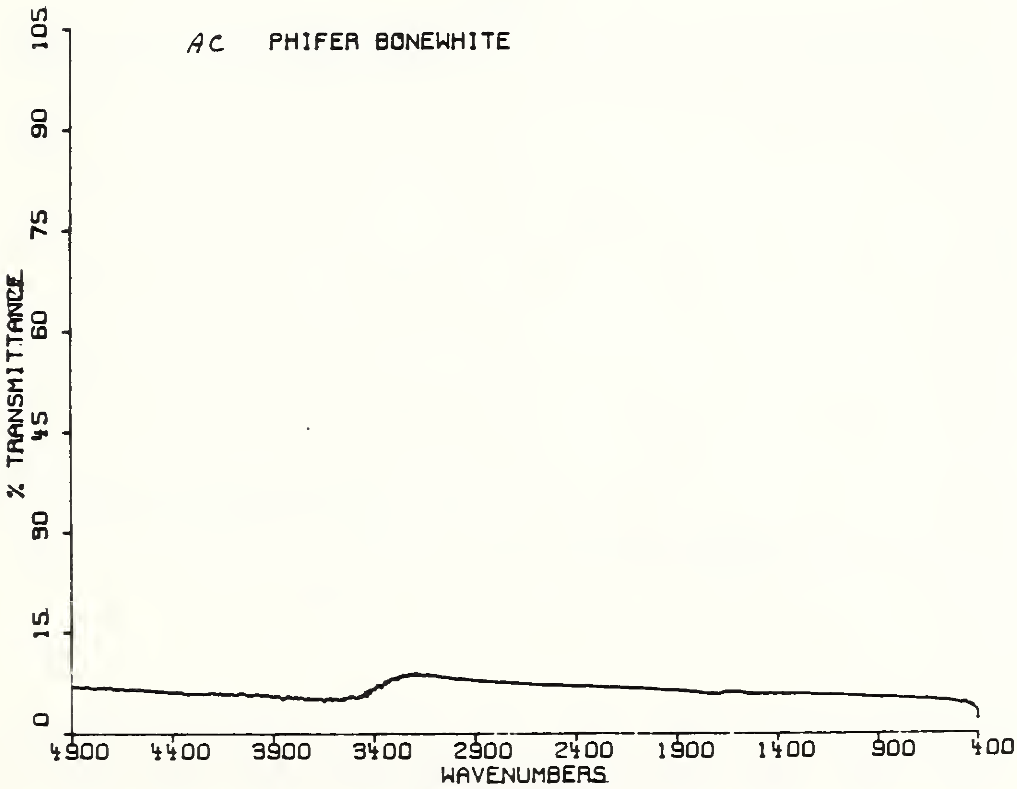


Figure 6.3d Sample AC, IR specular transmittance

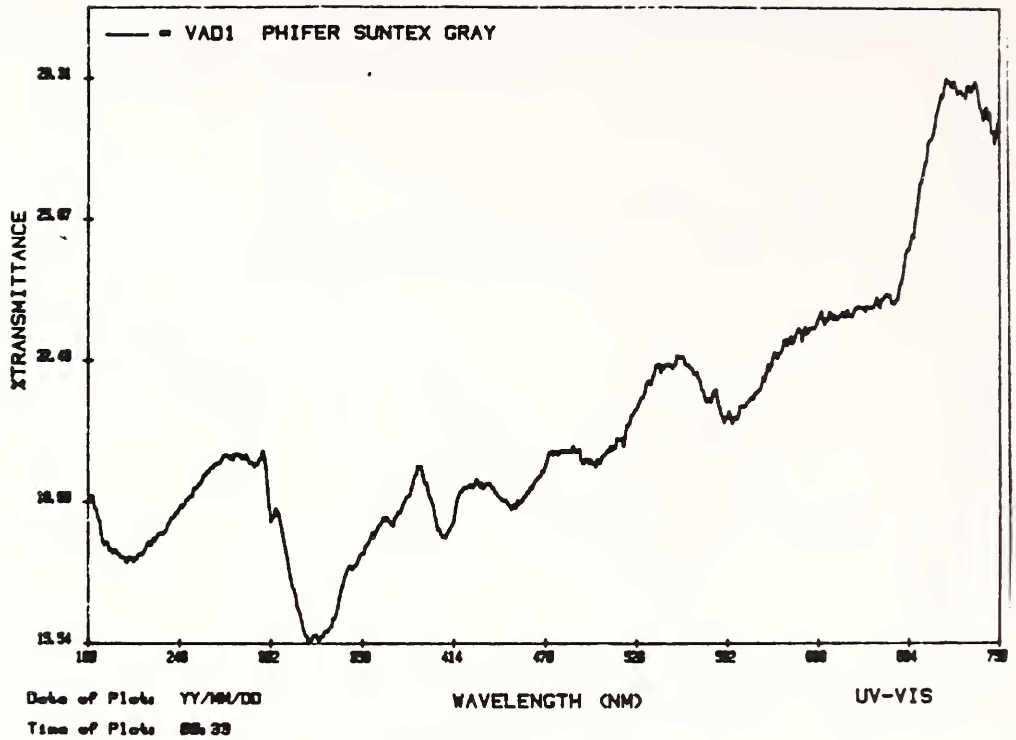


Figure 6.4a Sample AD, UV-visible total transmittance

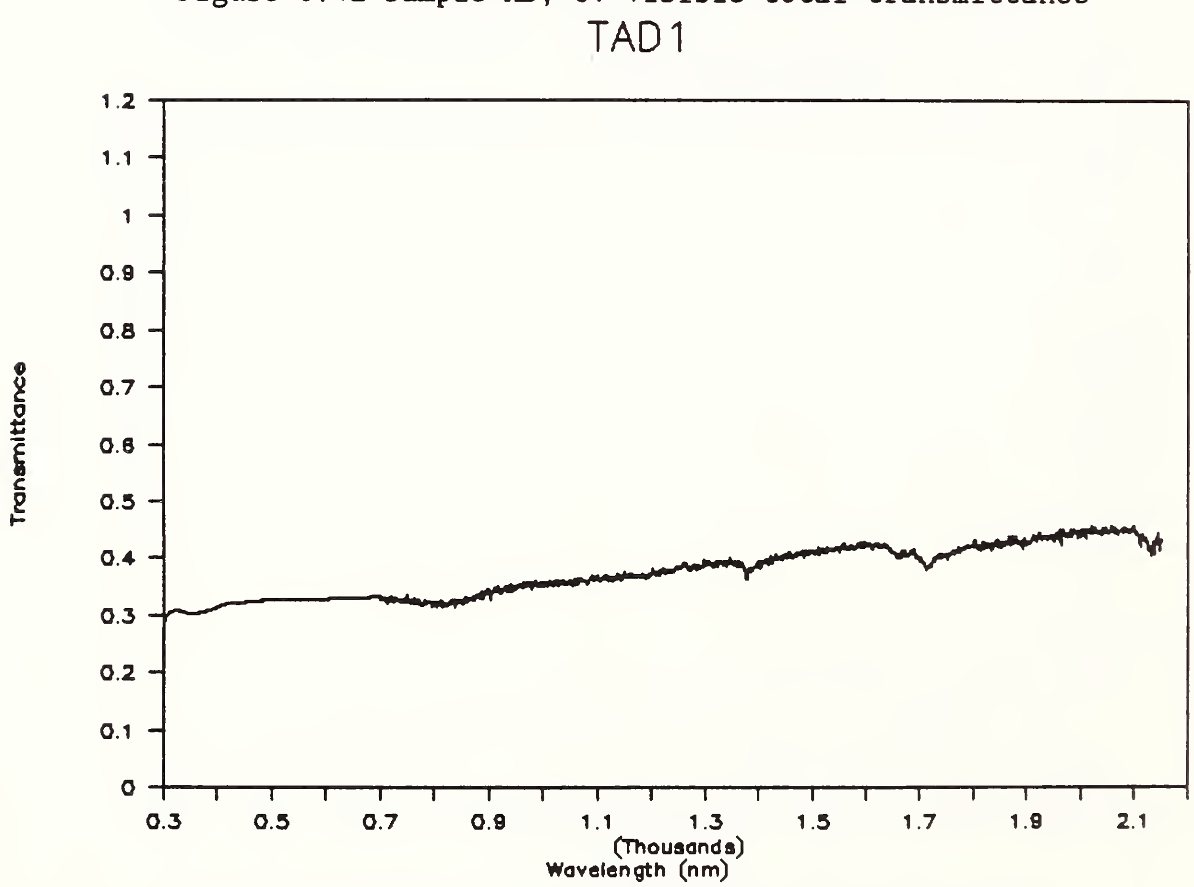


Figure 6.4b Sample AD, Visible specular transmittance

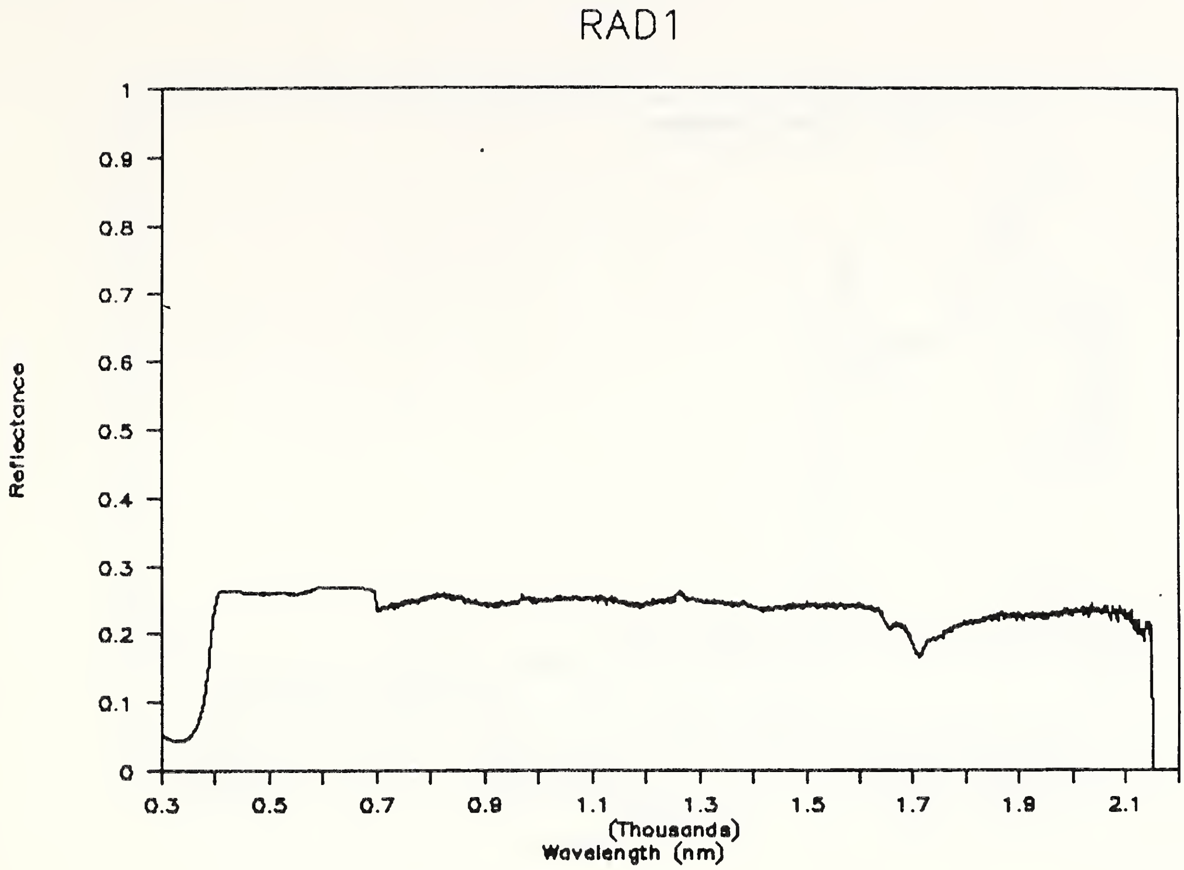


Figure 6.4c Sample AD, Visible specular reflectance

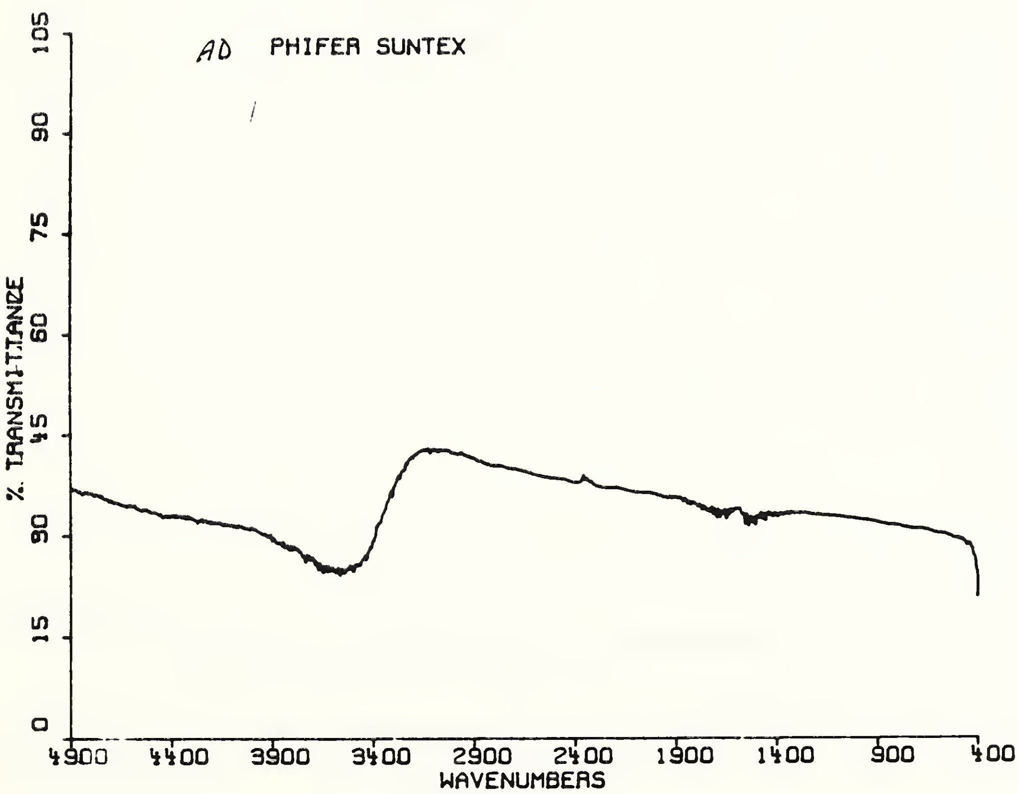


Figure 6.4d Sample AD, IR specular transmittance

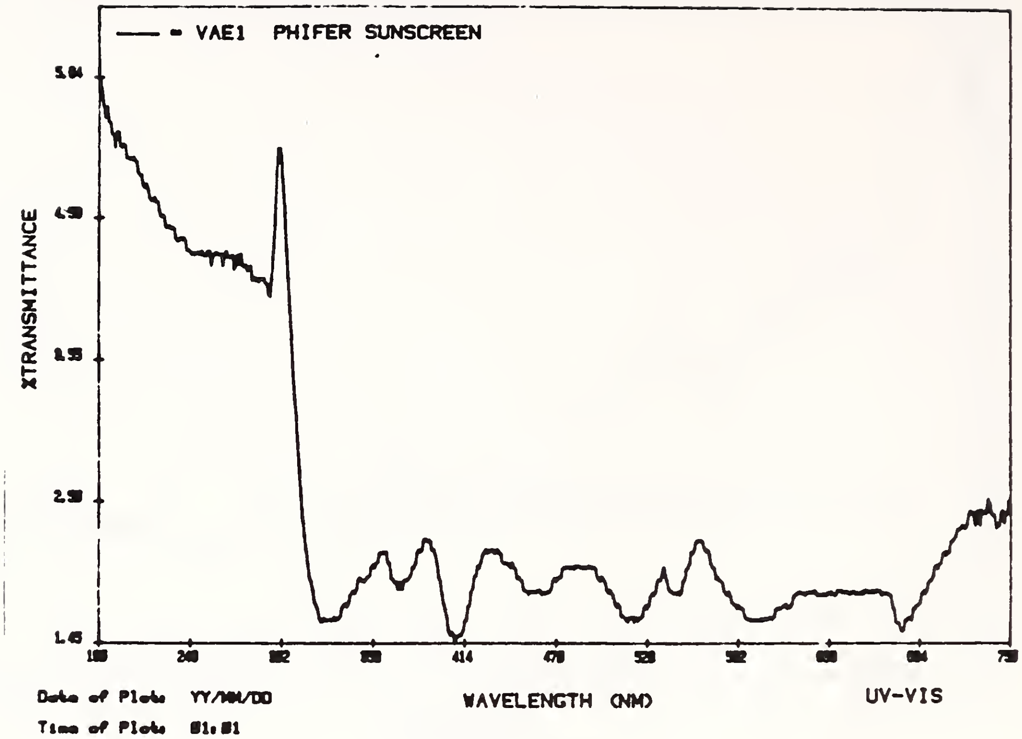


Figure 6.5a Sample AE, UV-visible total transmittance

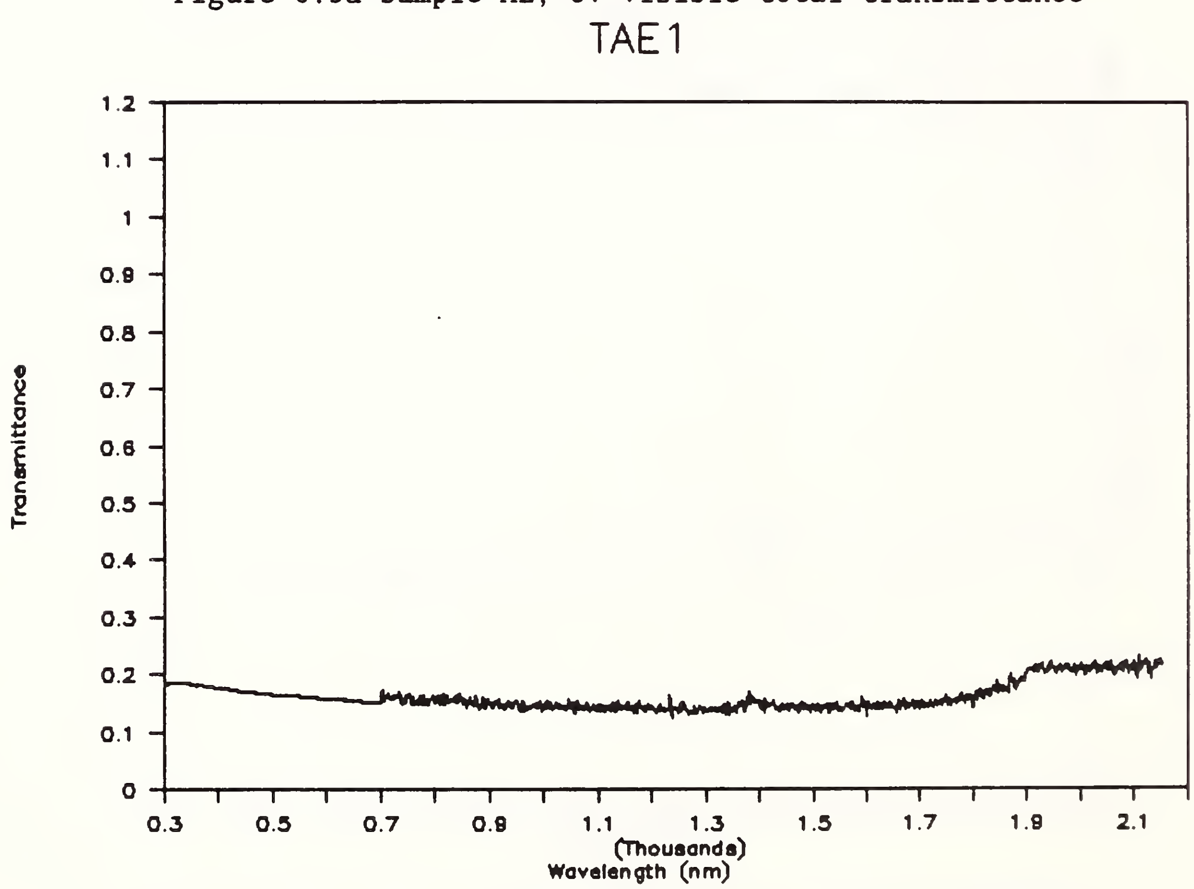


Figure 6.5b Sample AE, Visible specular transmittance

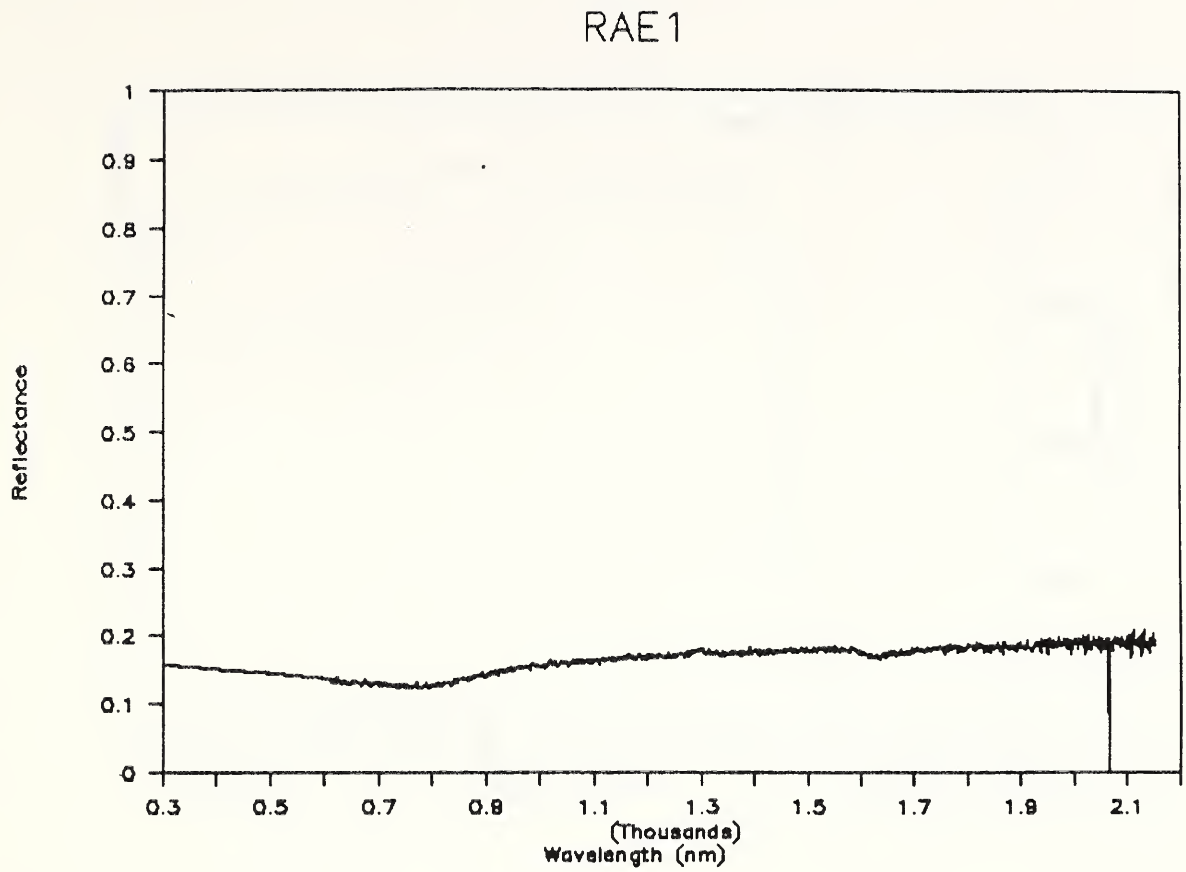


Figure 6.5c Sample AE, Visible specular reflectance

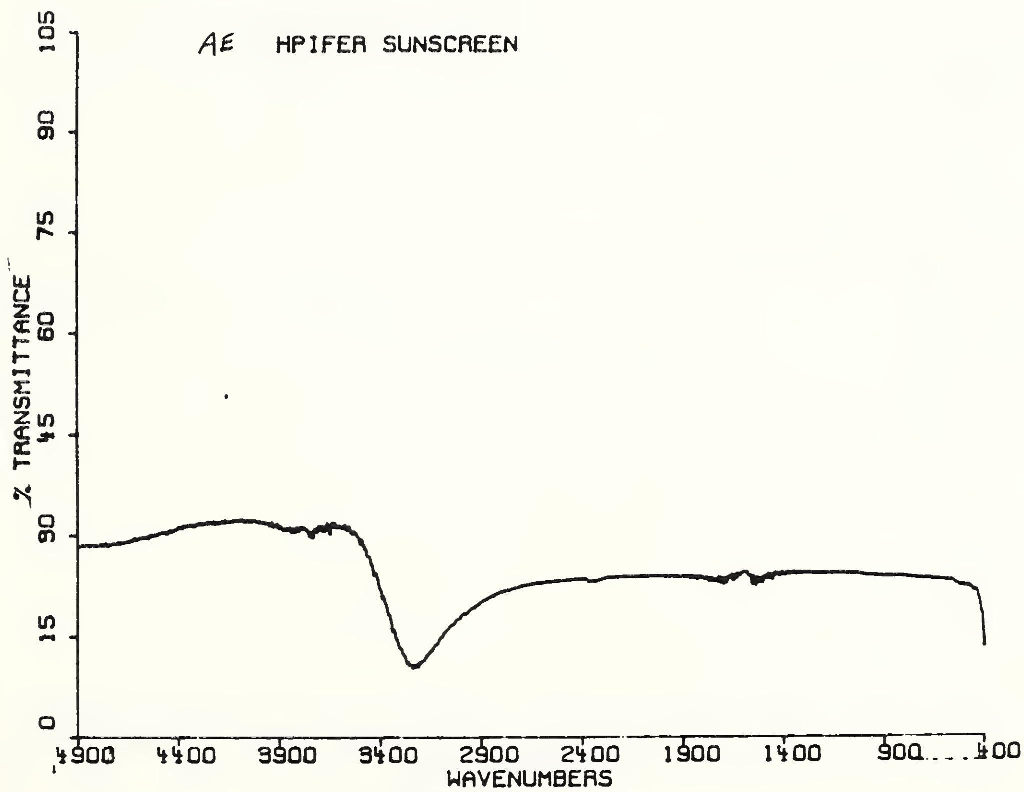


Figure 6.5d Sample AE, IR specular transmittance

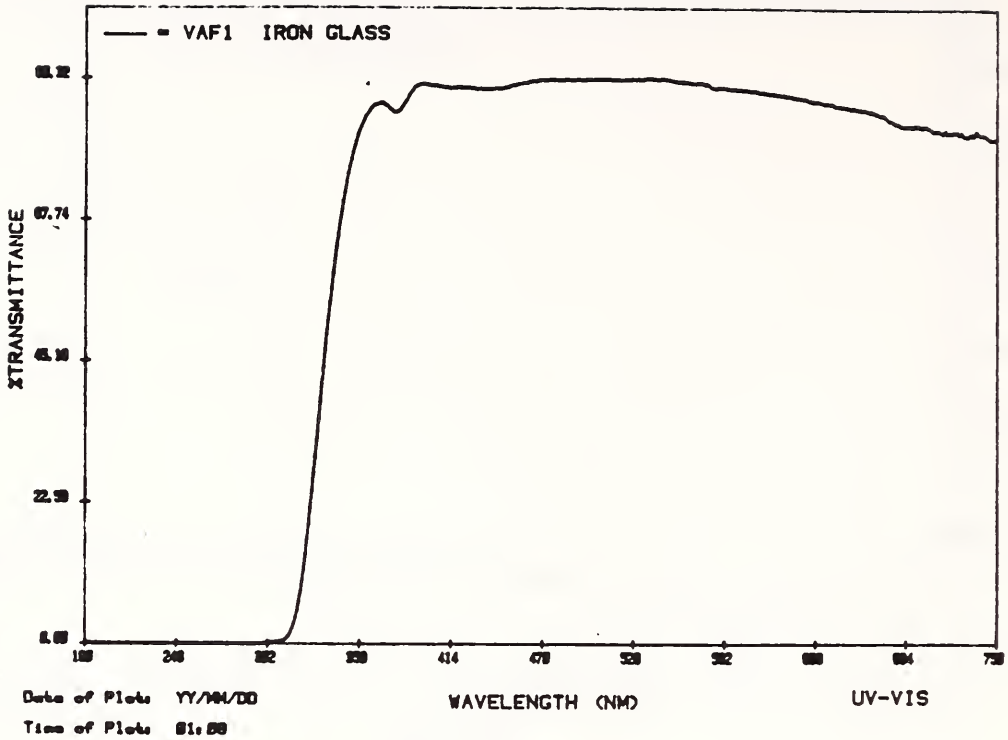


Figure 6.6a Sample AF, UV-visible total transmittance

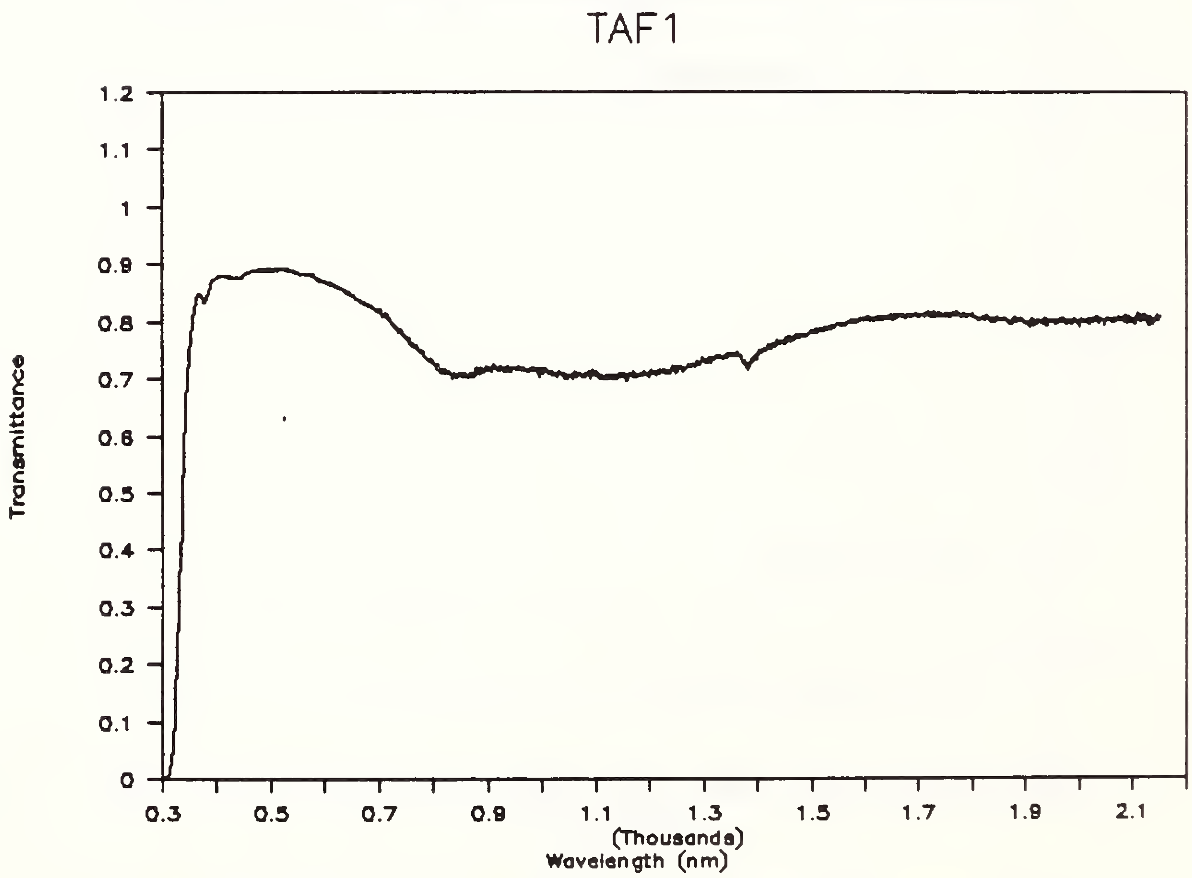


Figure 6.6b Sample AF, Visible specular transmittance

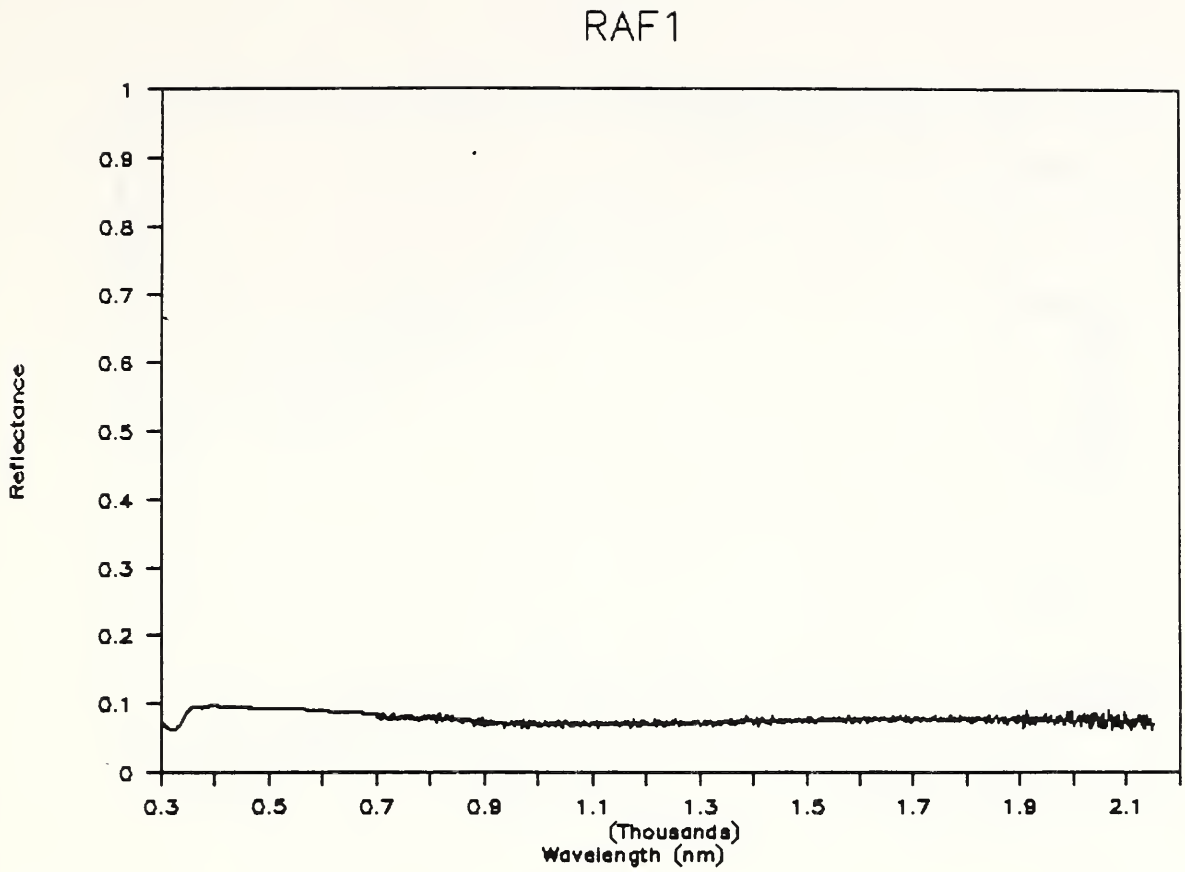


Figure 6.6c Sample AF, Visible specular reflectance

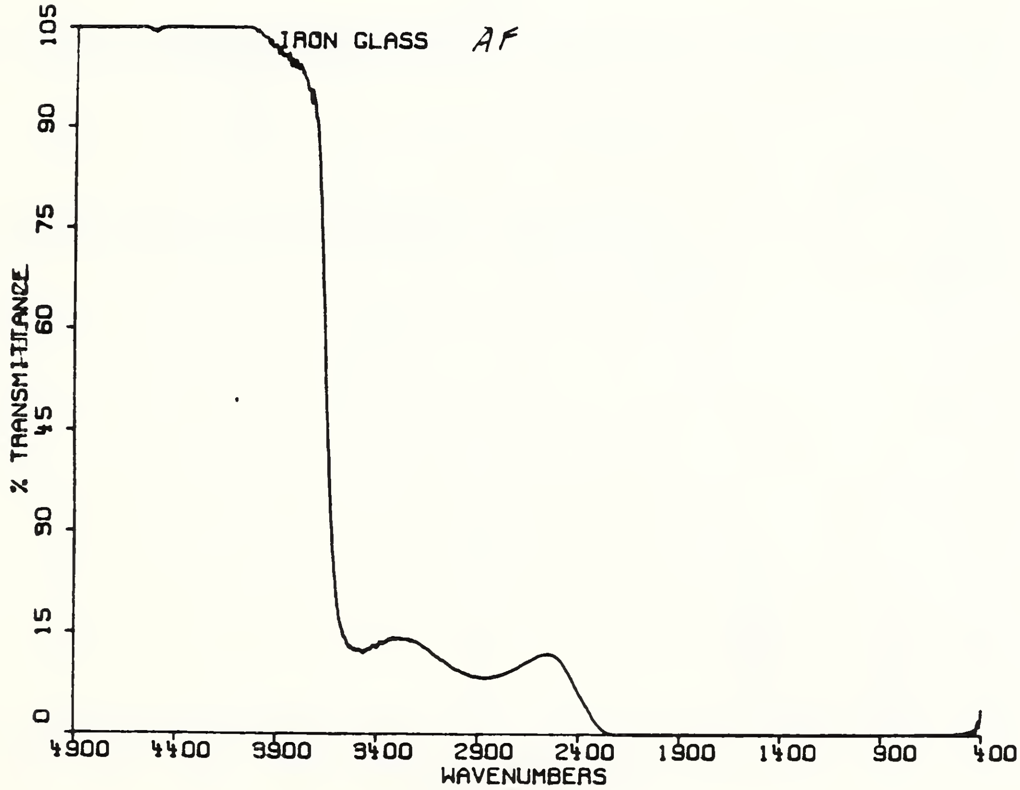


Figure 6.6d Sample AF, IR specular transmittance

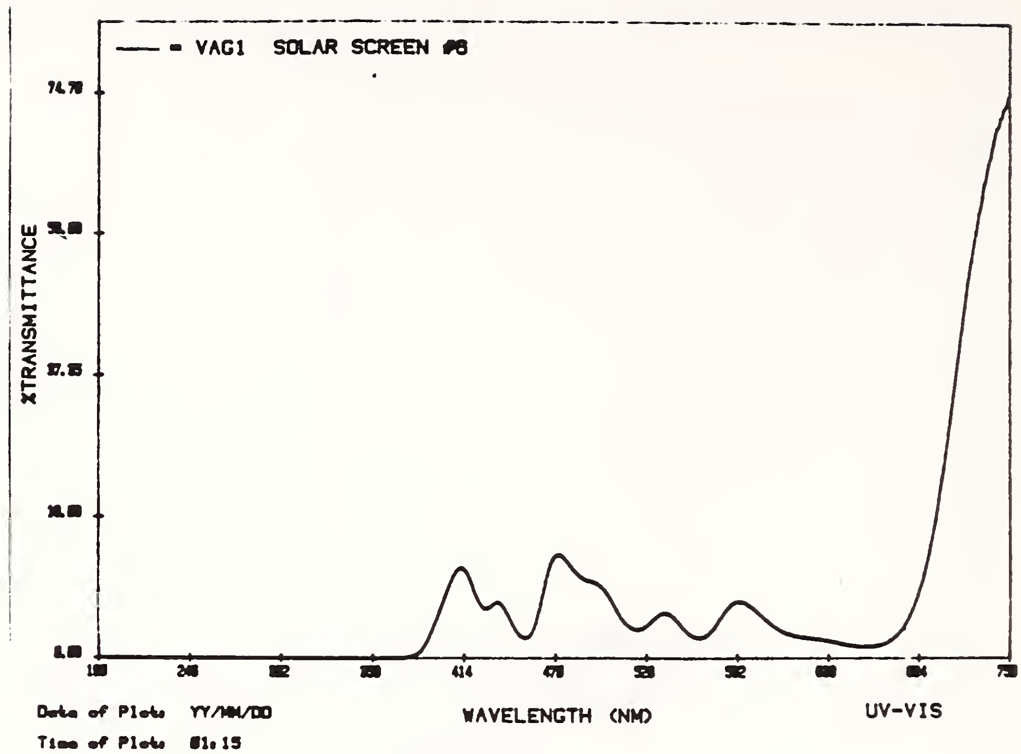


Figure 6.7a Sample AG, UV-visible total transmittance

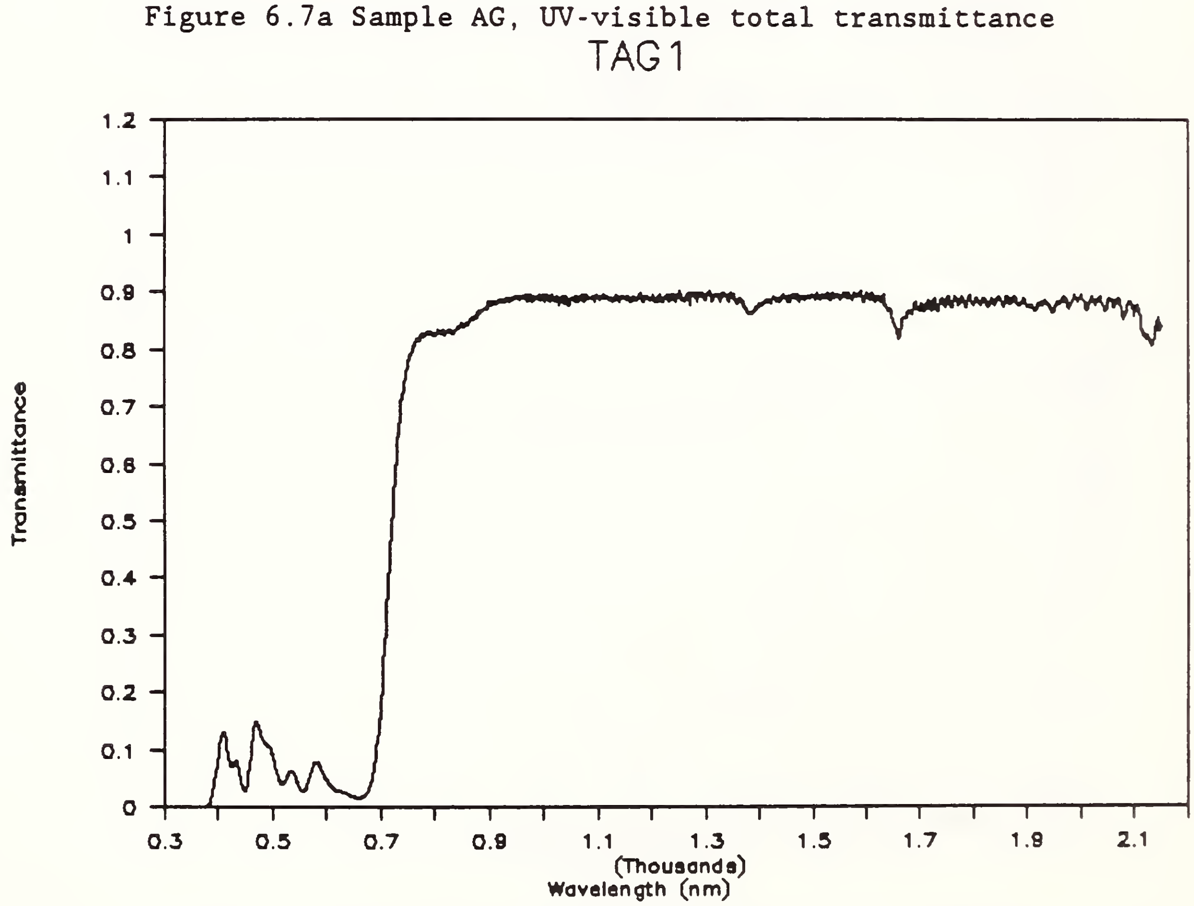


Figure 6.7b Sample AG, Visible specular transmittance

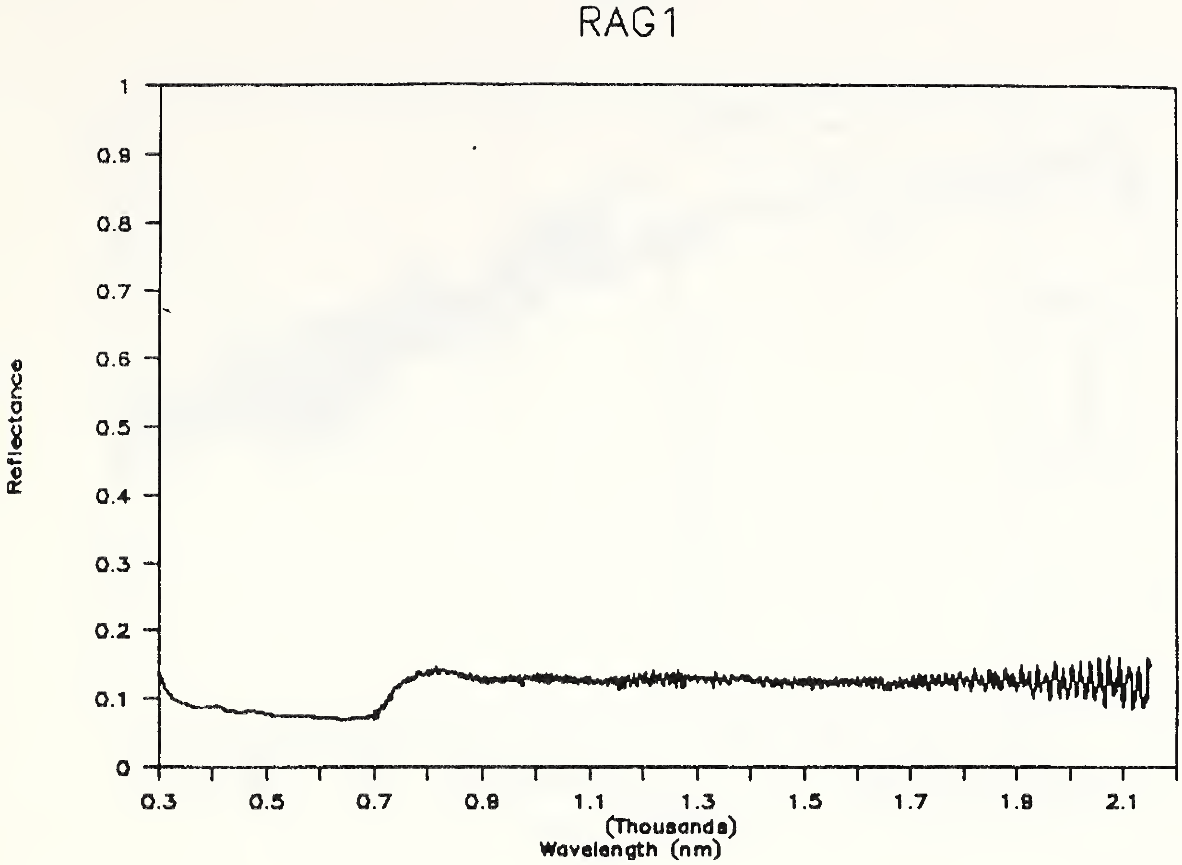


Figure 6.7c Sample AG, Visible specular reflectance

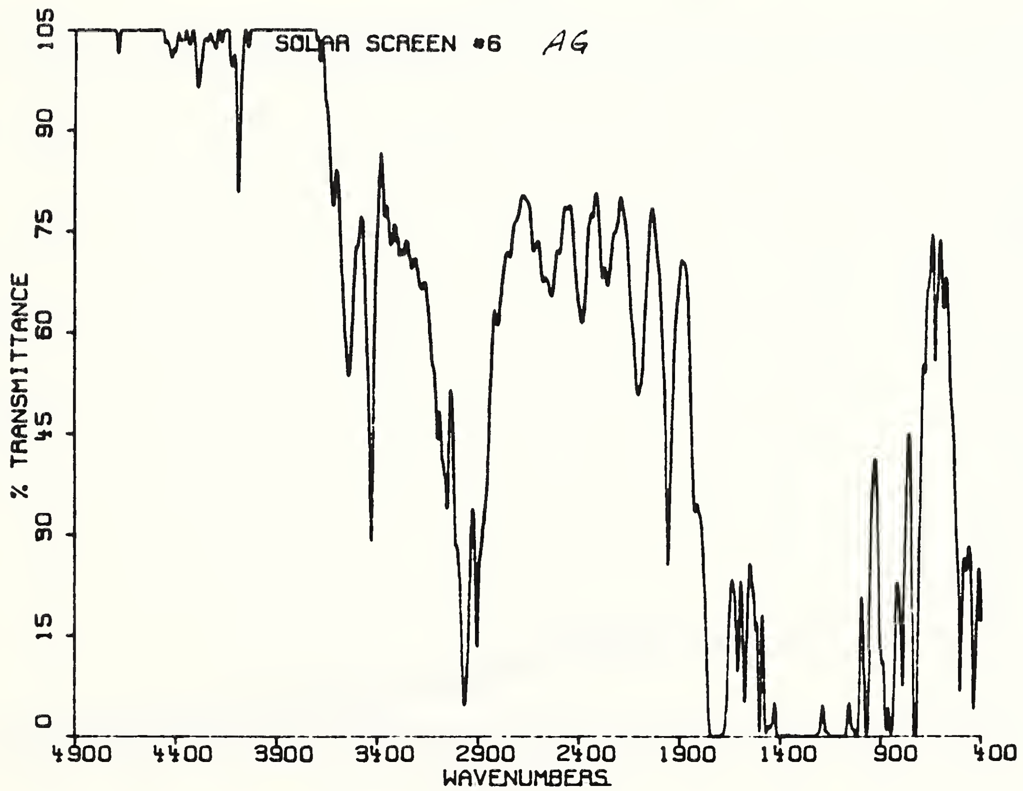


Figure 6.7d Sample AG, IR specular transmittance

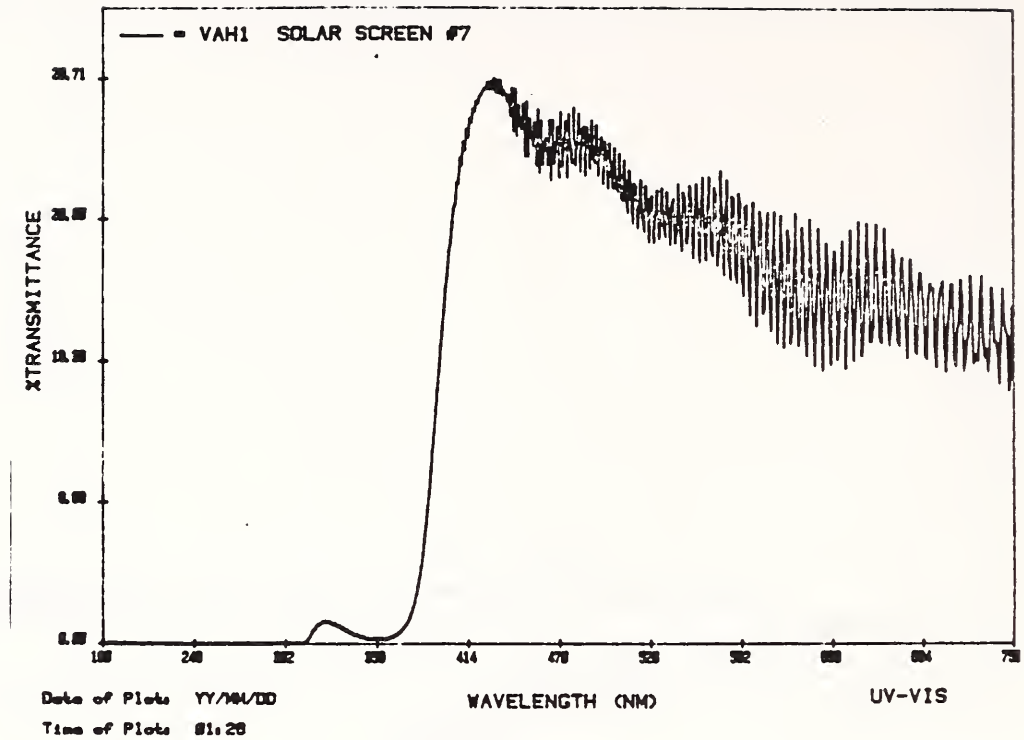


Figure 6.8a Sample AH, UV-visible total transmittance

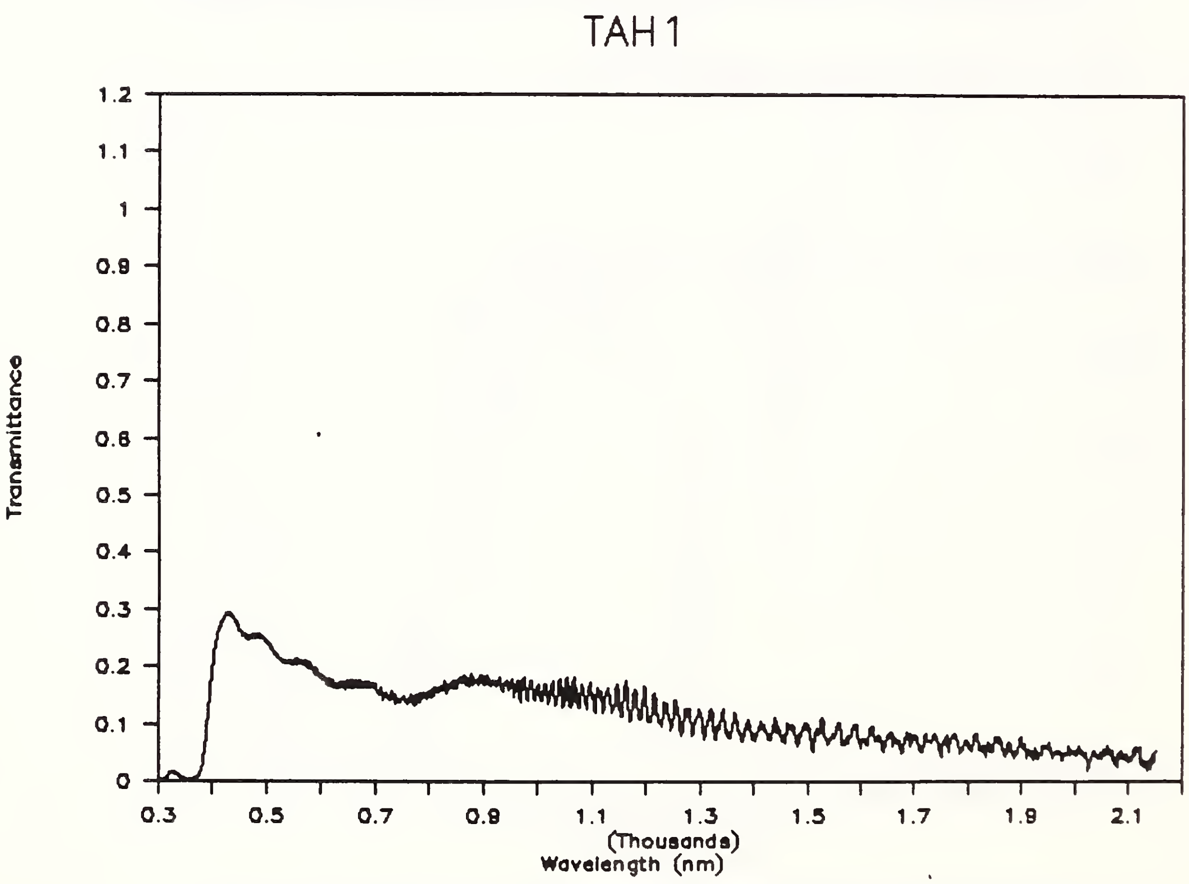


Figure 6.8b Sample AH, Visible specular transmittance

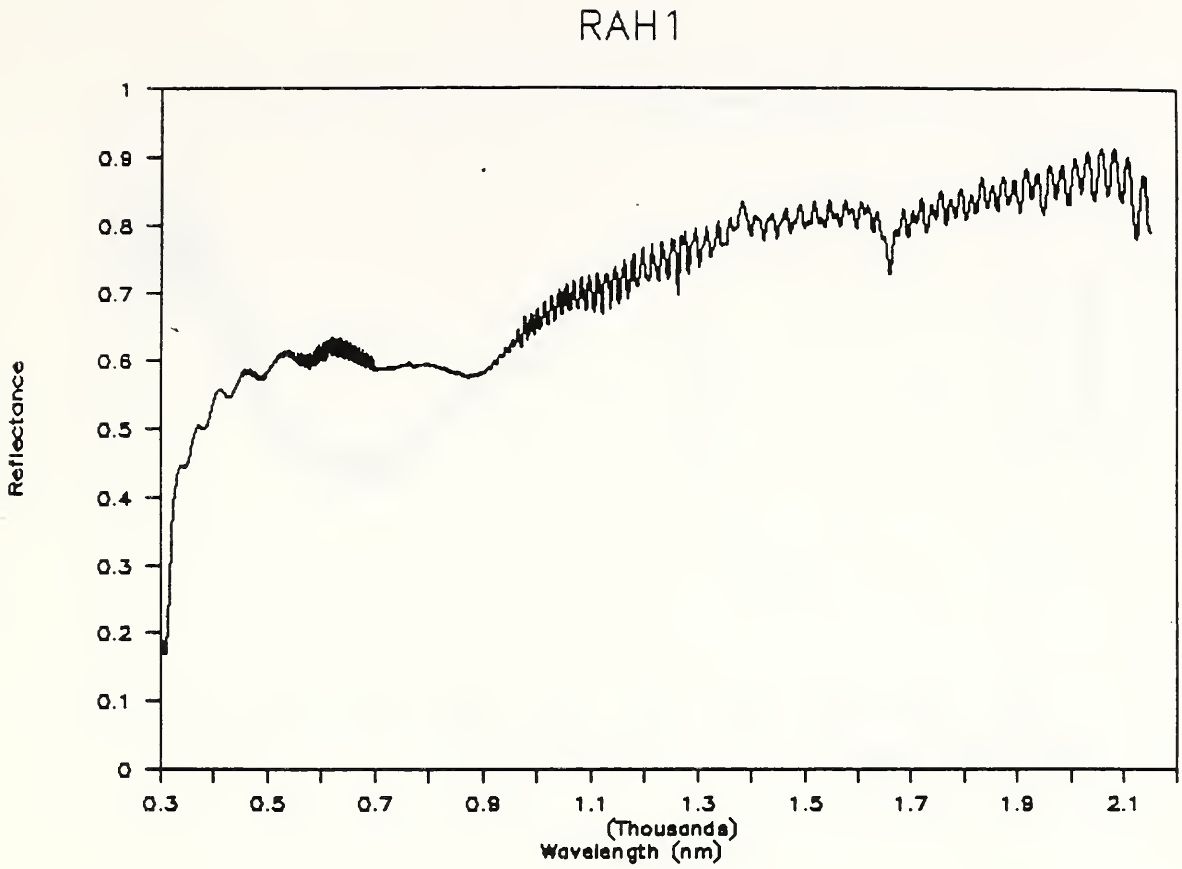


Figure 6.8c Sample AH, Visible specular reflectance

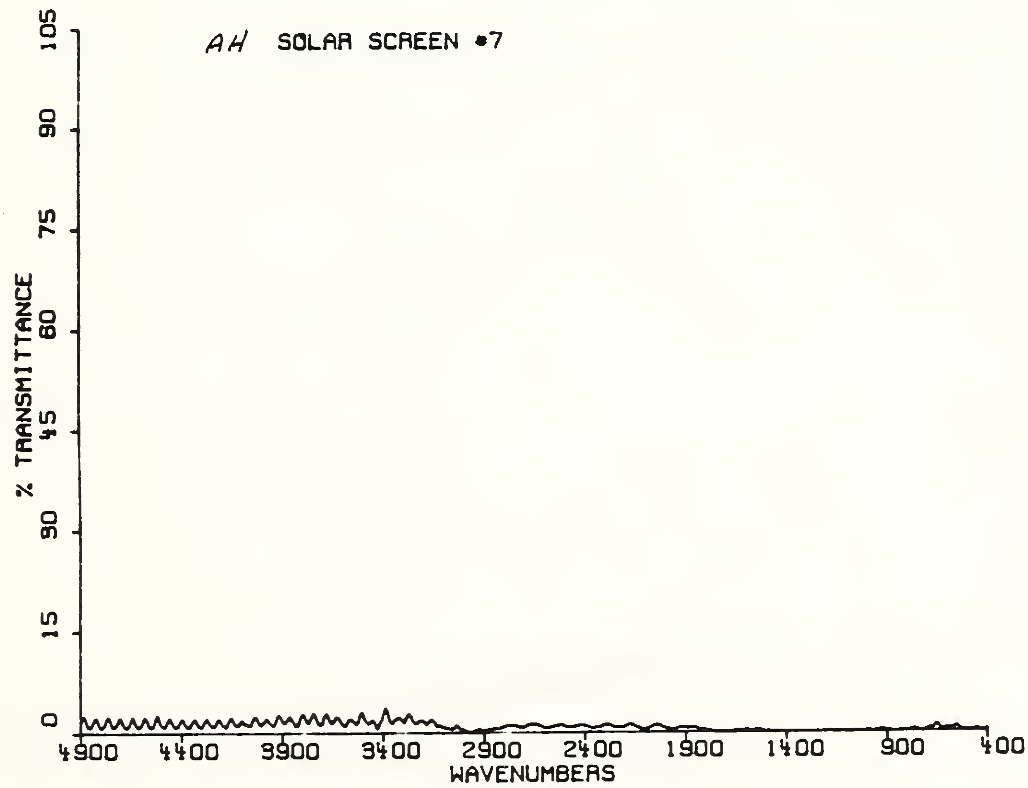


Figure 6.8d Sample AH, IR specular transmittance

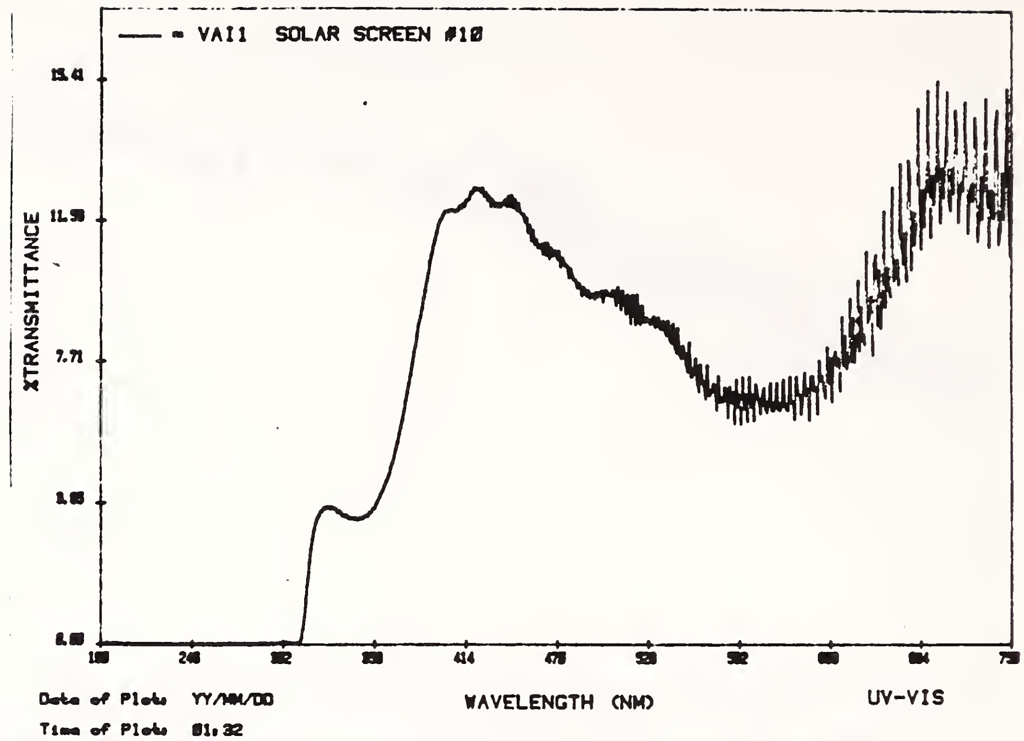


Figure 6.9a Sample AI, UV-visible total transmittance

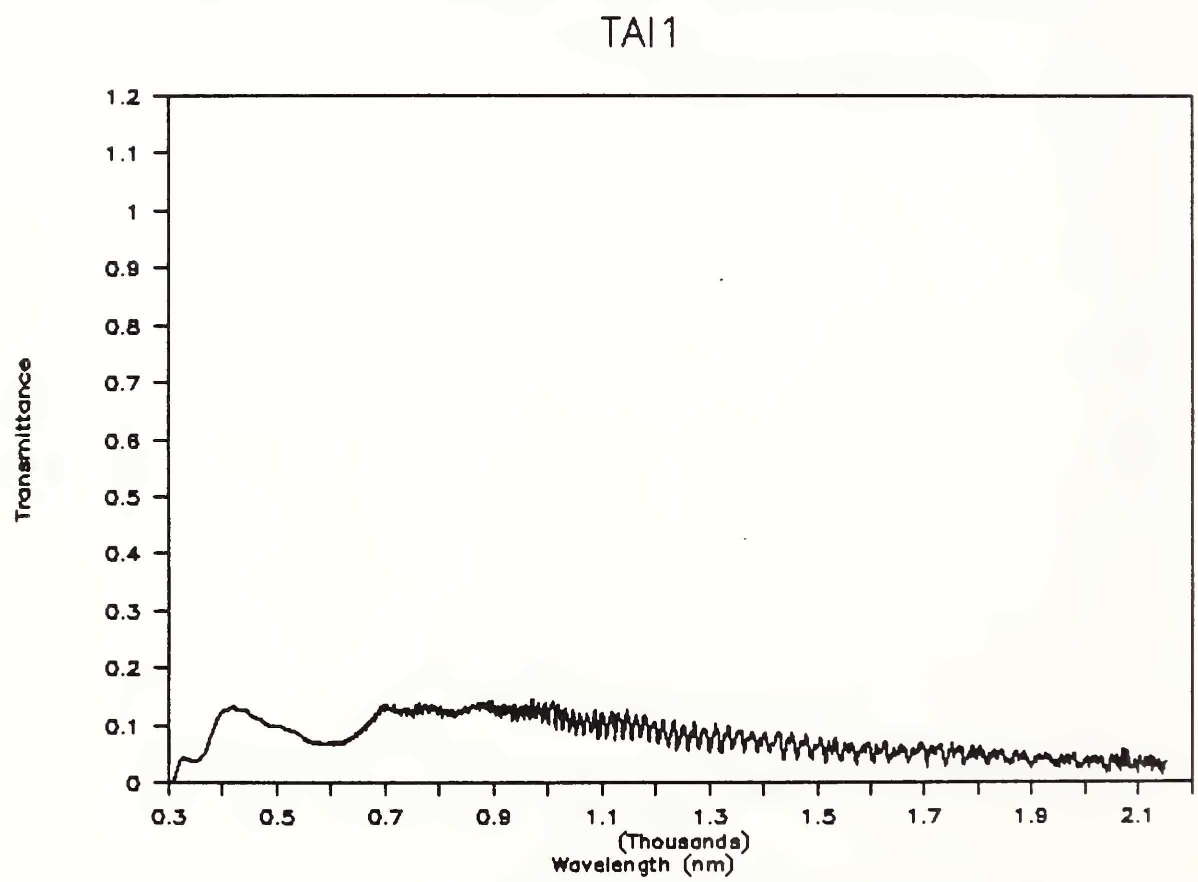


Figure 6.9b Sample AI, Visible specular transmittance

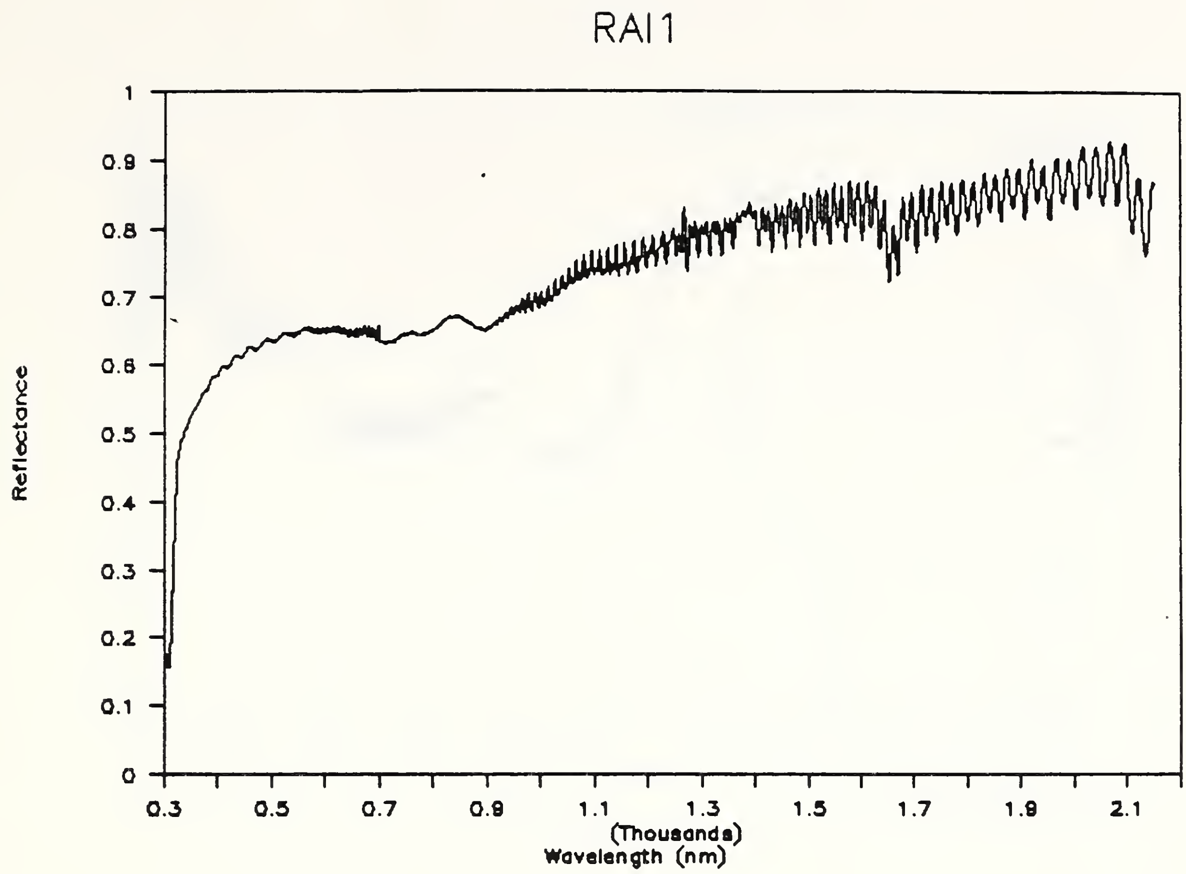


Figure 6.9c Sample AI, Visible specular reflectance

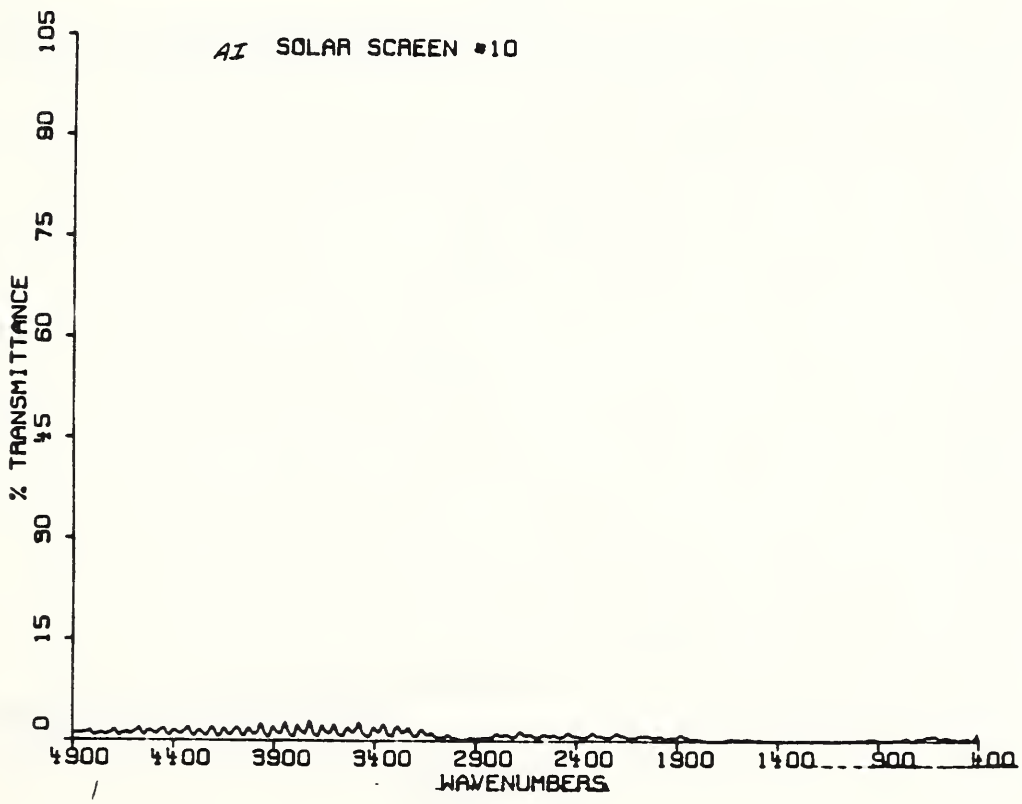


Figure 6.9d Sample AI, IR specular transmittance

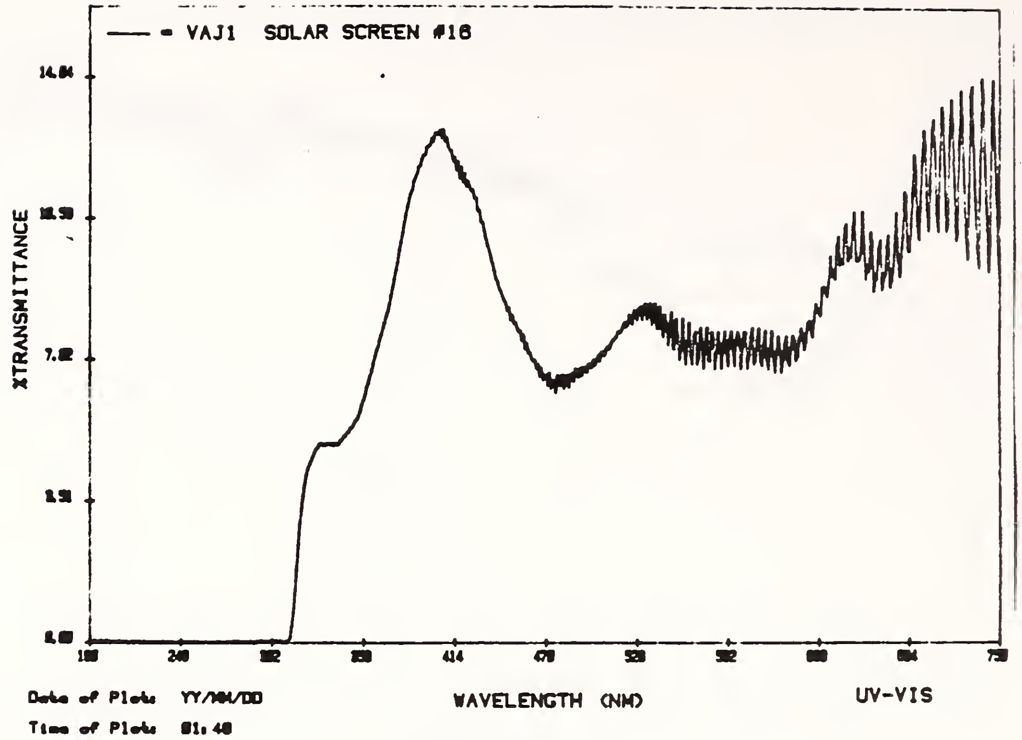


Figure 6.10a Sample AJ, UV-visible total transmittance

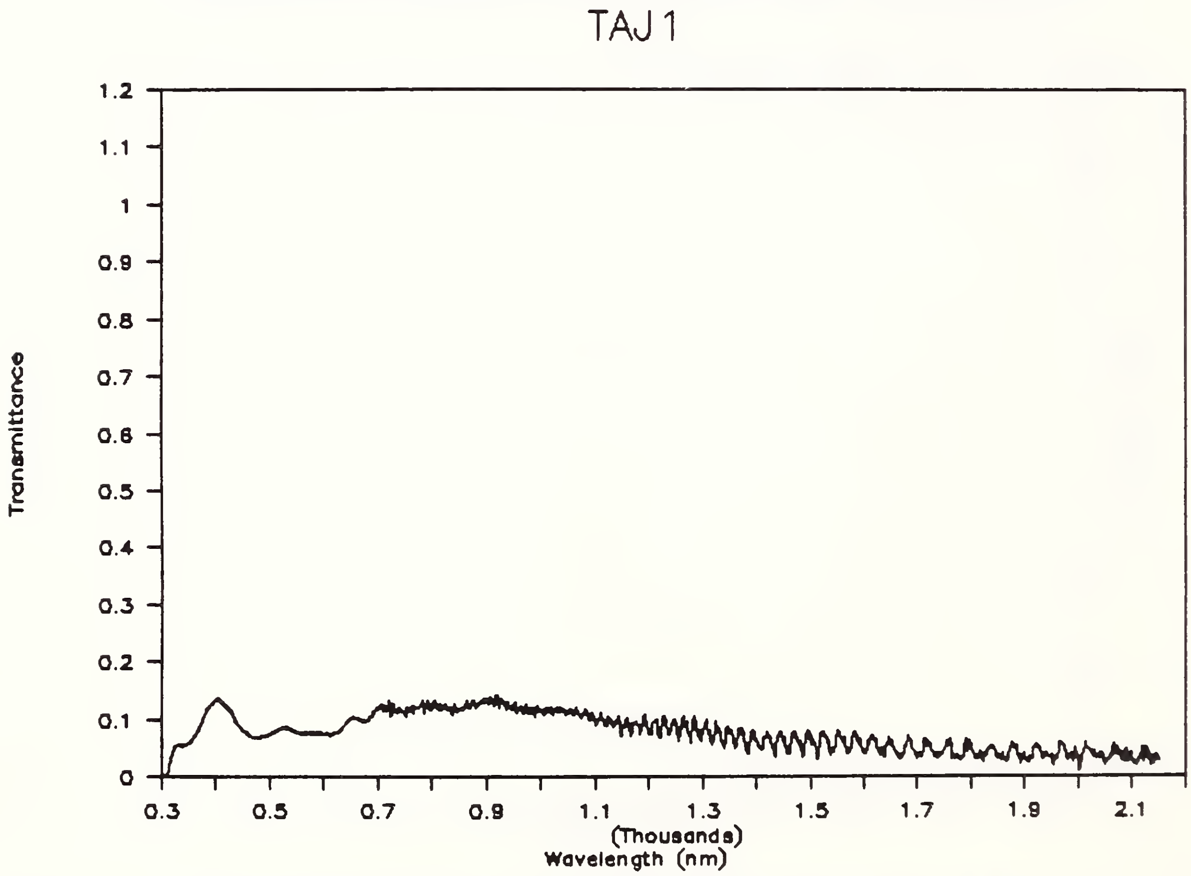


Figure 6.10b Sample AJ, Visible specular transmittance

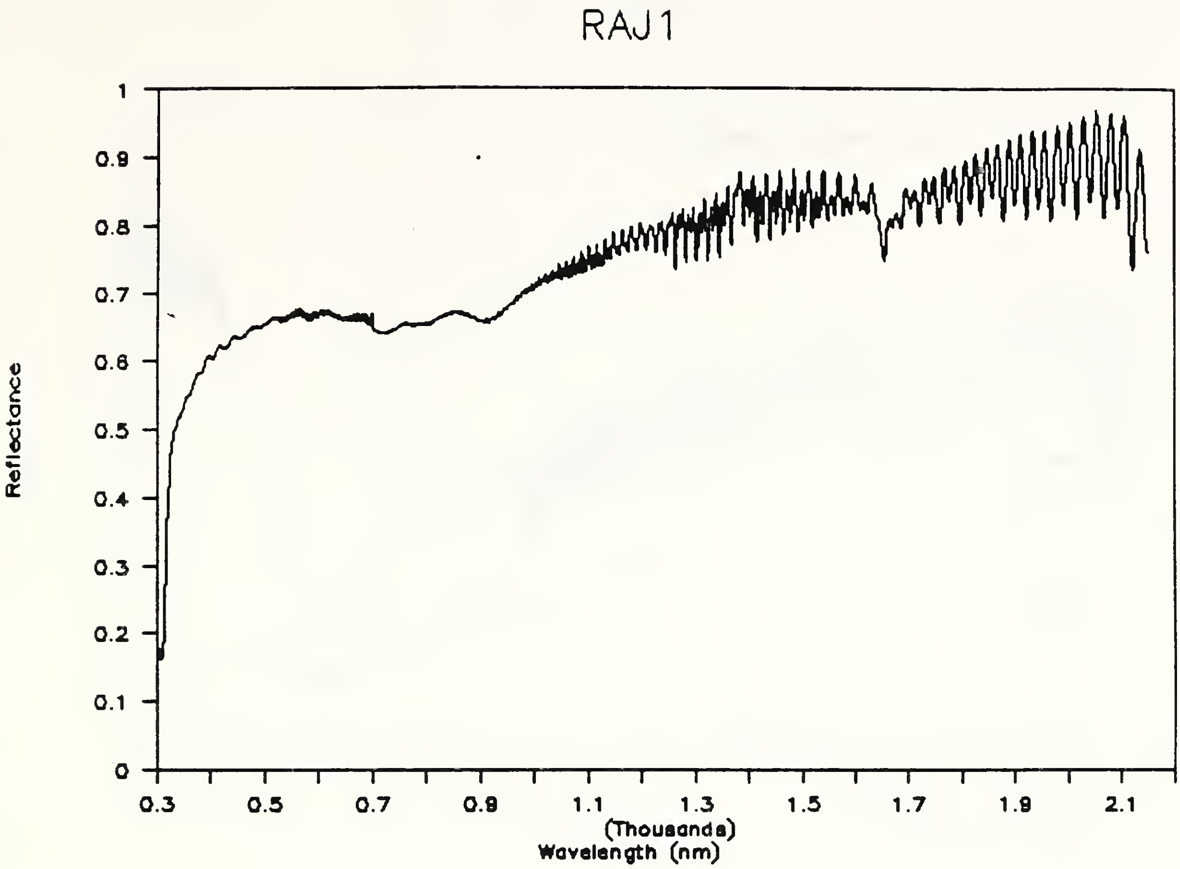


Figure 6.10c Sample AJ, Visible specular reflectance

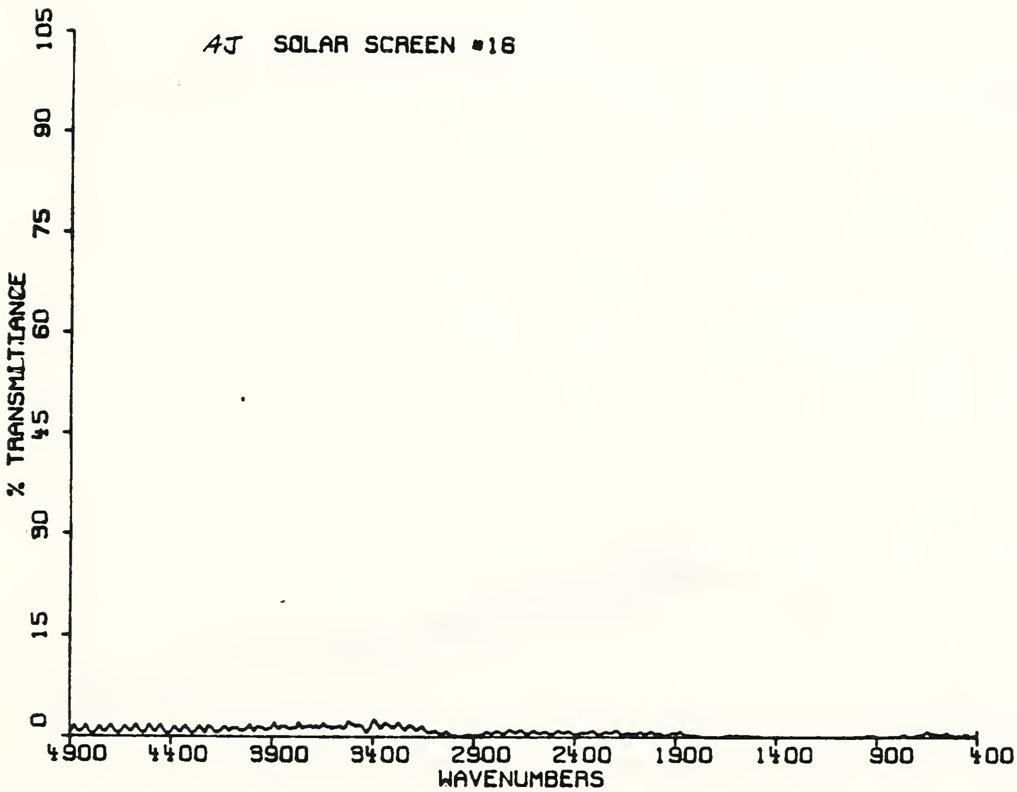


Figure 6.10d Sample AJ, IR specular transmittance

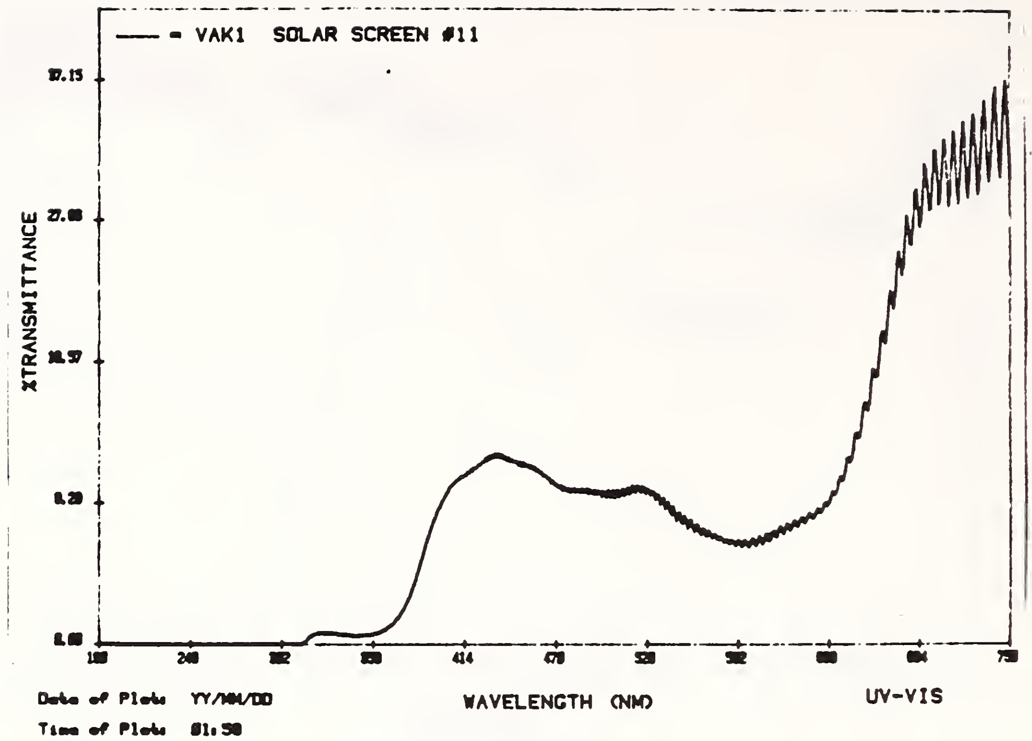


Figure 6.11a Sample AK, UV-visible total transmittance

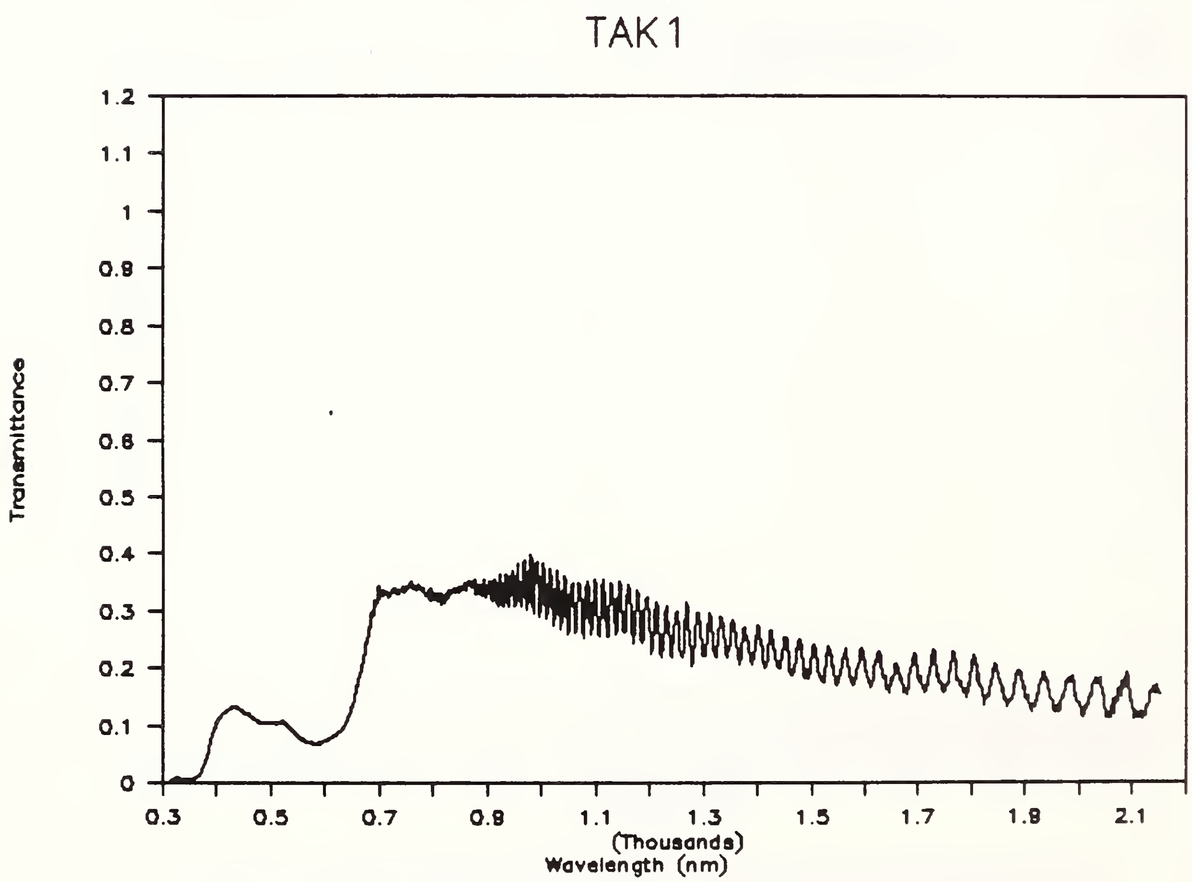


Figure 6.11b Sample AK, Visible specular transmittance

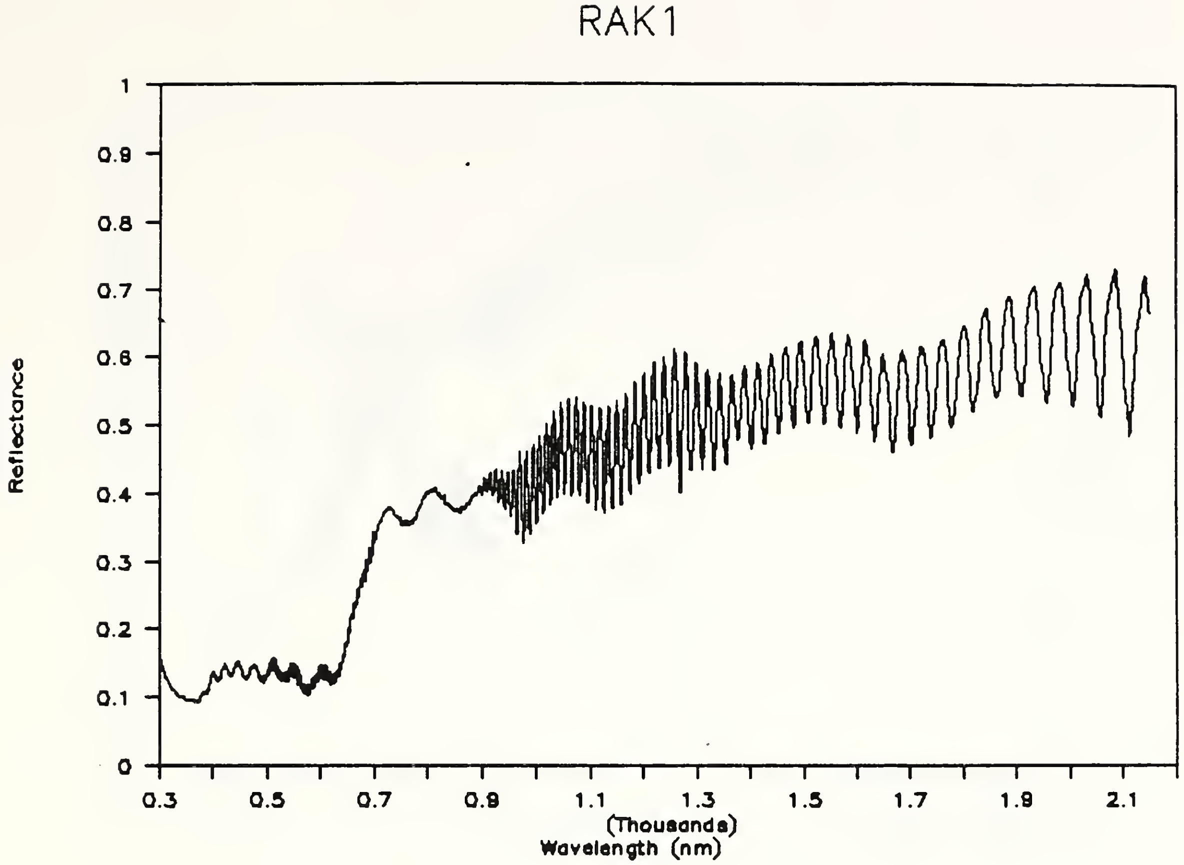


Figure 6.11c Sample AK, Visible specular reflectance

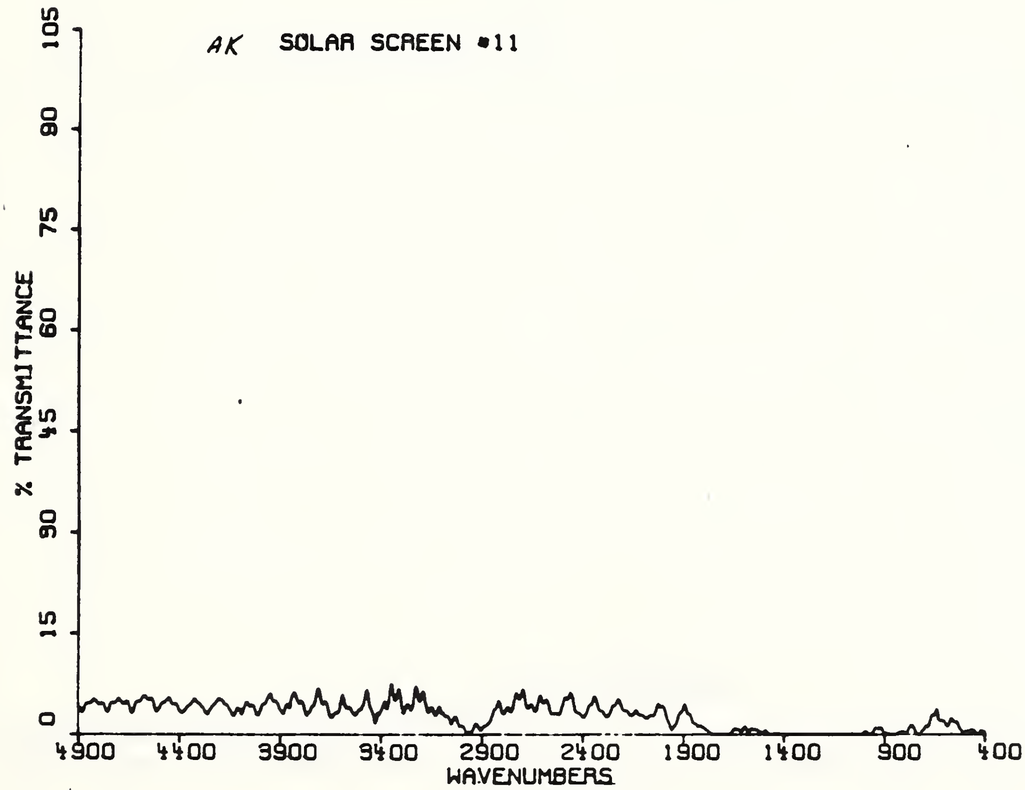


Figure 6.11d Sample AK, IR specular transmittance

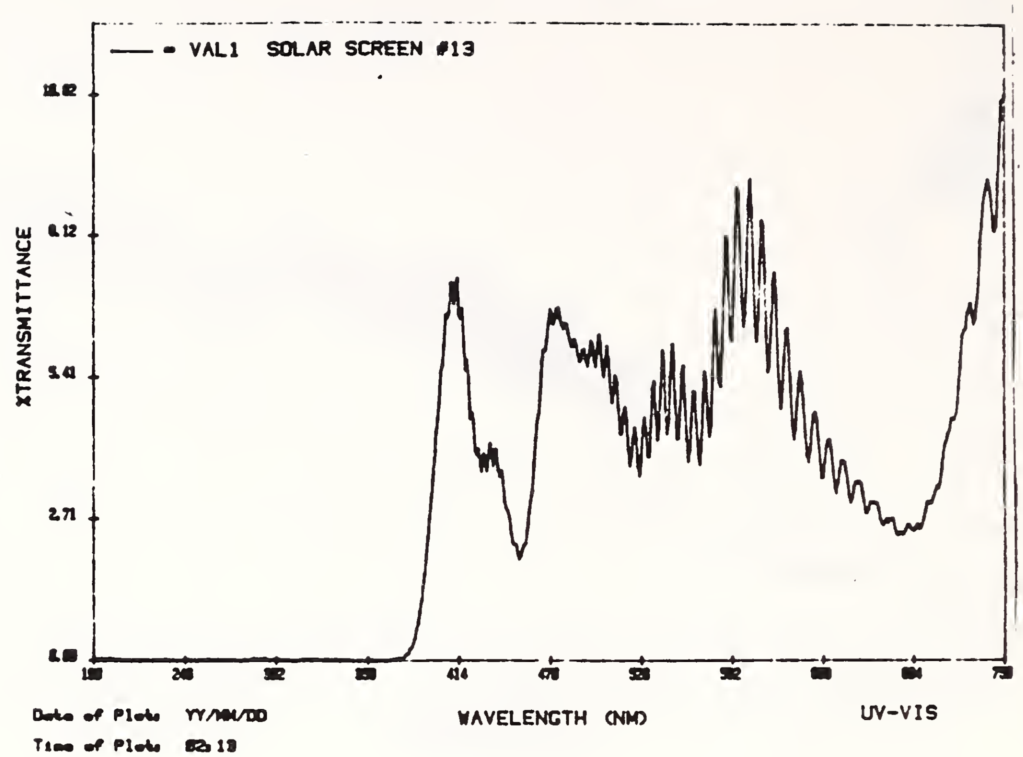


Figure 6.12a Sample AL, UV-visible total transmittance

TAL1

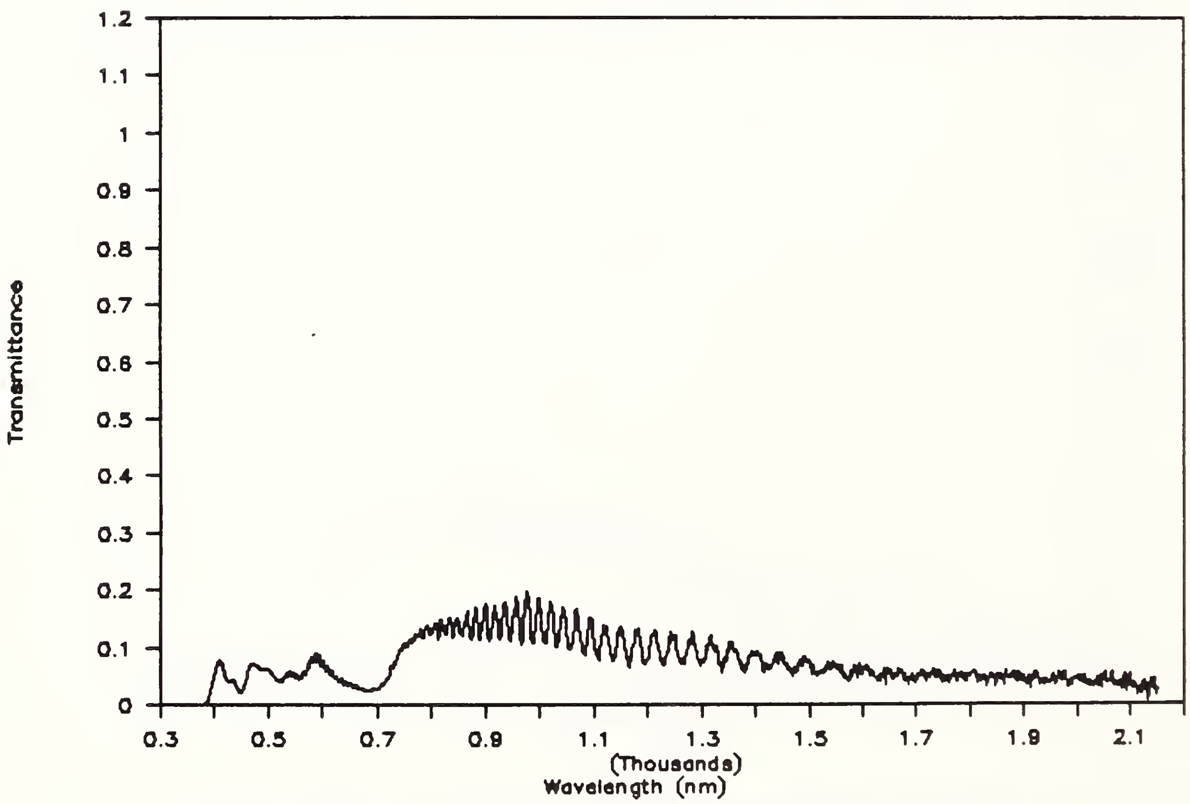


Figure 6.12b Sample AL, Visible specular transmittance

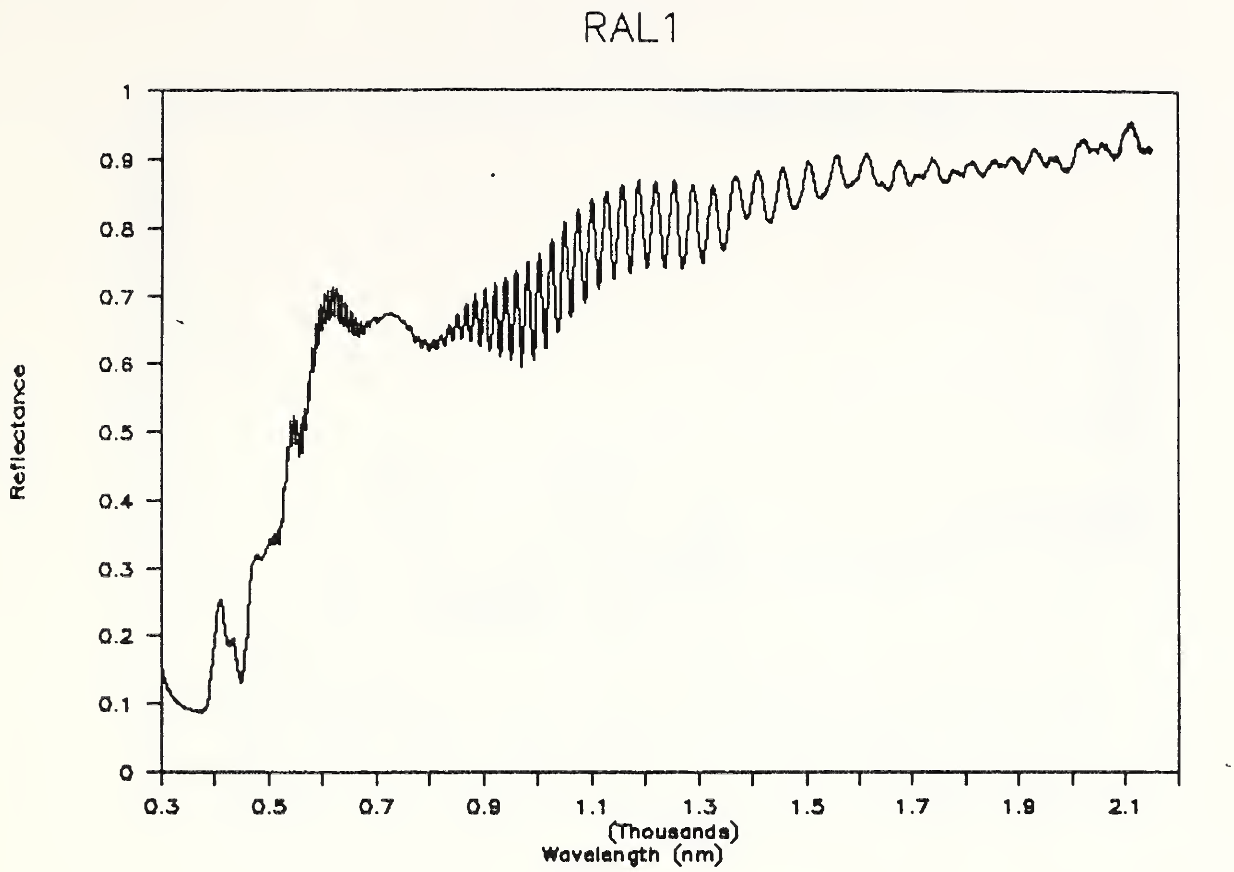


Figure 6.12c Sample AL, Visible specular reflectance

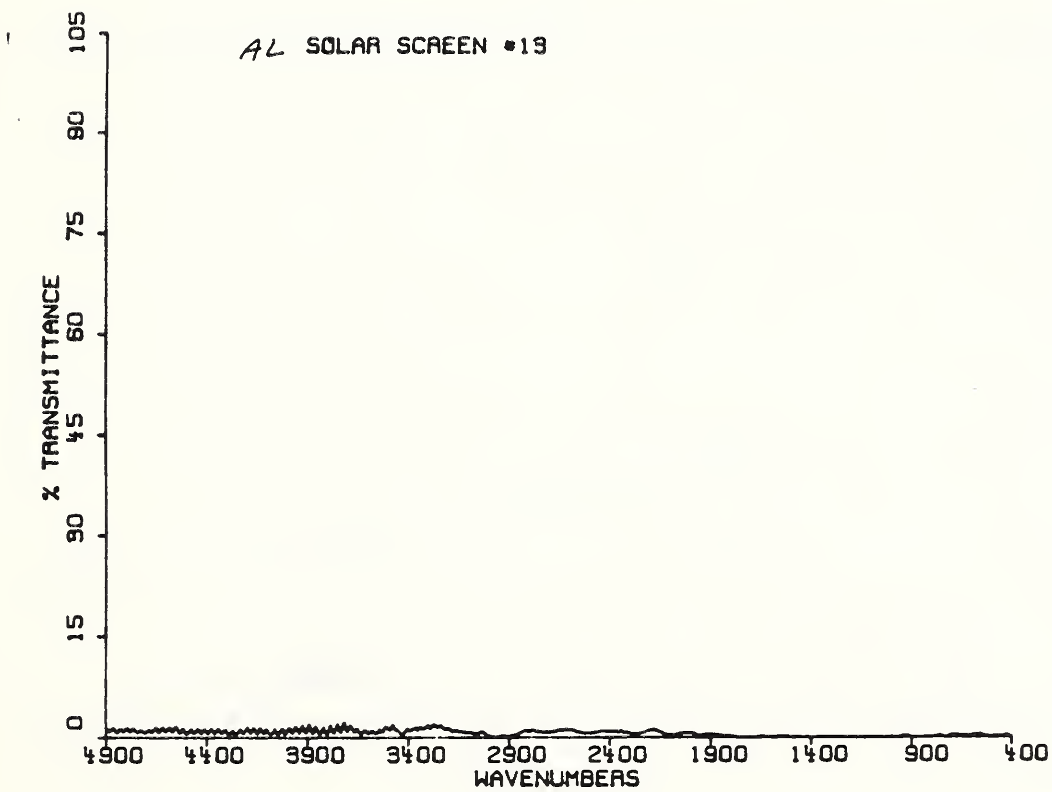


Figure 6.12d Sample AL, IR specular transmittance

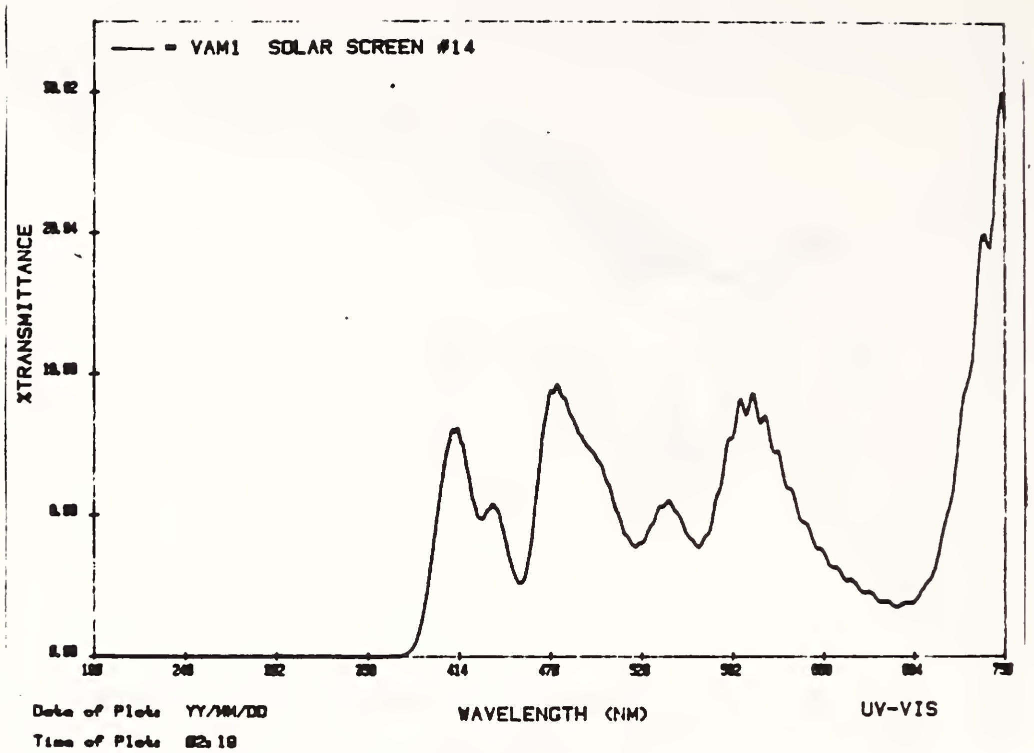


Figure 6.13a Sample AM, UV-visible total transmittance

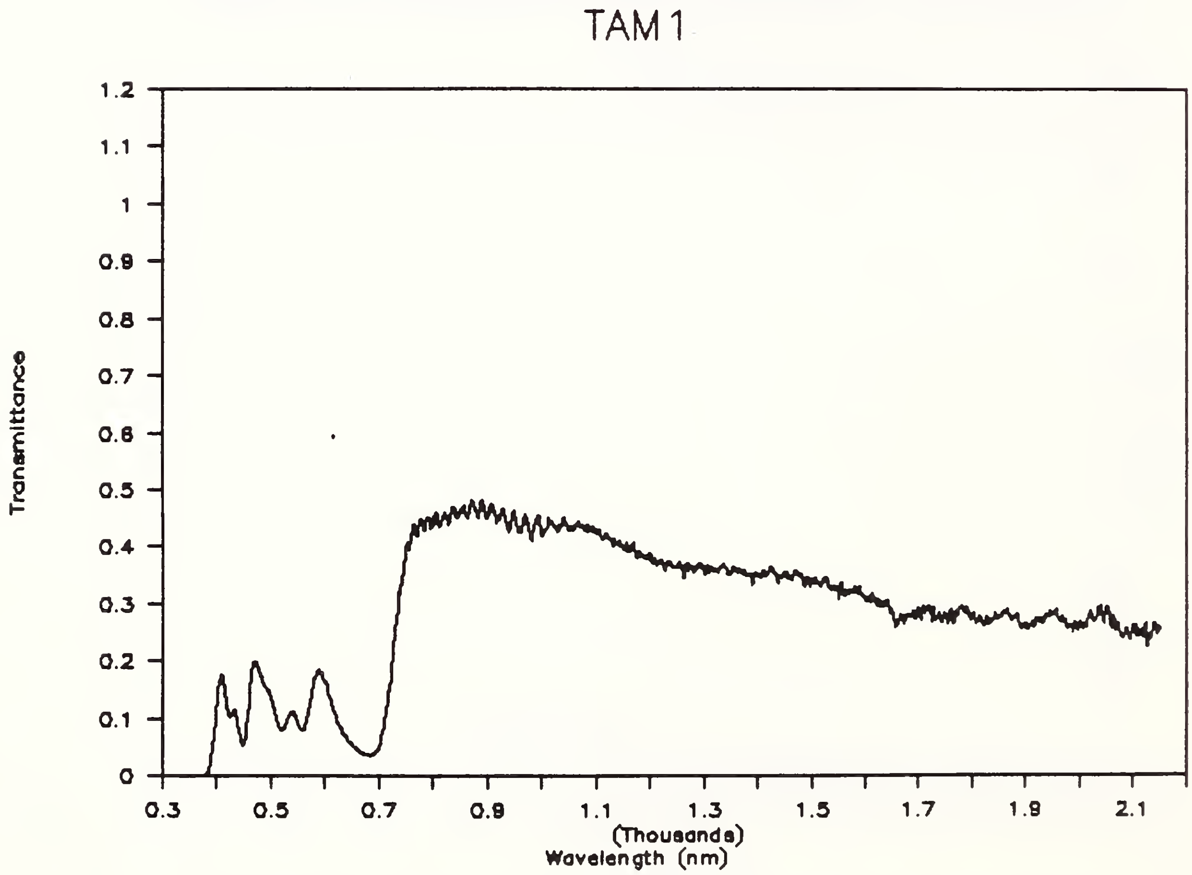


Figure 6.13b Sample AM, Visible specular transmittance

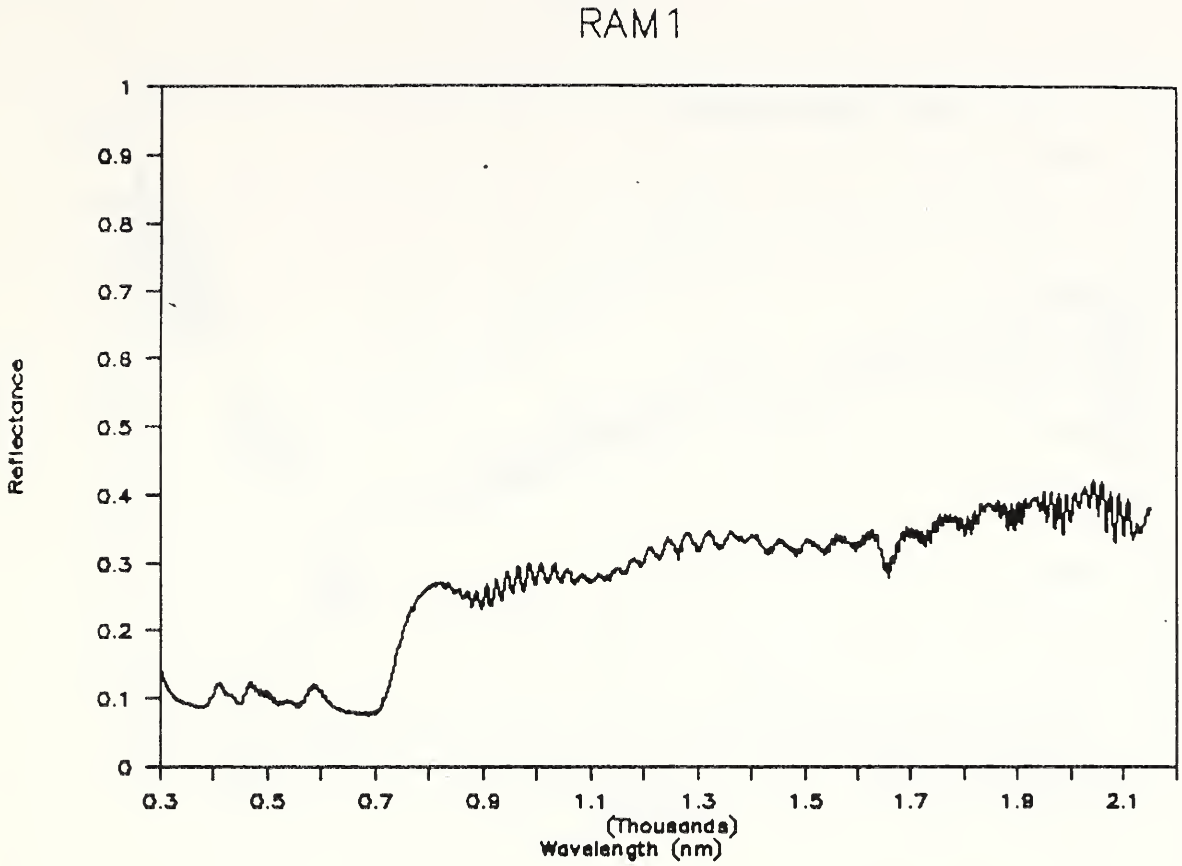


Figure 6.13c Sample AM, Visible specular reflectance

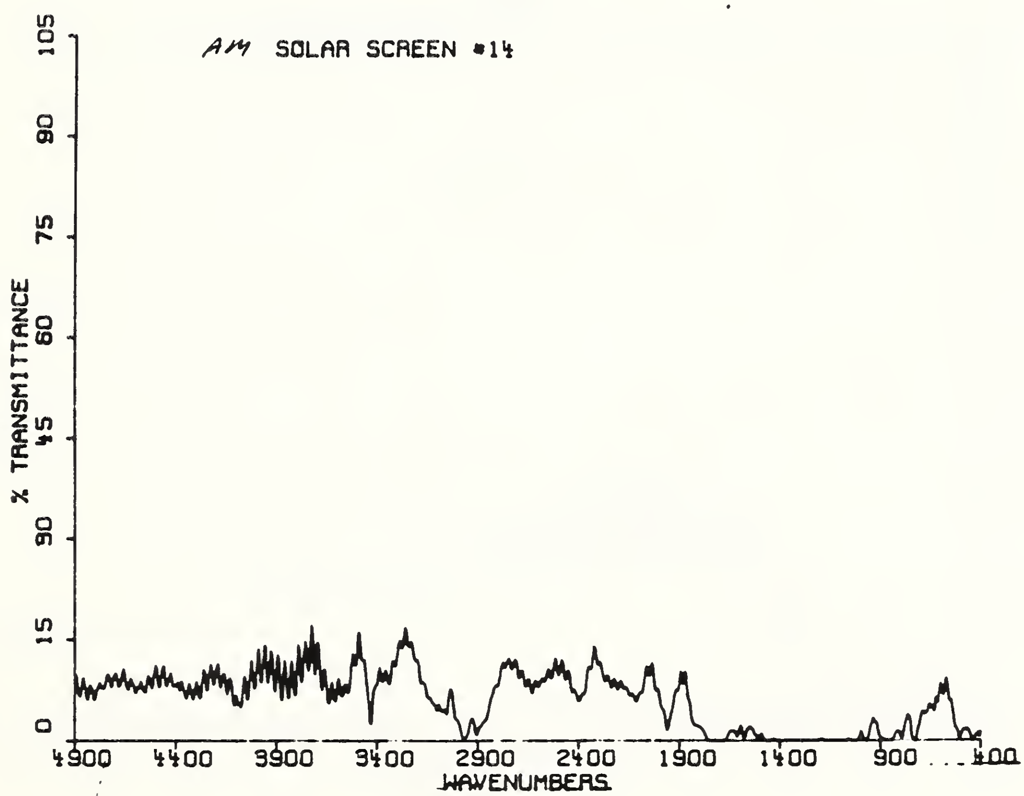


Figure 6.13d Sample AM, IR specular transmittance

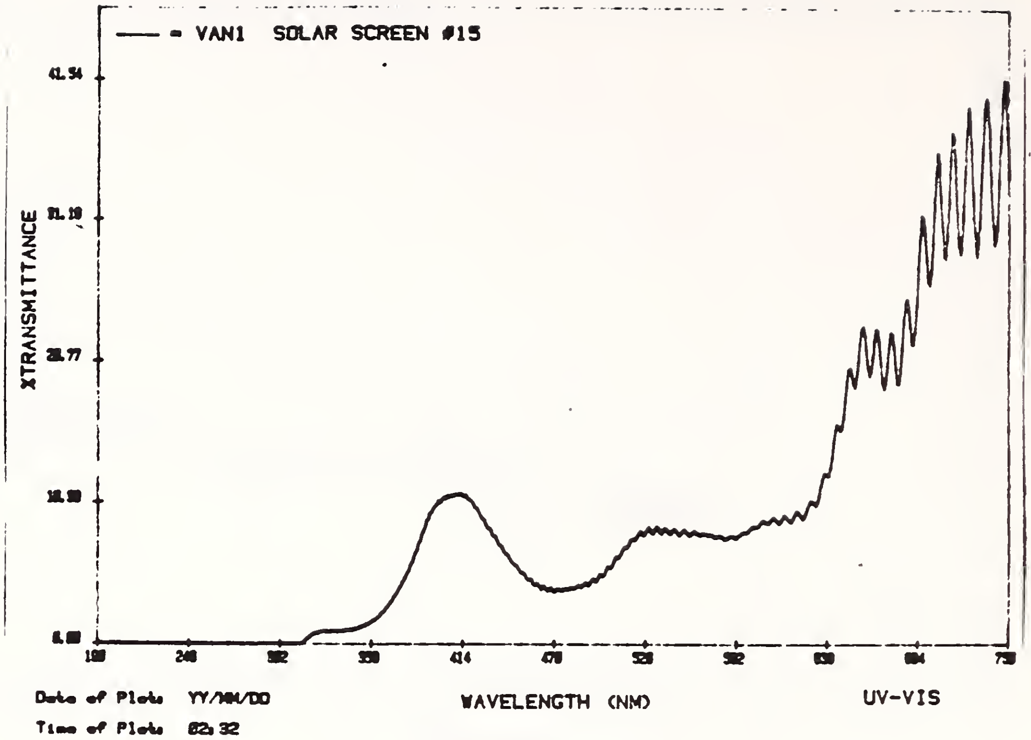


Figure 6.14a Sample AN, UV-visible total transmittance

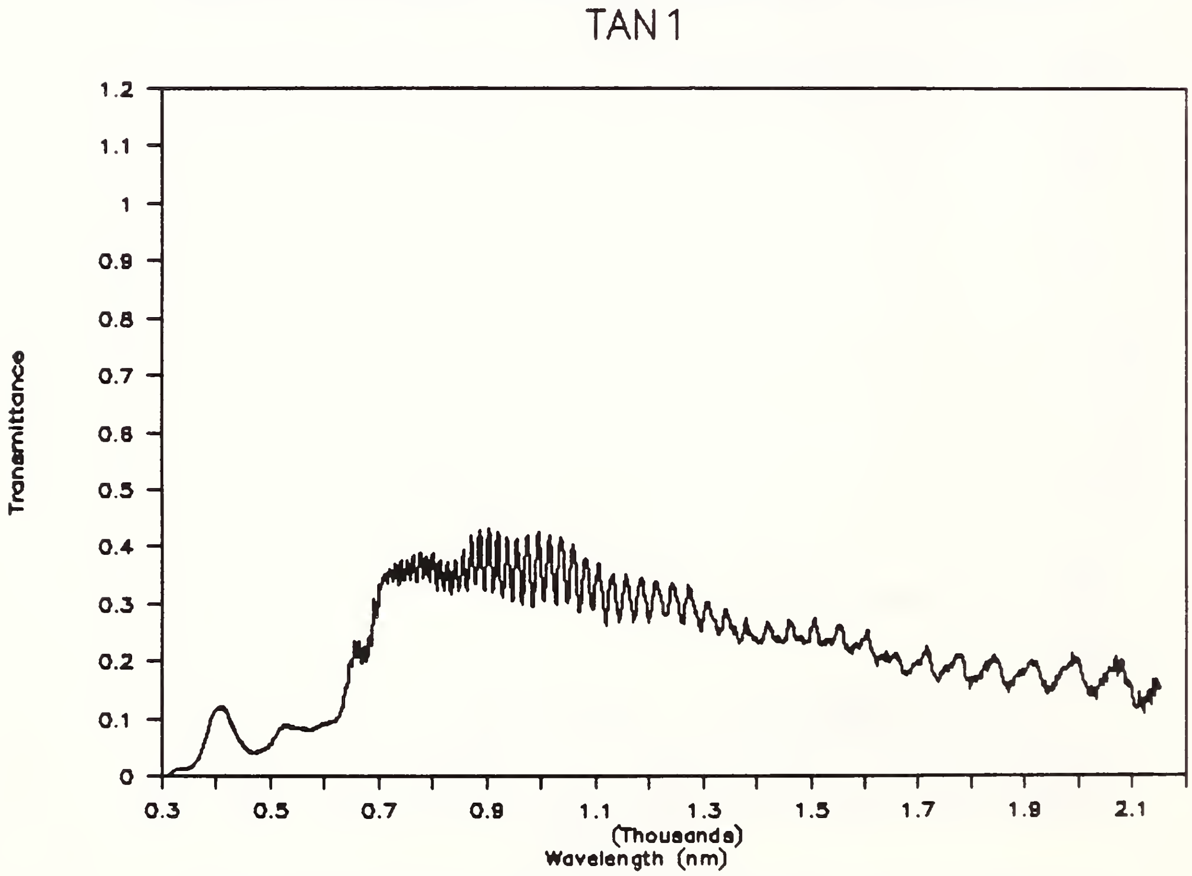


Figure 6.14b Sample AN, Visible specular transmittance

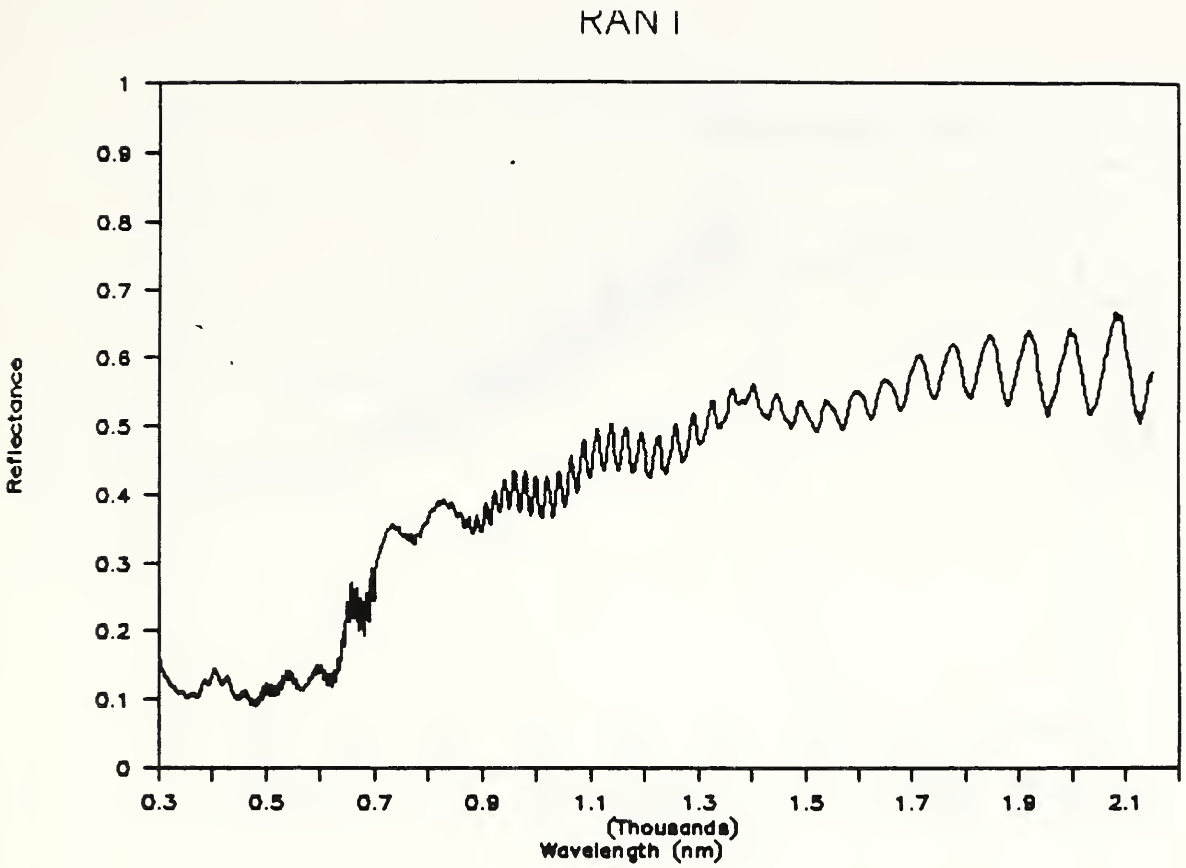


Figure 6.14c Sample AN, Visible specular reflectance

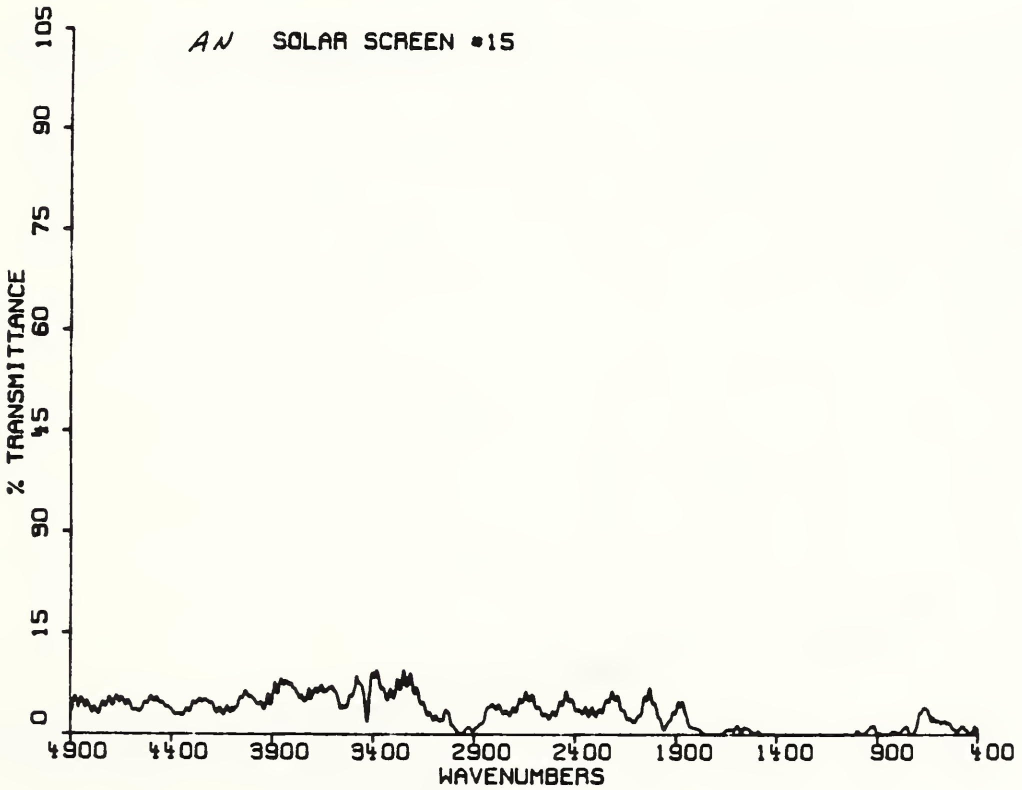


Figure 6.14d Sample AN, IR specular transmittance

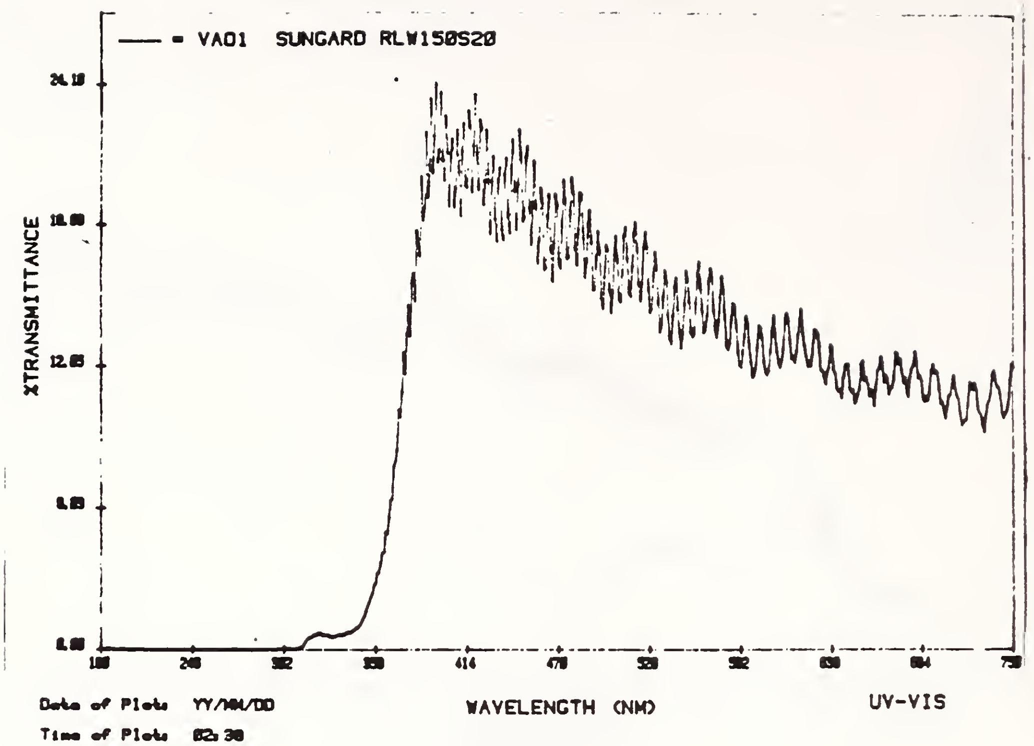


Figure 6.15a Sample AO, UV-visible total transmittance

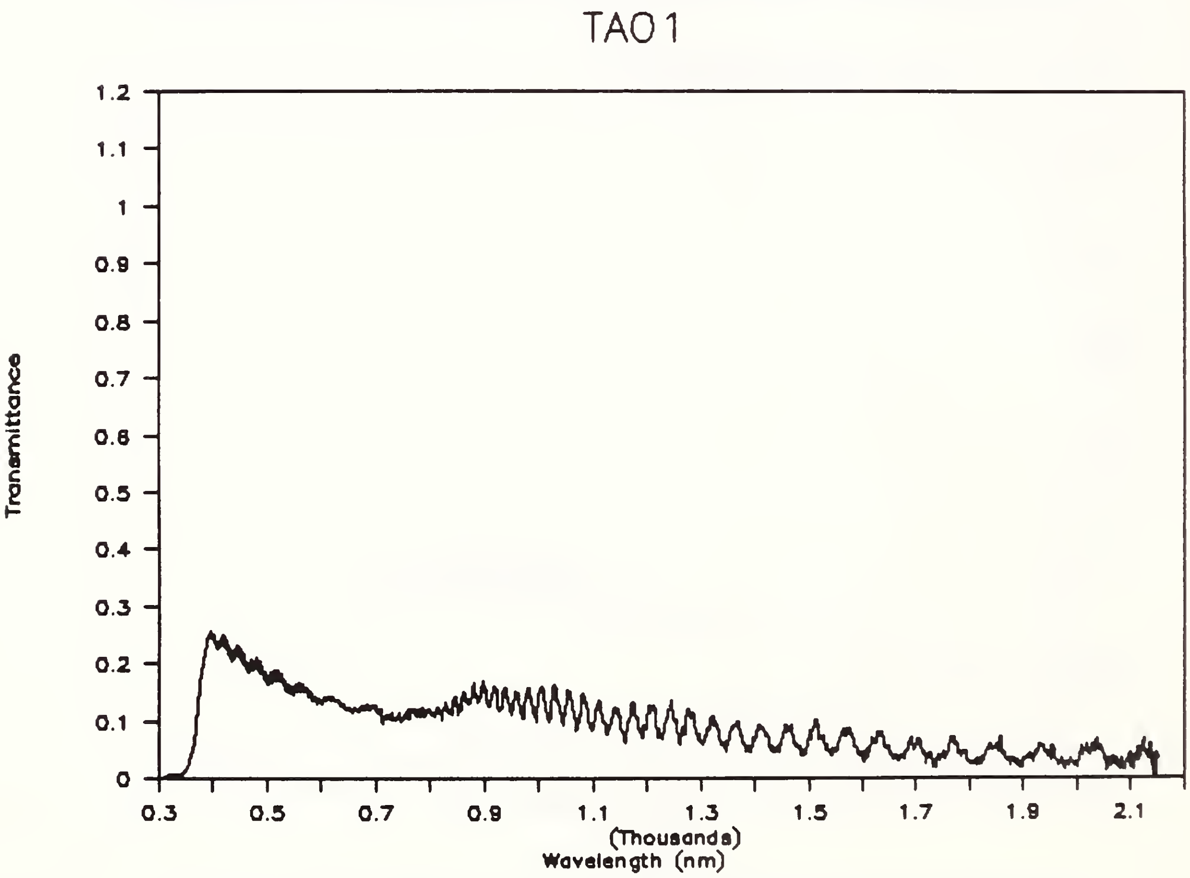


Figure 6.15b Sample AO, Visible specular transmittance

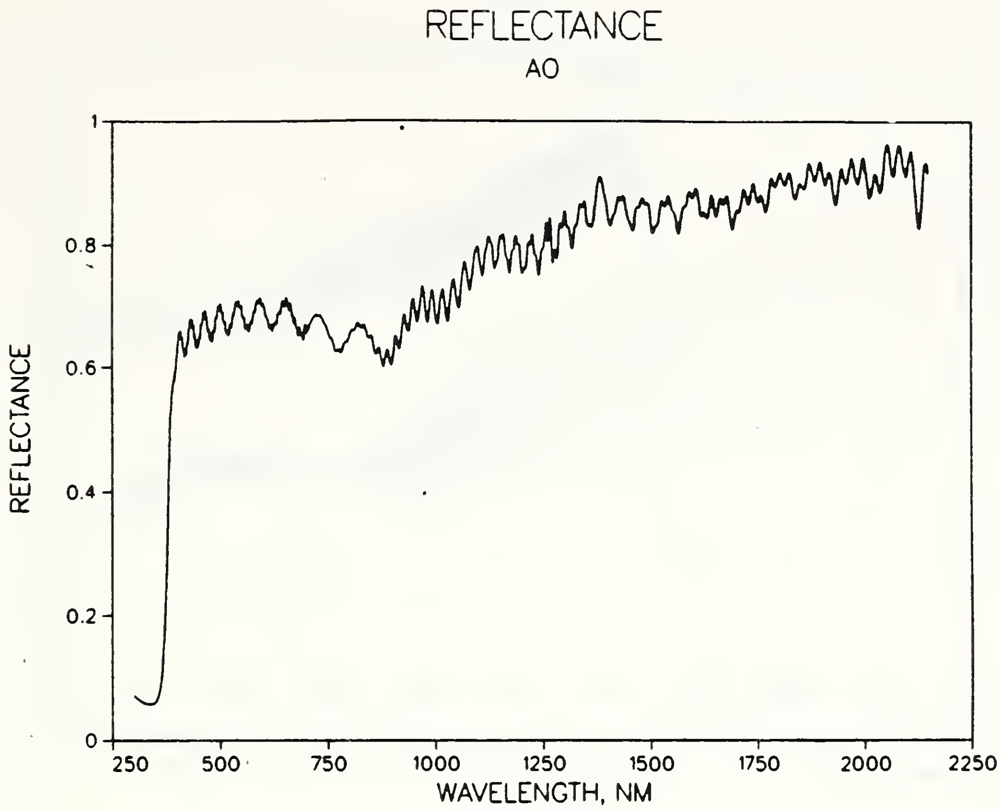


Figure 6.15c Sample AO, Visible specular reflectance

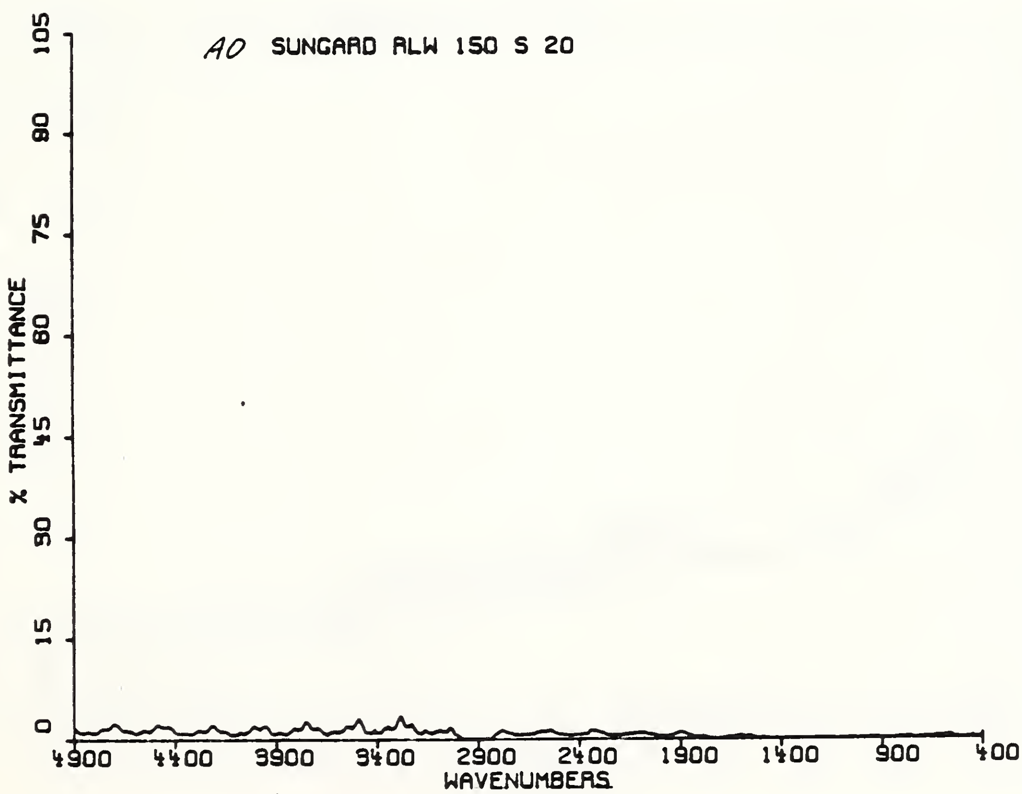


Figure 6.15d Sample AO, IR specular transmittance

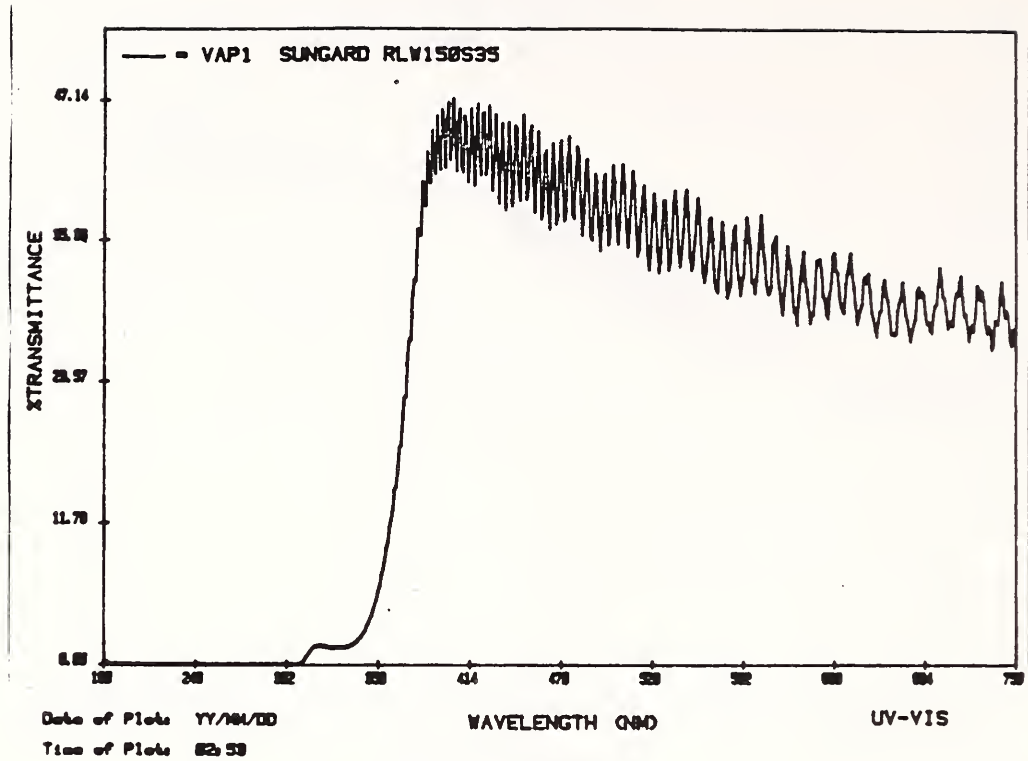


Figure 6.16a Sample AP, UV-visible total transmittance

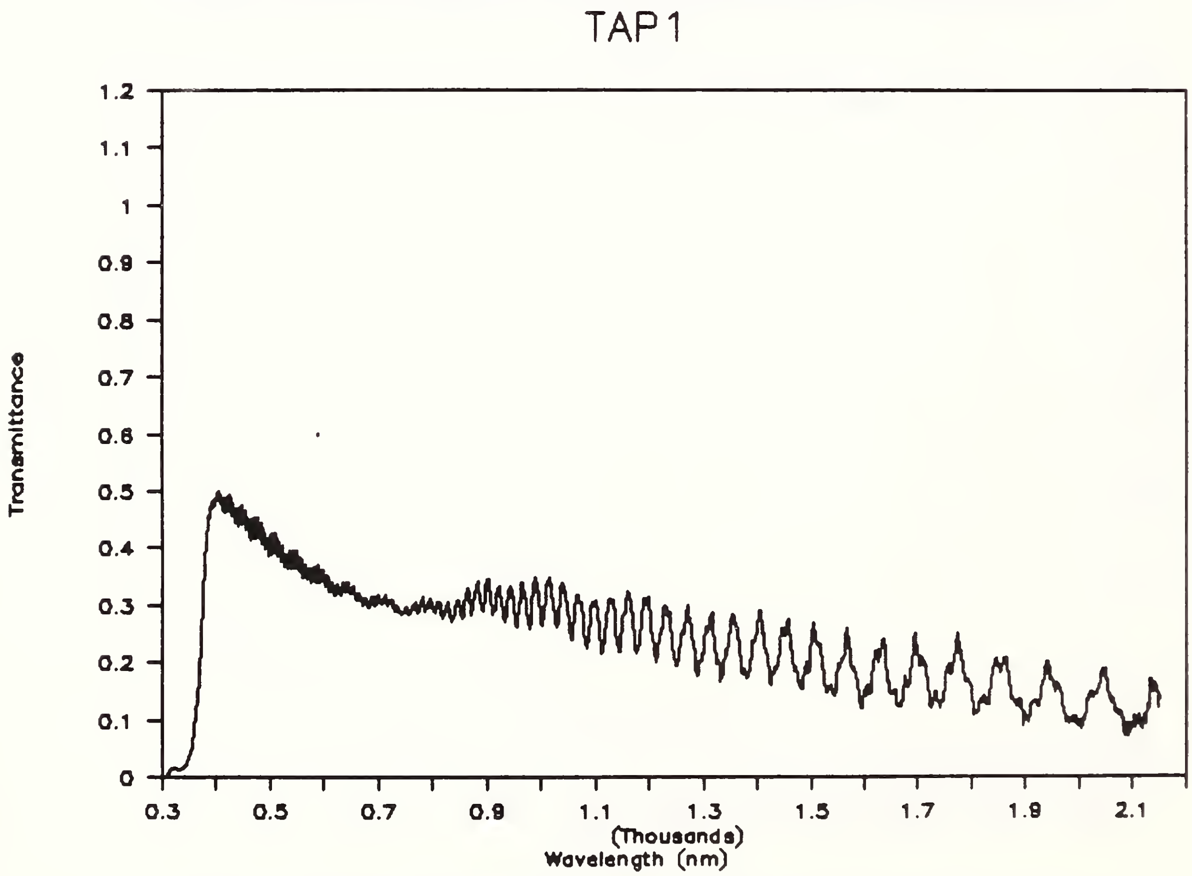


Figure 6.16b Sample AP, Visible specular transmittance

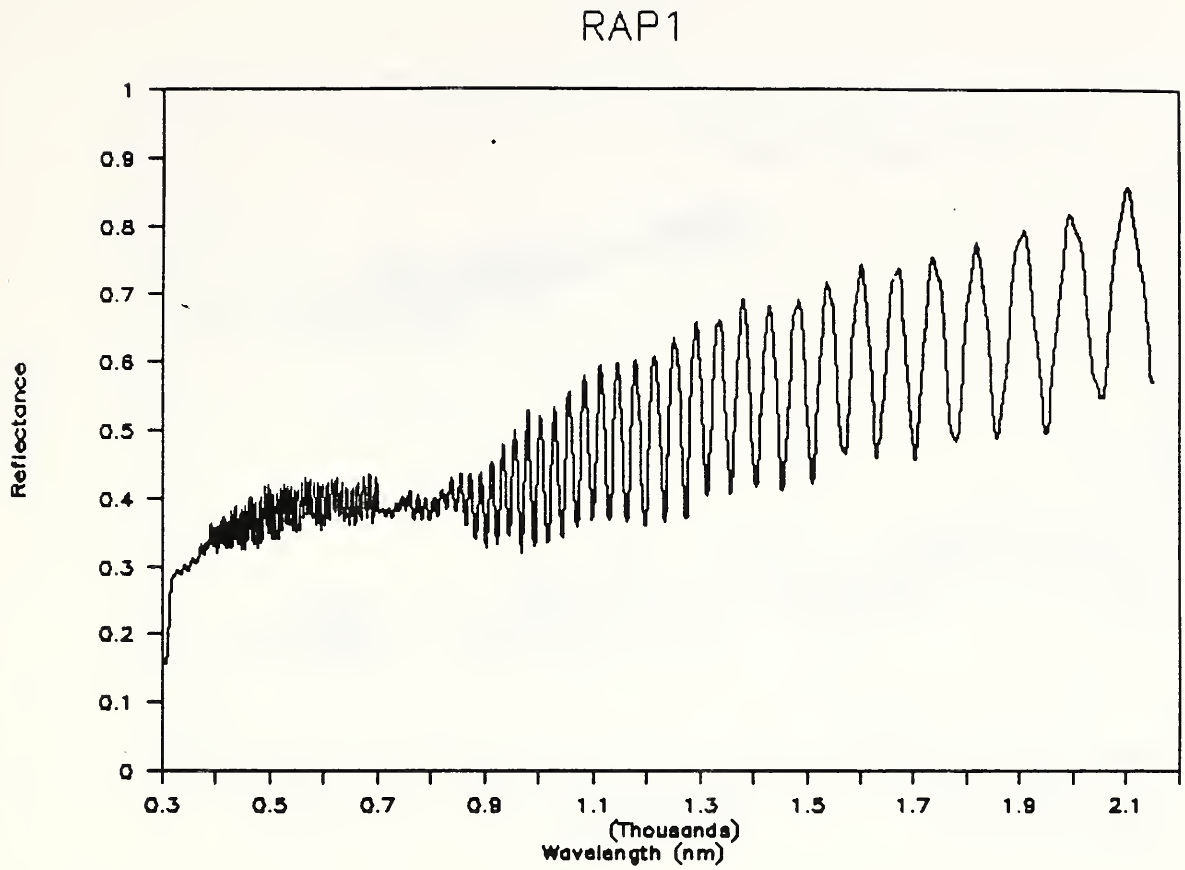


Figure 6.16c Sample AP, Visible specular reflectance

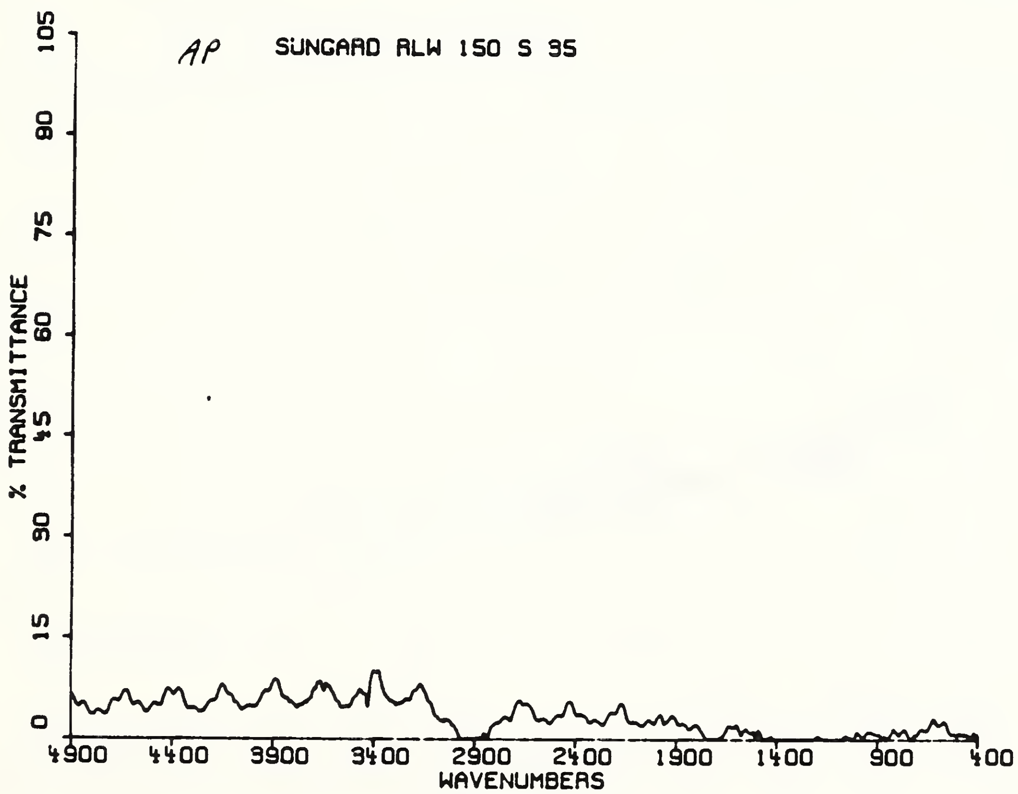


Figure 6.16d Sample AP, IR specular transmittance

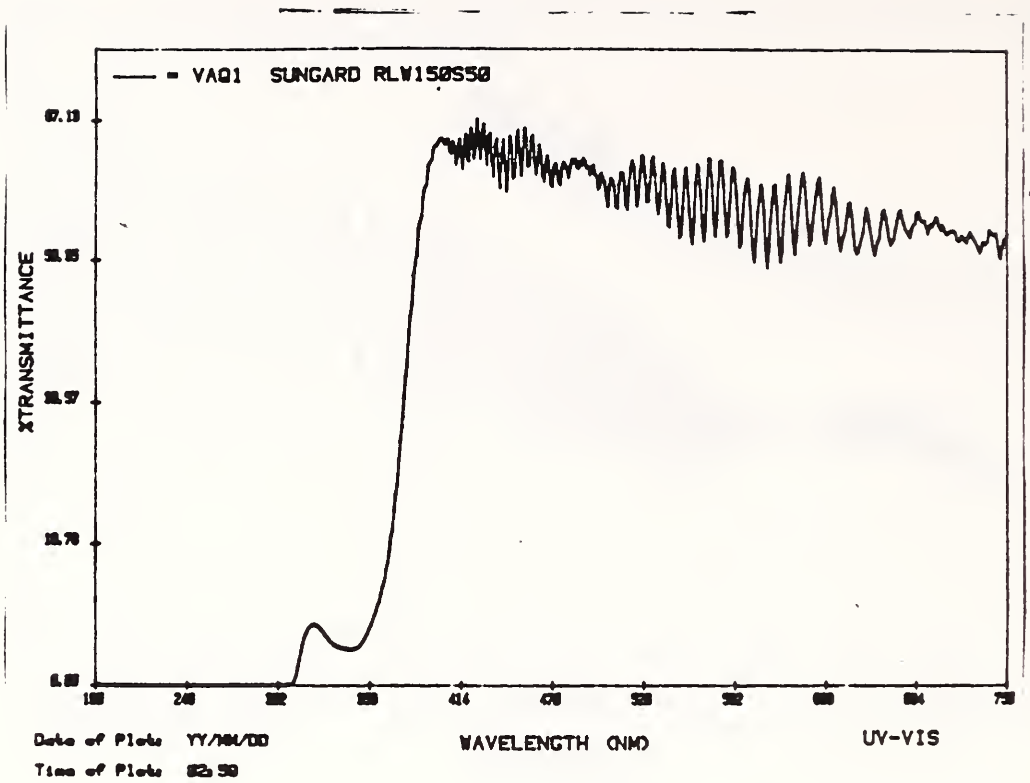


Figure 6.17a Sample AQ, UV-visible total transmittance

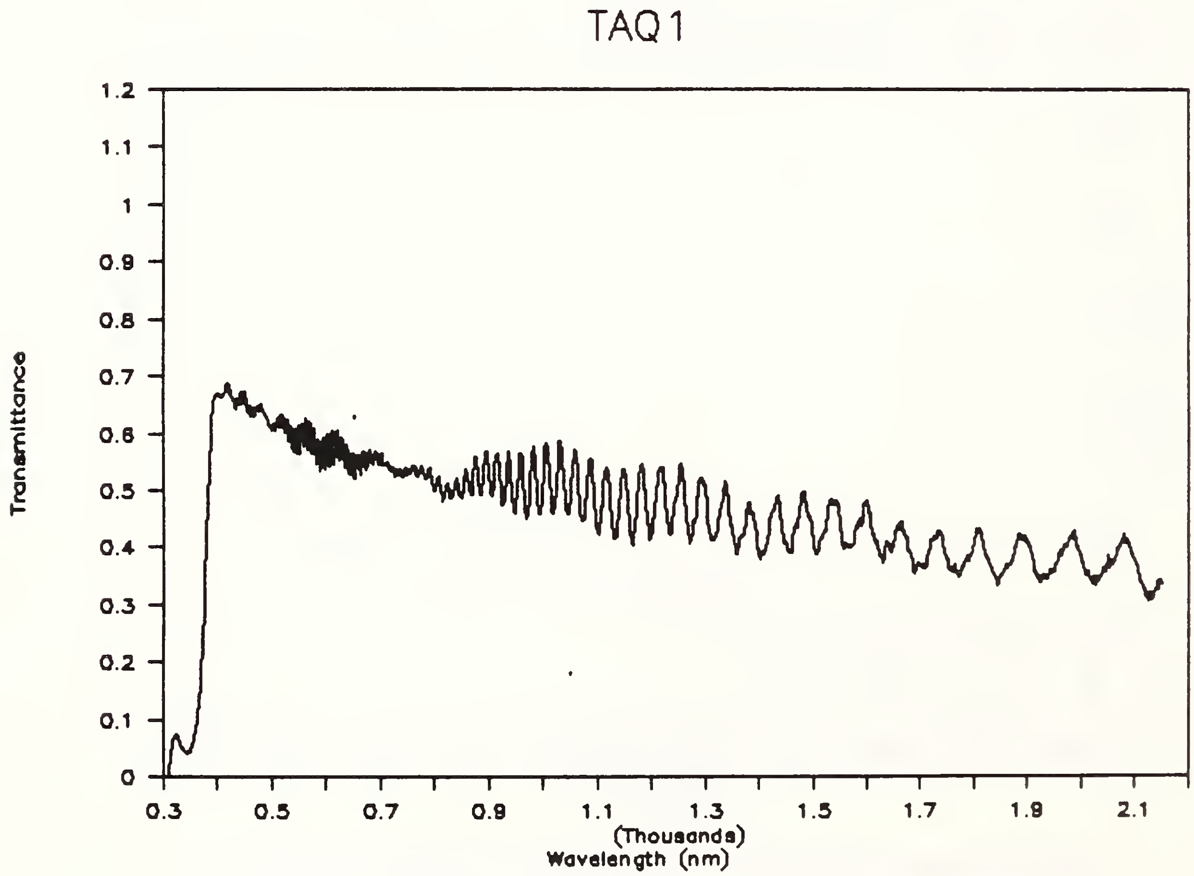


Figure 6.17b Sample AQ, Visible specular transmittance

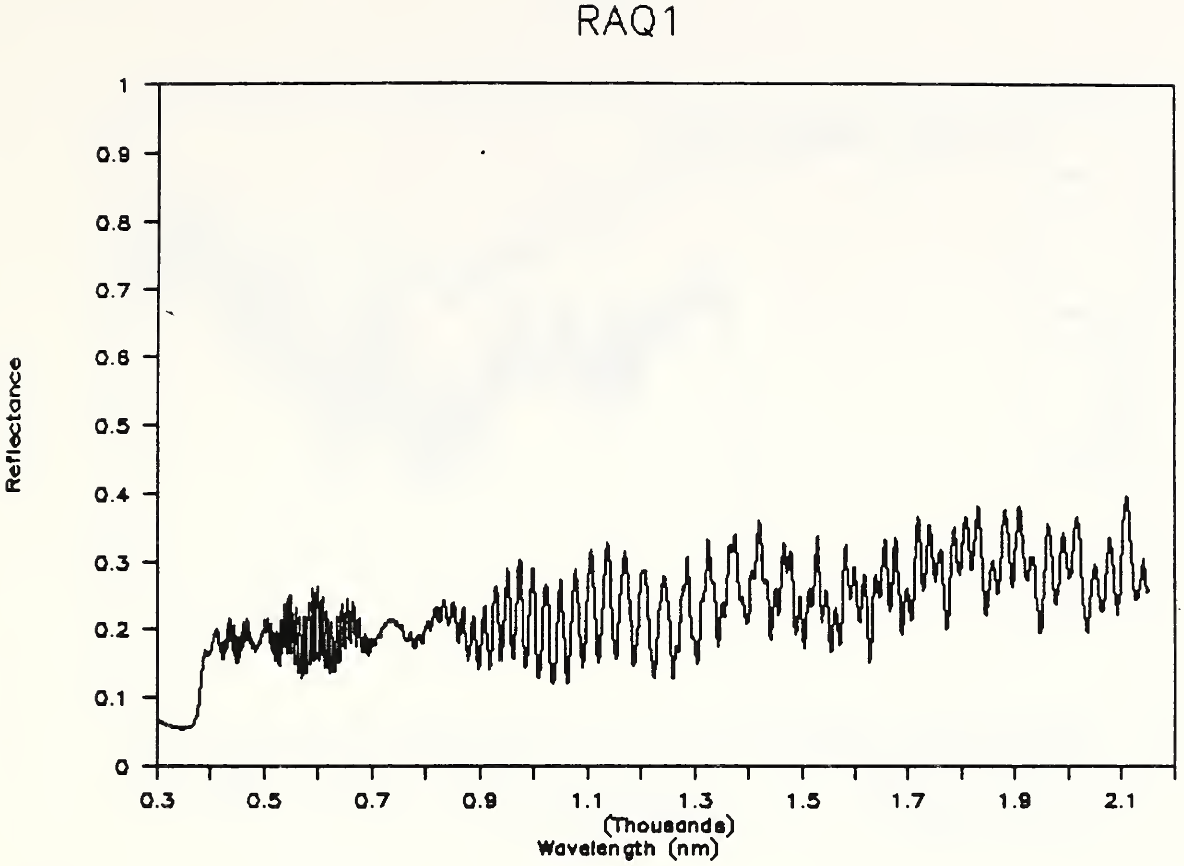


Figure 6.17c Sample AQ, Visible specular reflectance

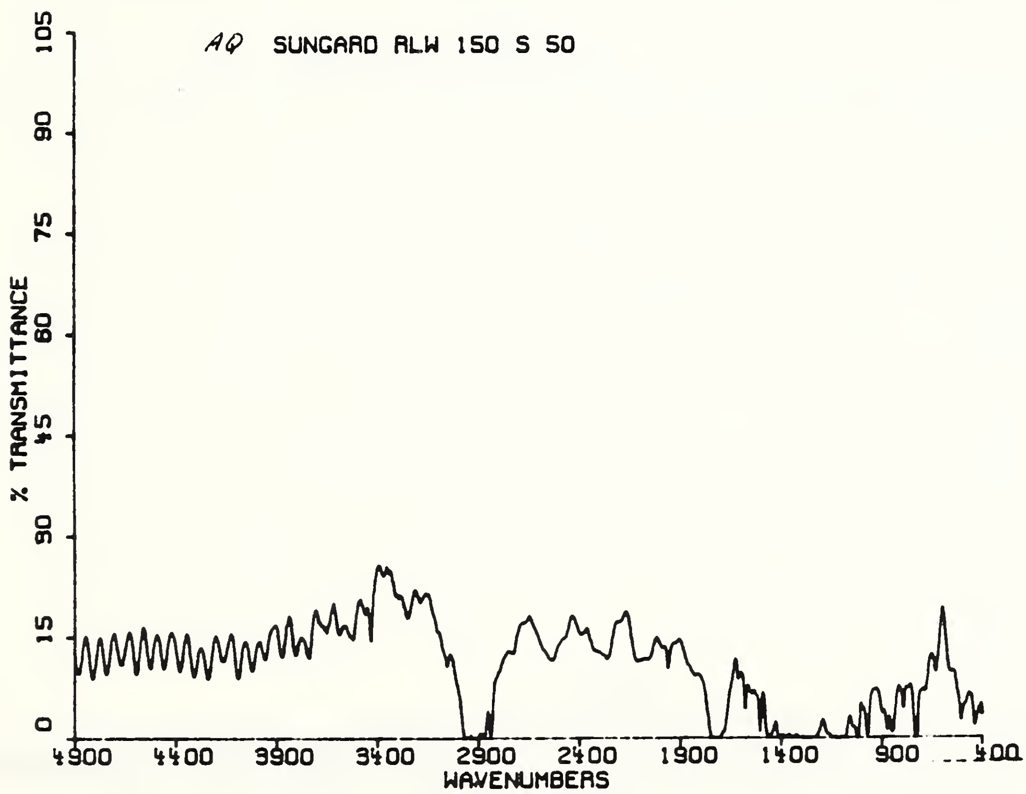


Figure 6.17d Sample AQ, IR specular transmittance

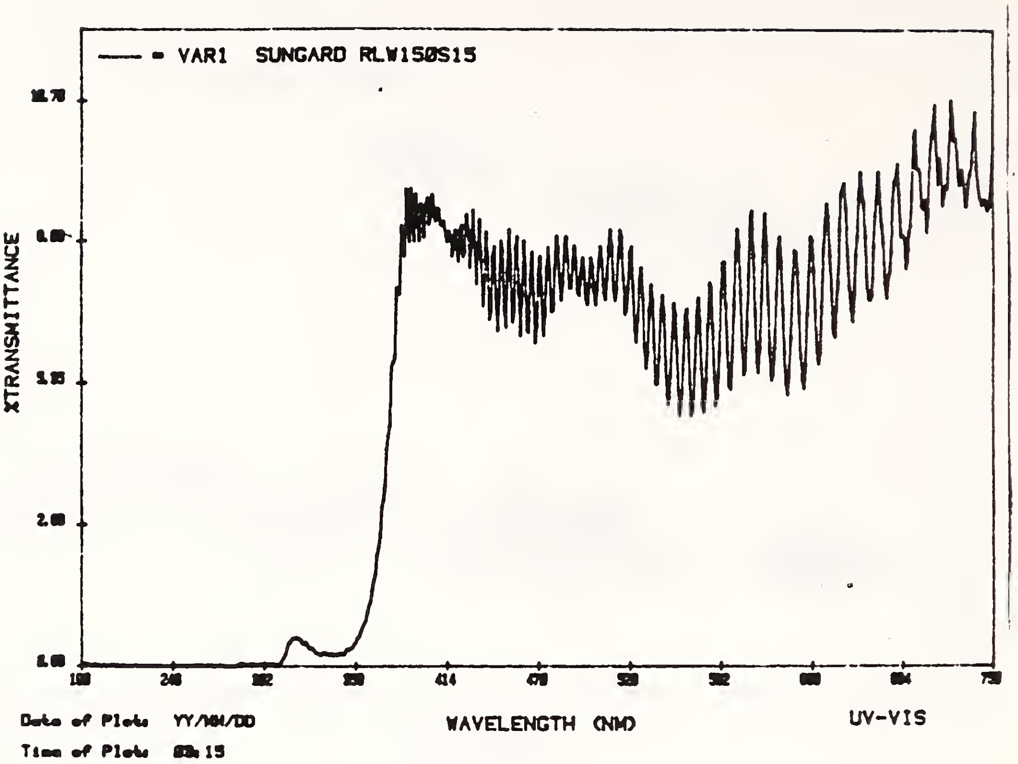


Figure 6.18a Sample AR, UV-visible total transmittance

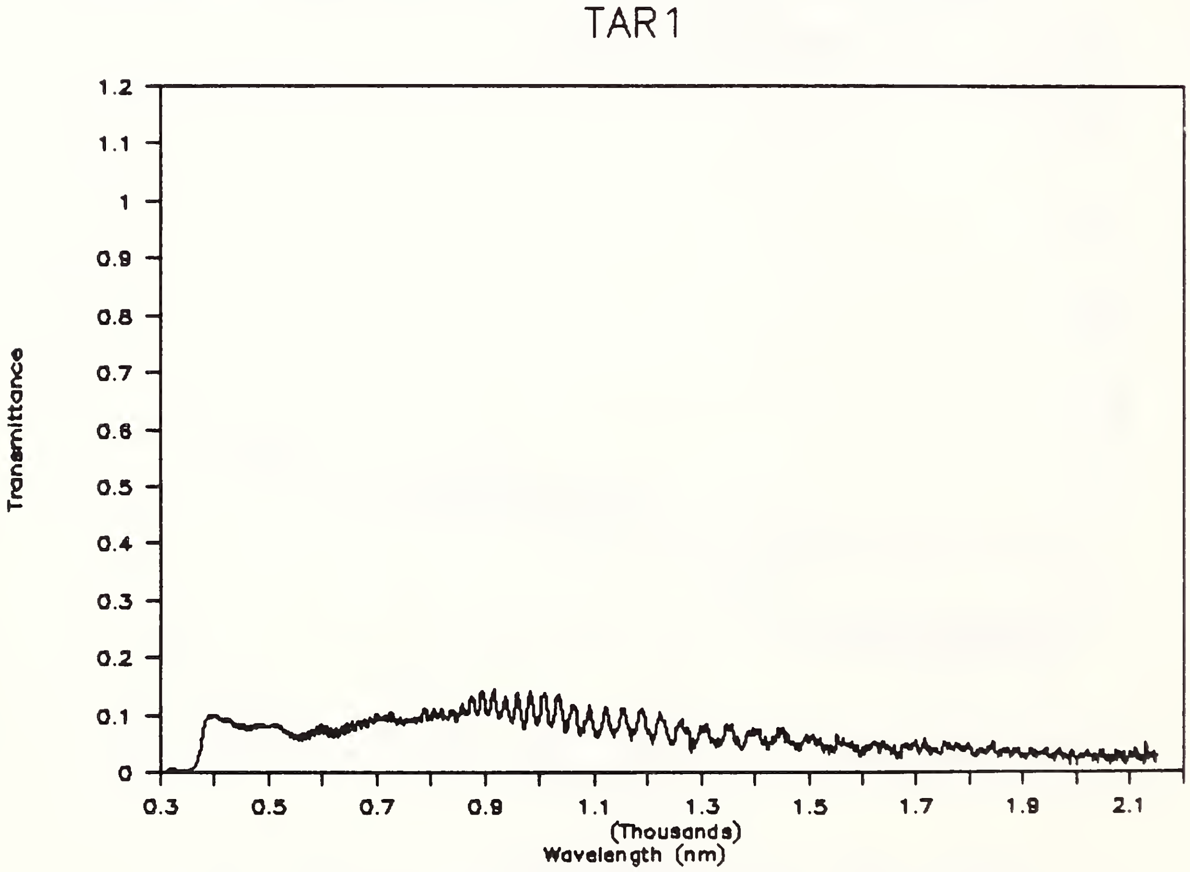


Figure 6.18b Sample AR, Visible specular transmittance

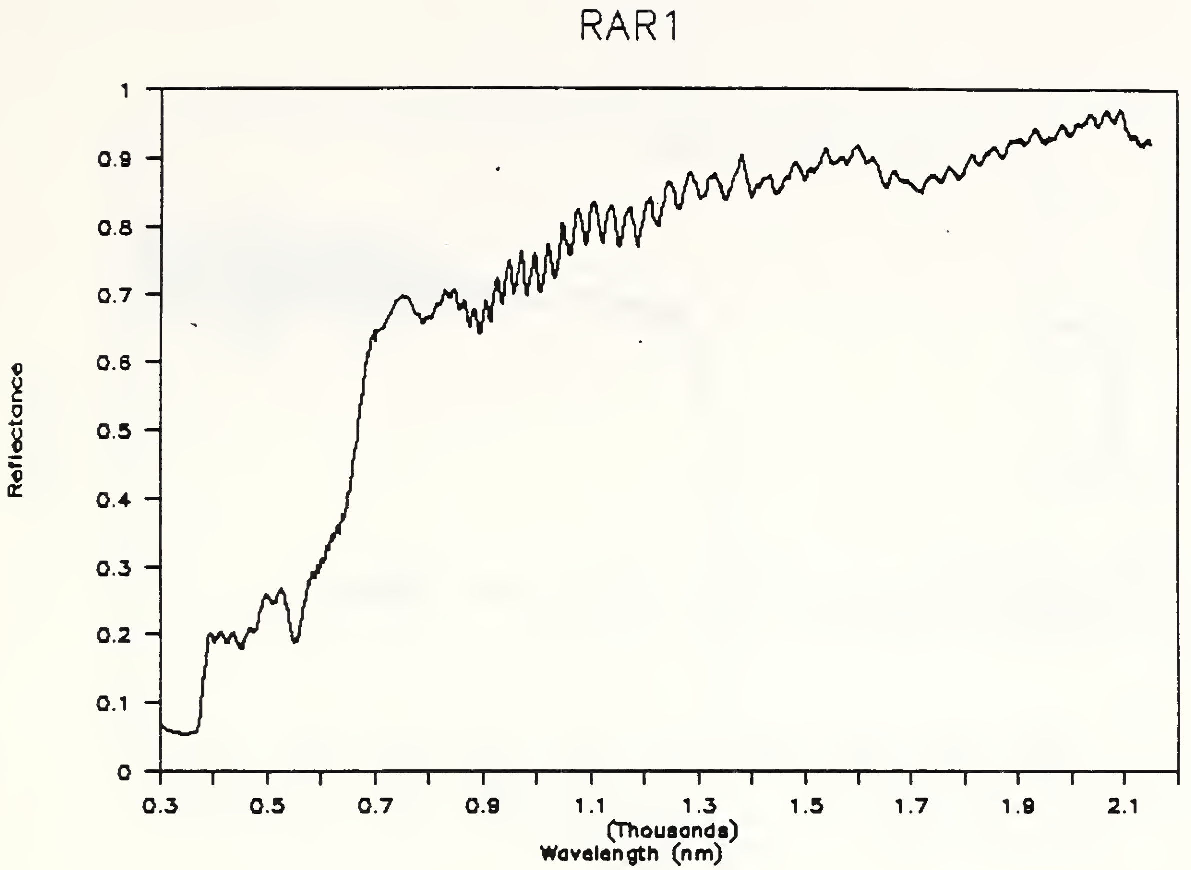


Figure 6.18c Sample AR, Visible specular reflectance

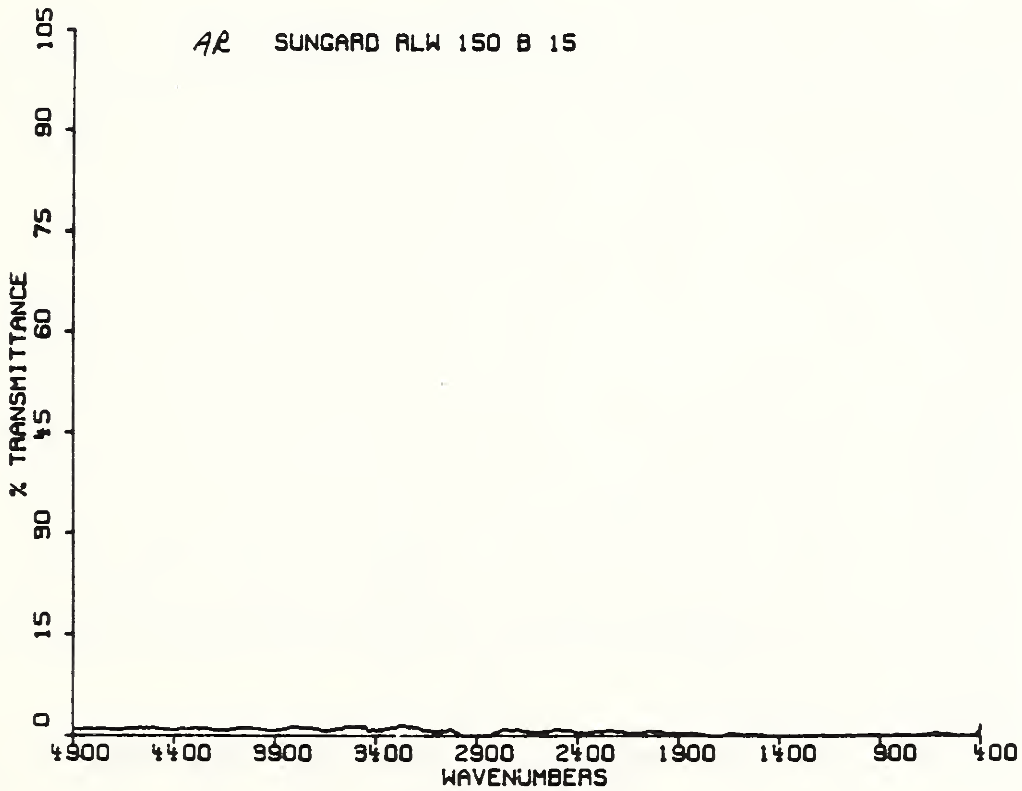


Figure 6.18d Sample AR, IR specular transmittance

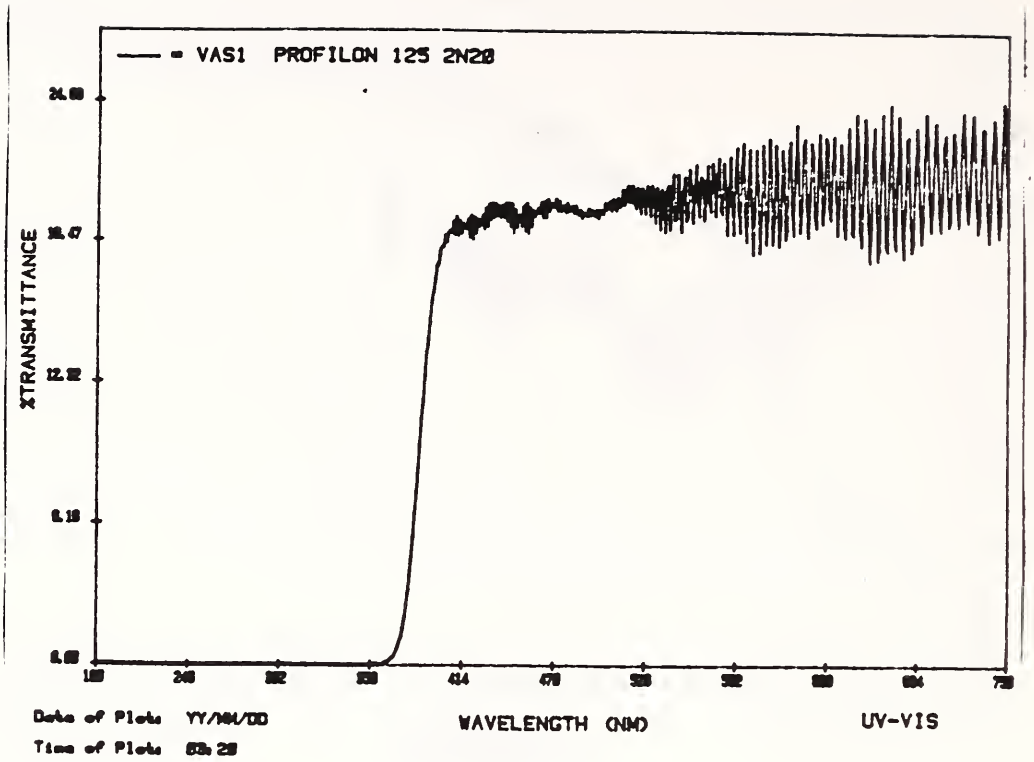


Figure 6.19a Sample AS, UV-visible total transmittance

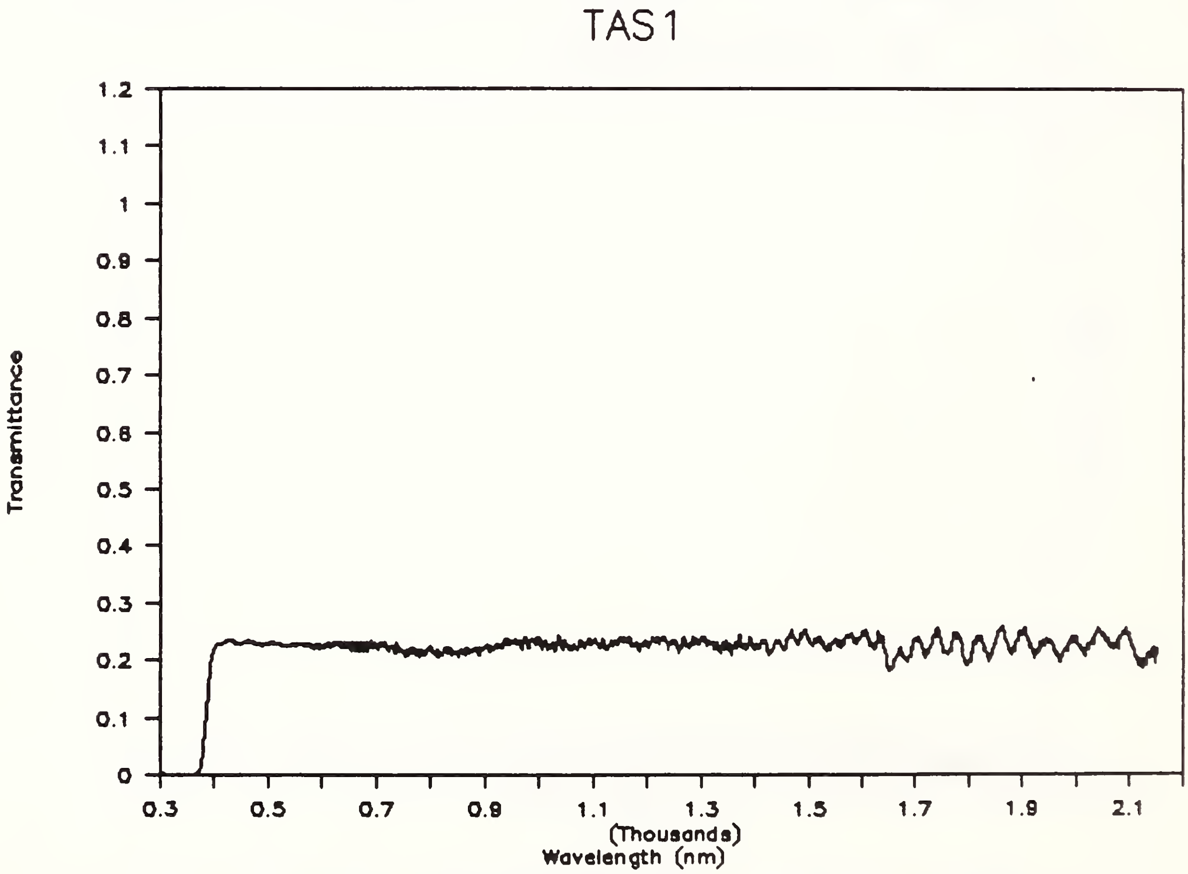


Figure 6.19b Sample AS, Visible specular transmittance

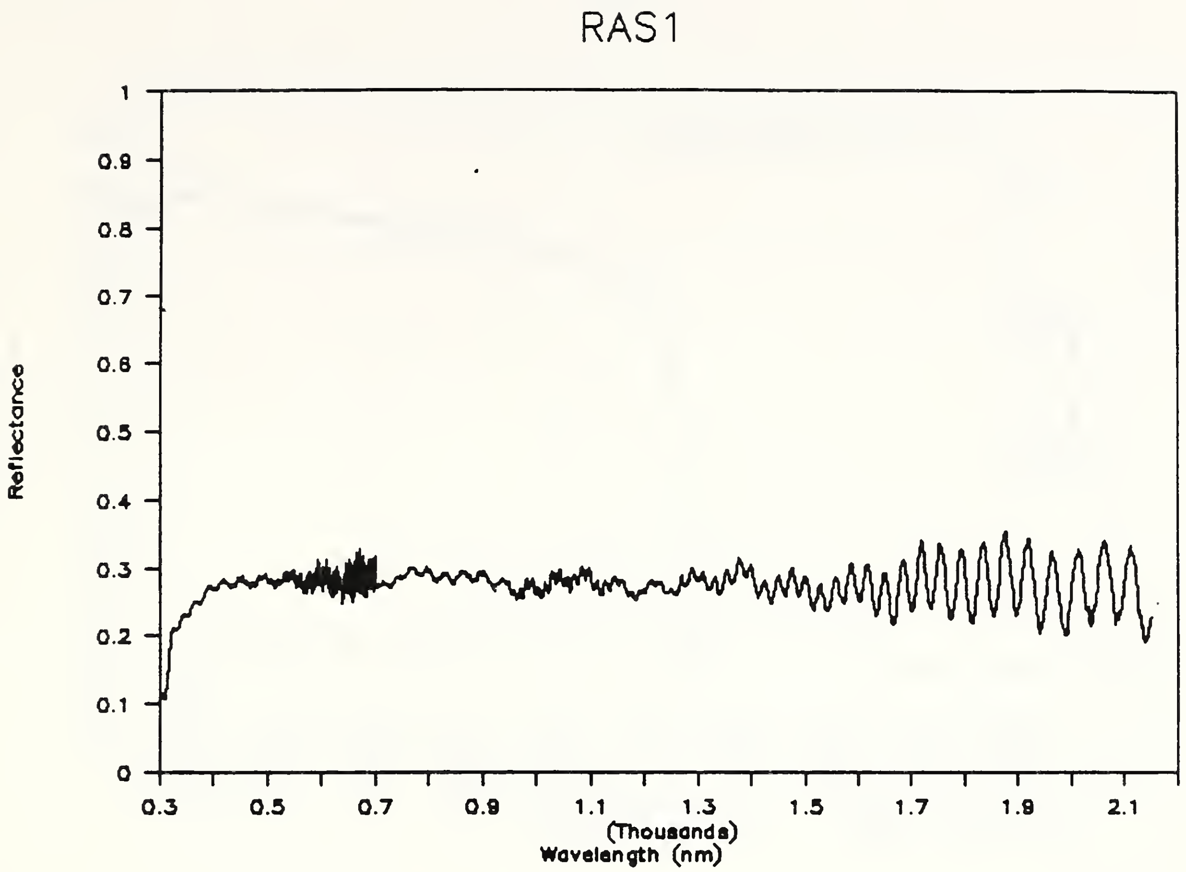


Figure 6.19c Sample AS, Visible specular reflectance

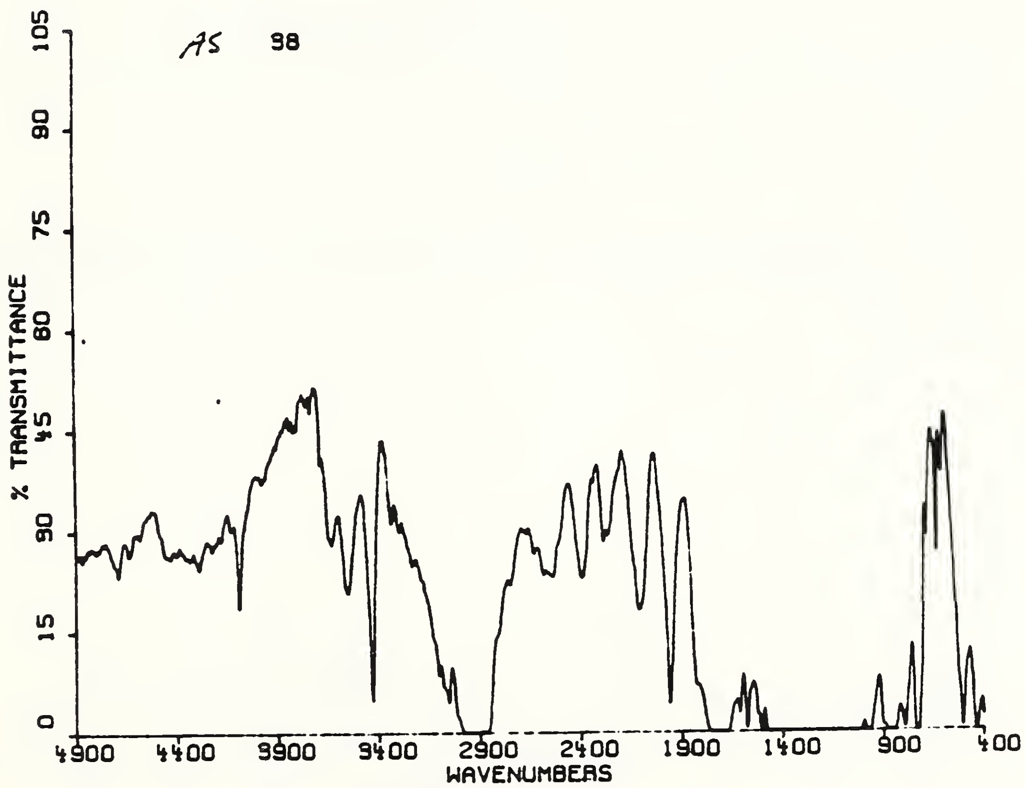


Figure 6.19d Sample AS, IR specular transmittance

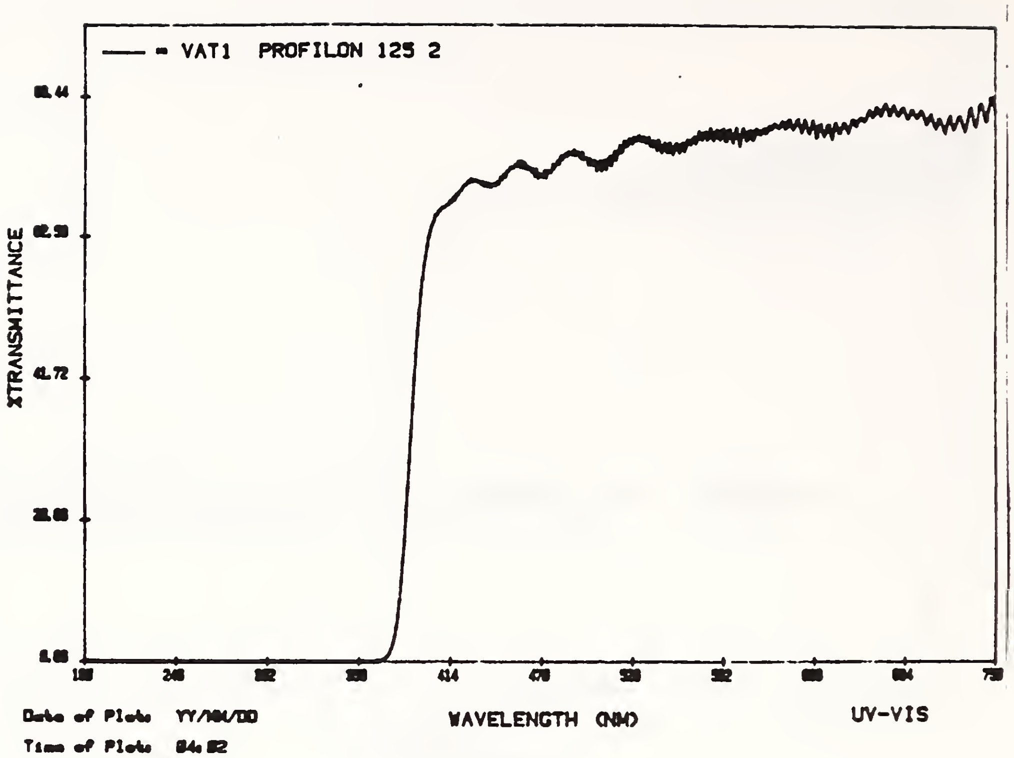


Figure 6.20a Sample AT, UV-visible total transmittance

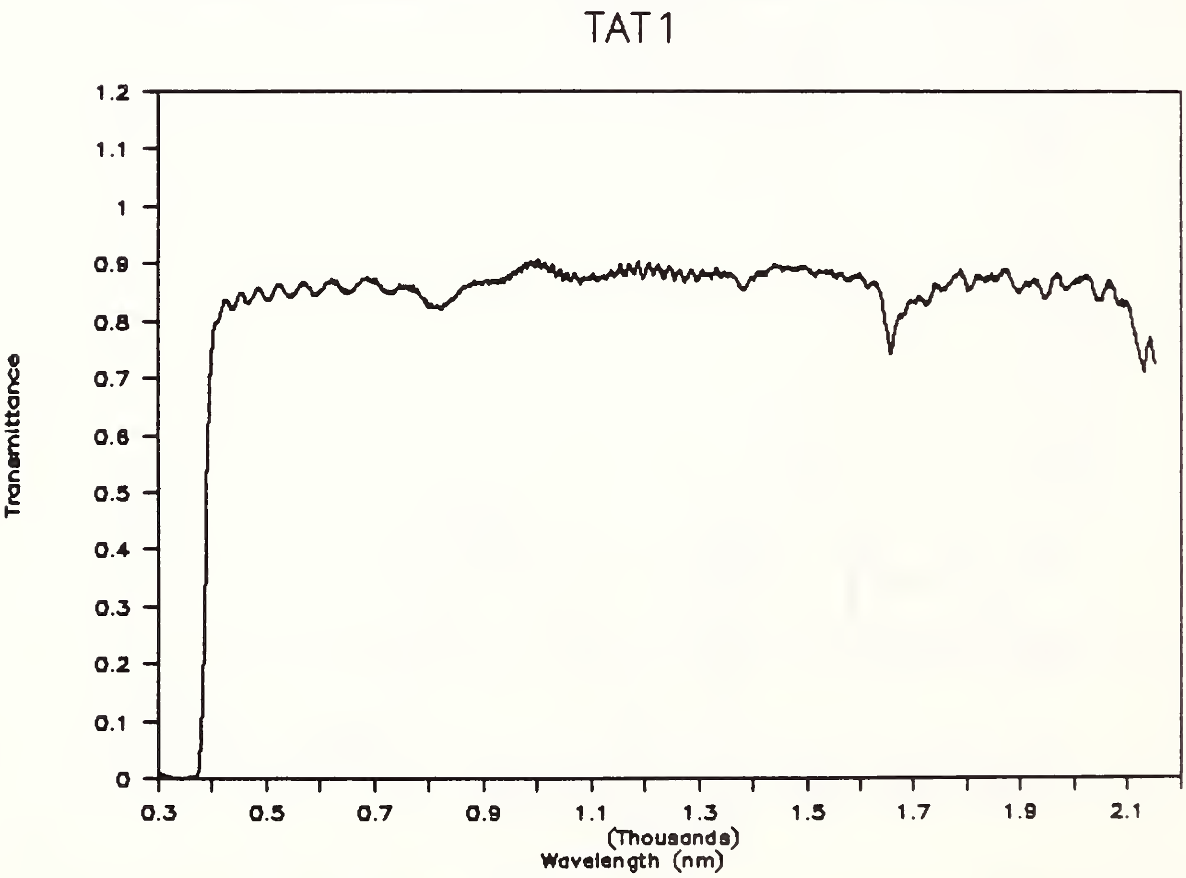


Figure 6.20b Sample AT, Visible specular transmittance

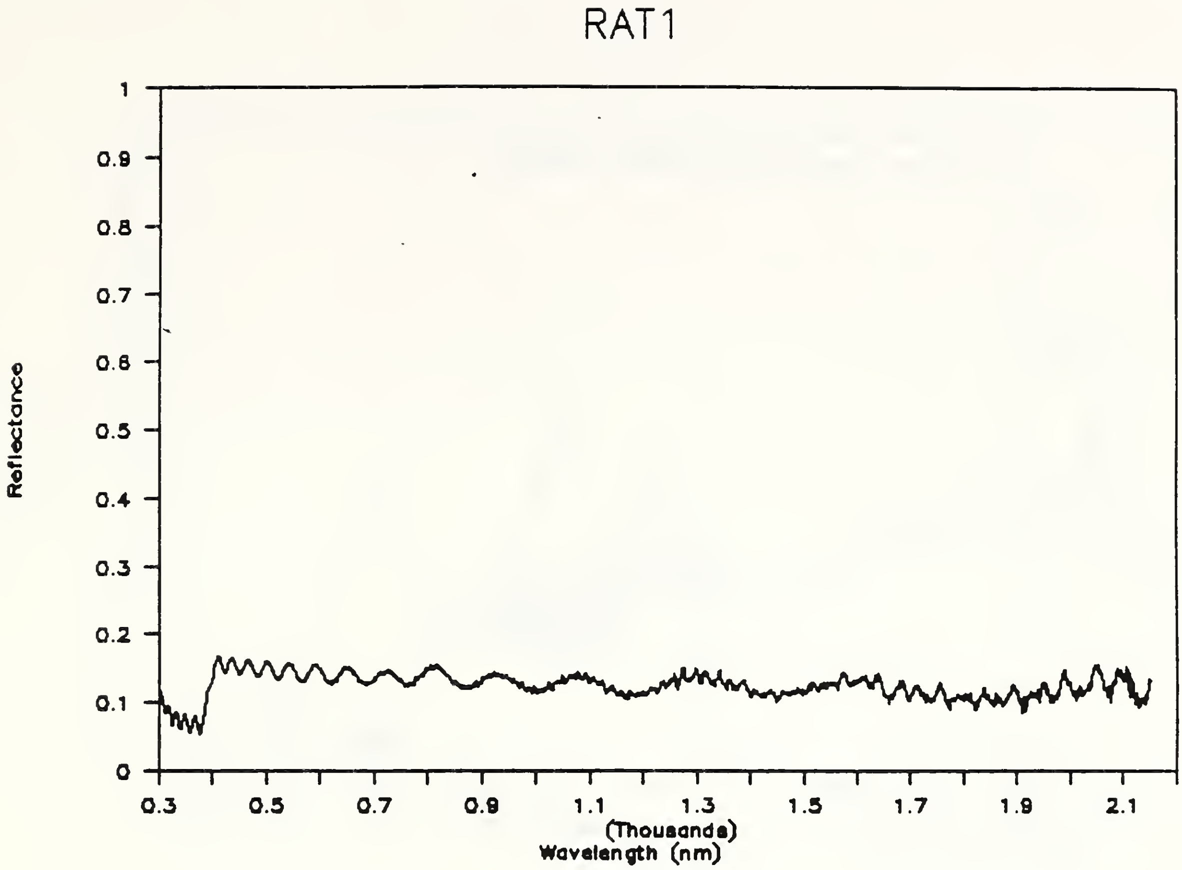


Figure 6.20c Sample AT, Visible specular reflectance

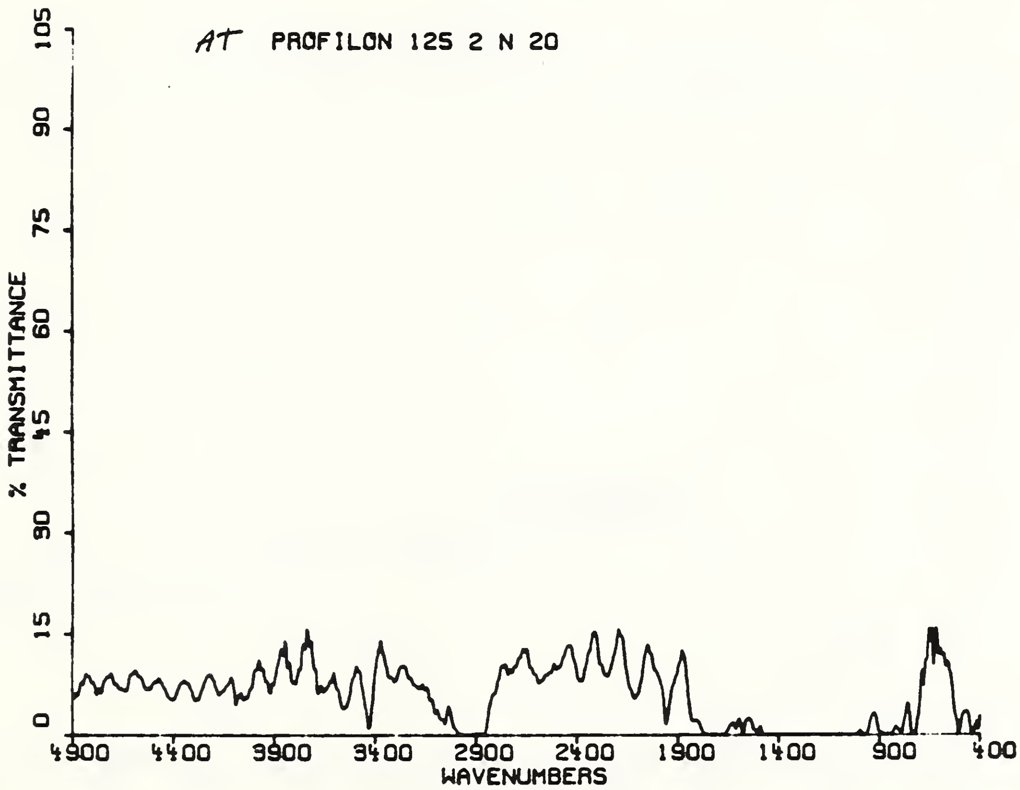


Figure 6.20d Sample AT, IR specular transmittance

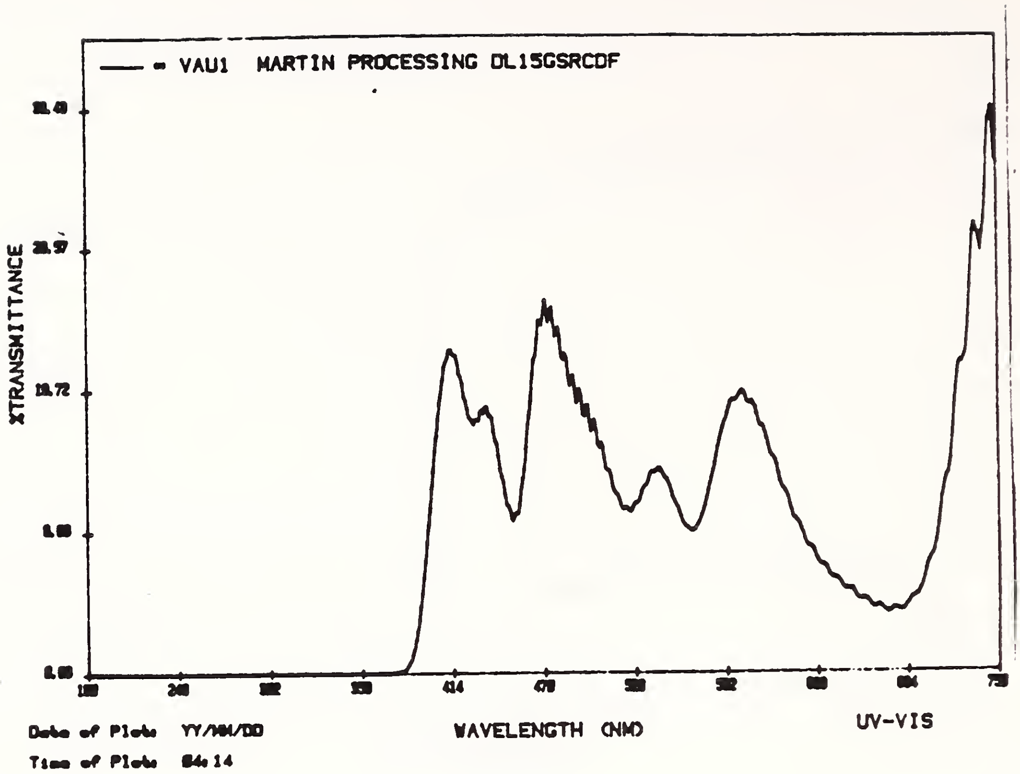


Figure 6.21a Sample AU, UV-visible total transmittance

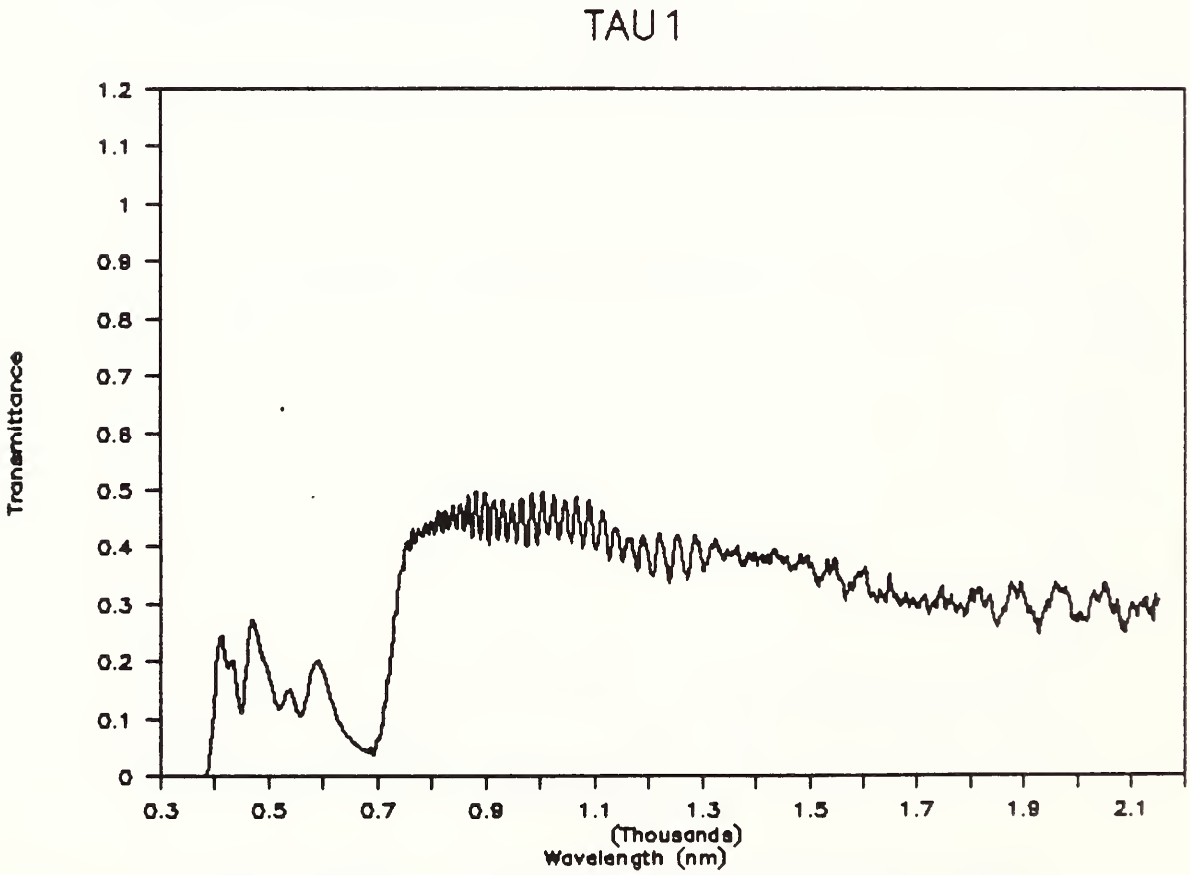


Figure 6.21b Sample AU, Visible specular transmittance

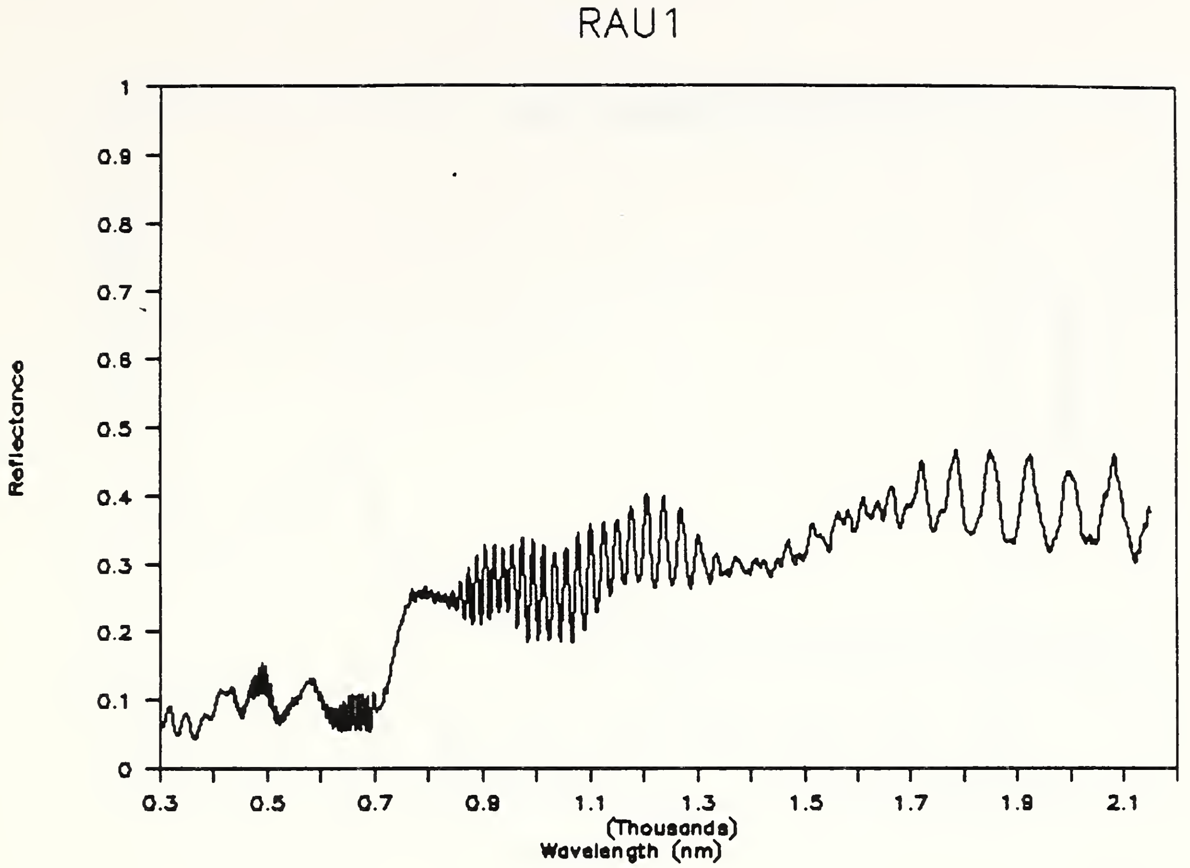


Figure 6.21c Sample AU, Visible specular reflectance

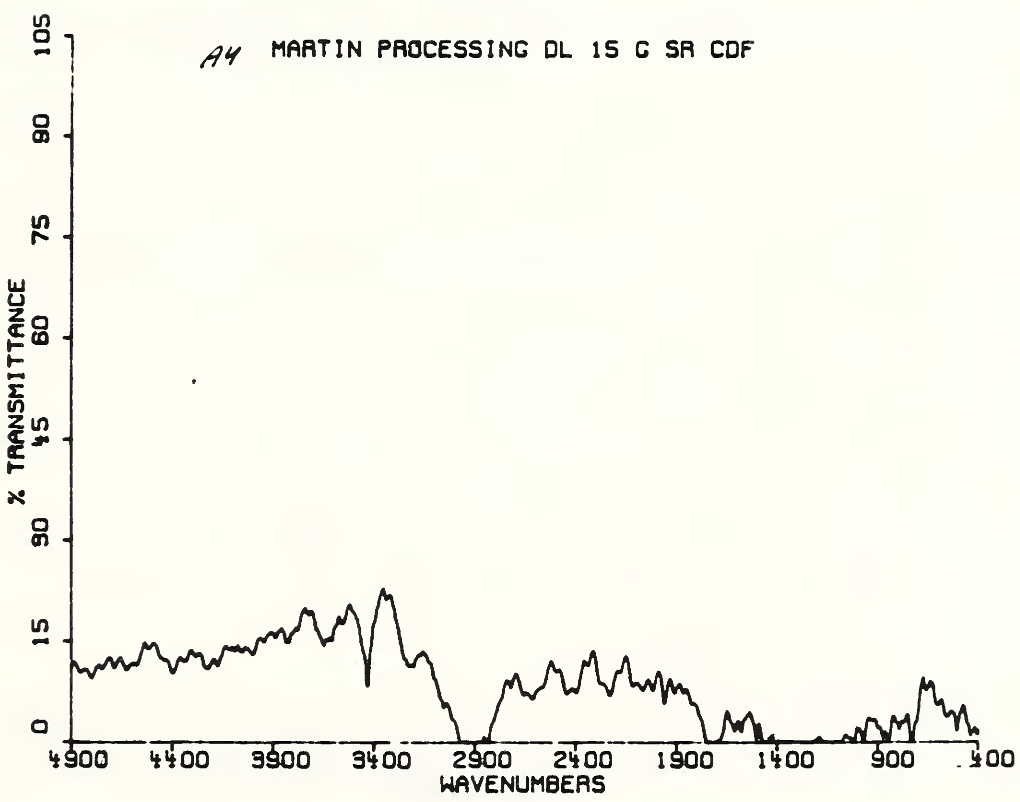


Figure 6.21d Sample AU, IR specular transmittance

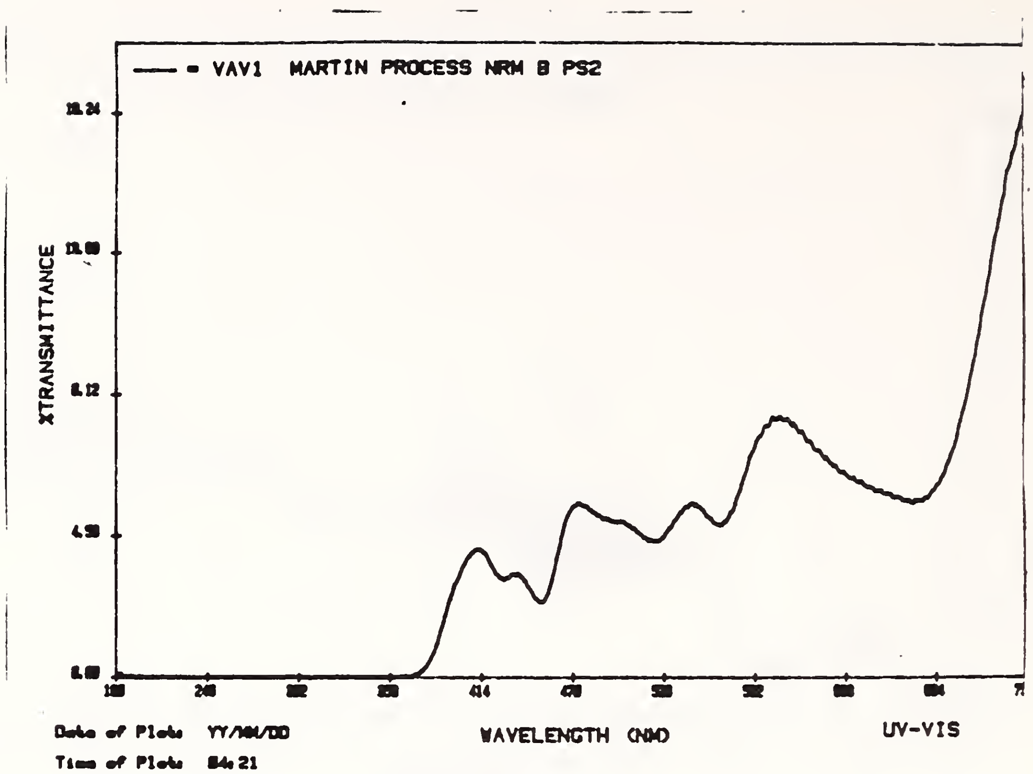


Figure 6.22a Sample AV, UV-visible total transmittance

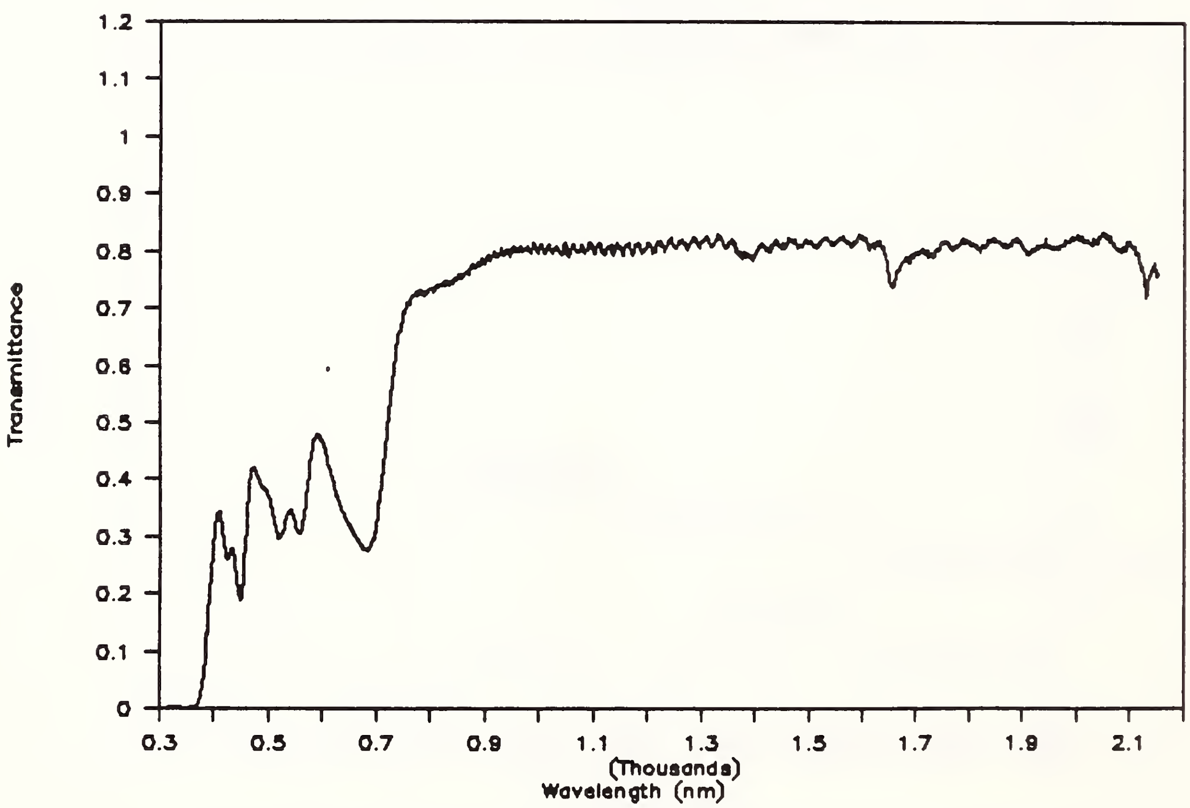


Figure 6.22b Sample AV, Visible specular transmittance

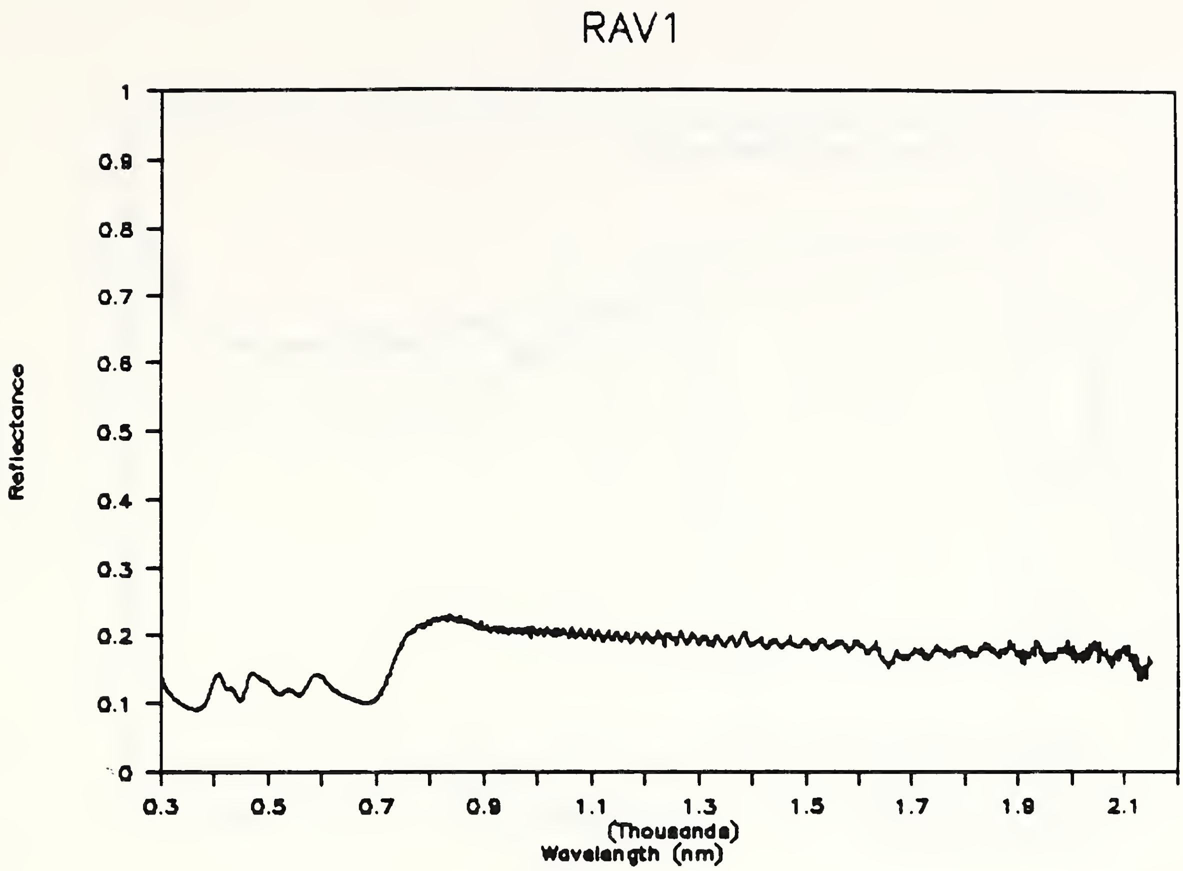


Figure 6.22c Sample AV, Visible specular reflectance

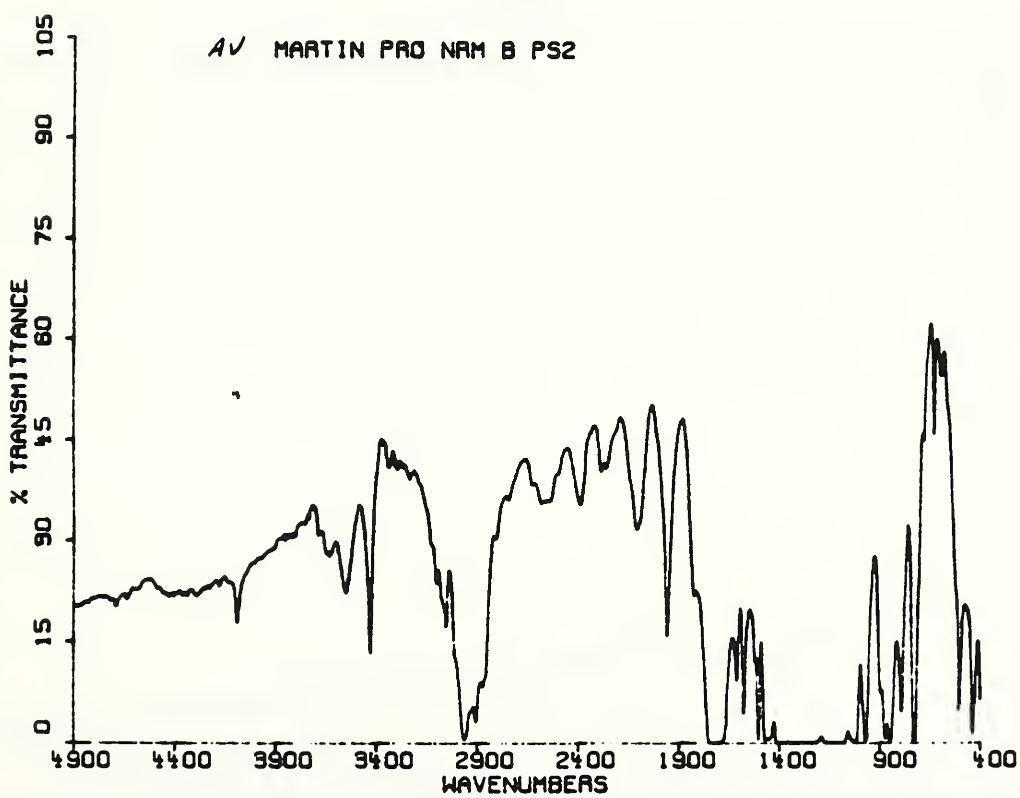


Figure 6.22d Sample AV, IR specular transmittance

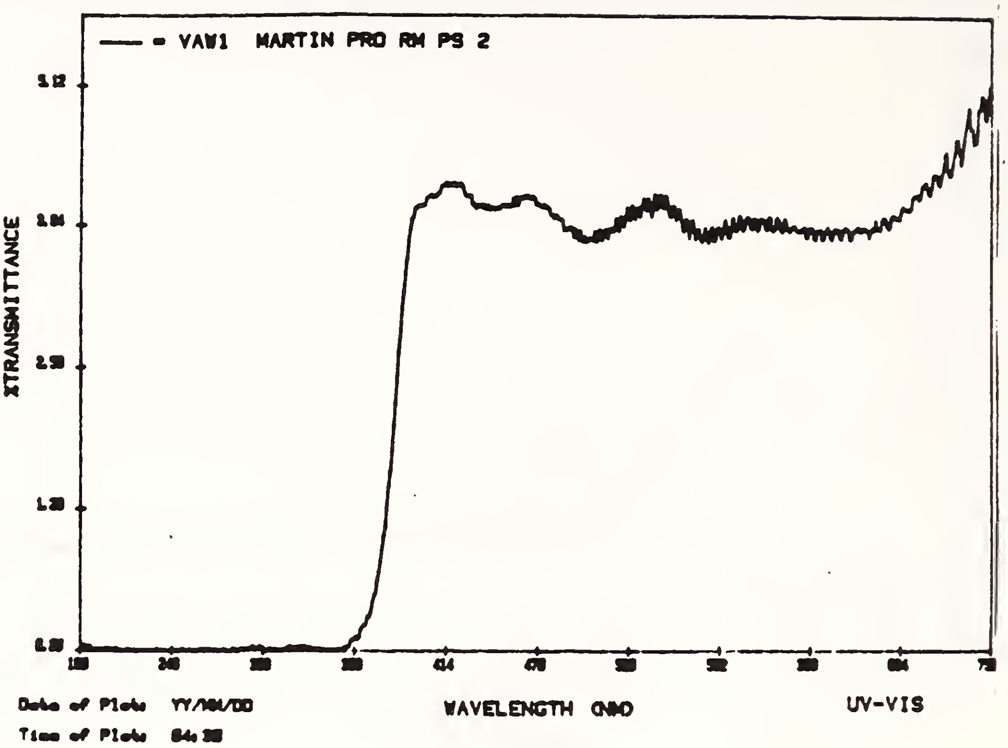


Figure 6.23a Sample AW, UV-visible total transmittance

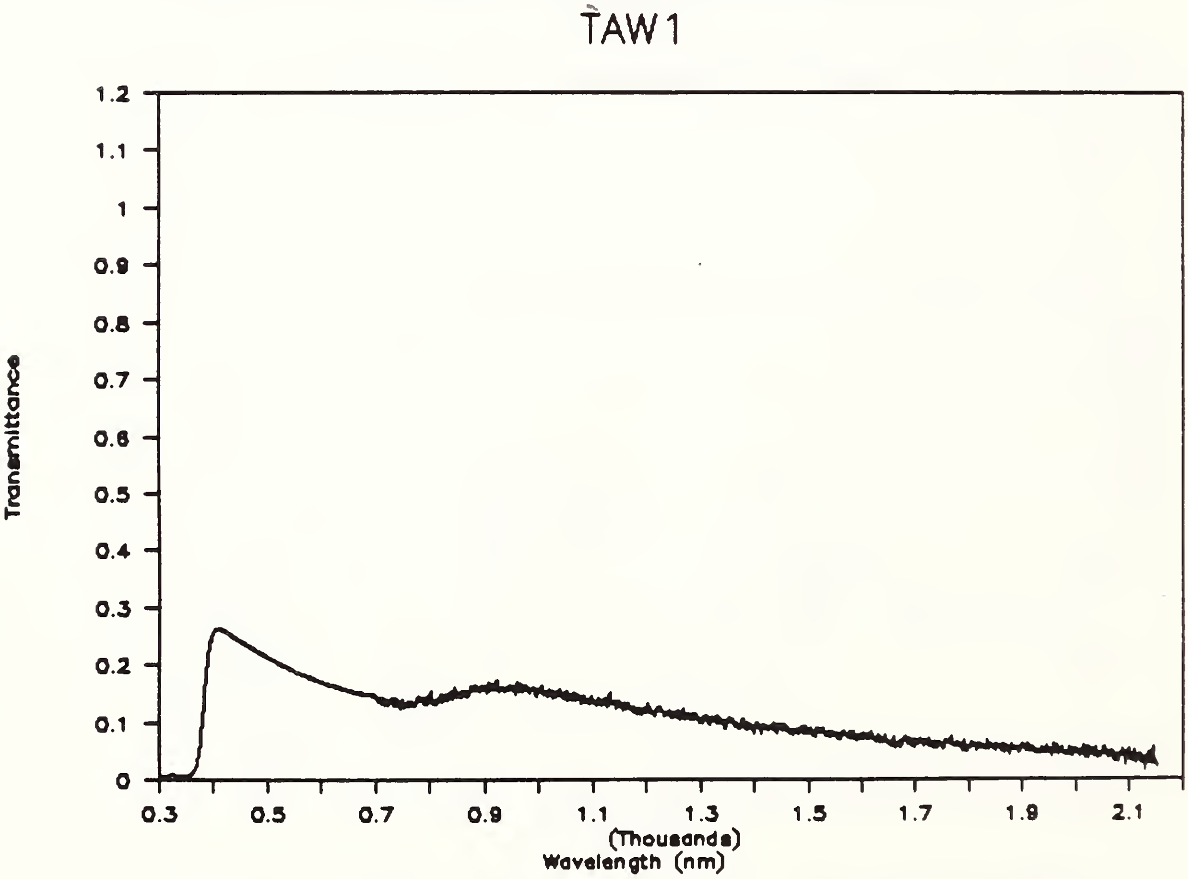


Figure 6.23b Sample AW, Visible specular transmittance

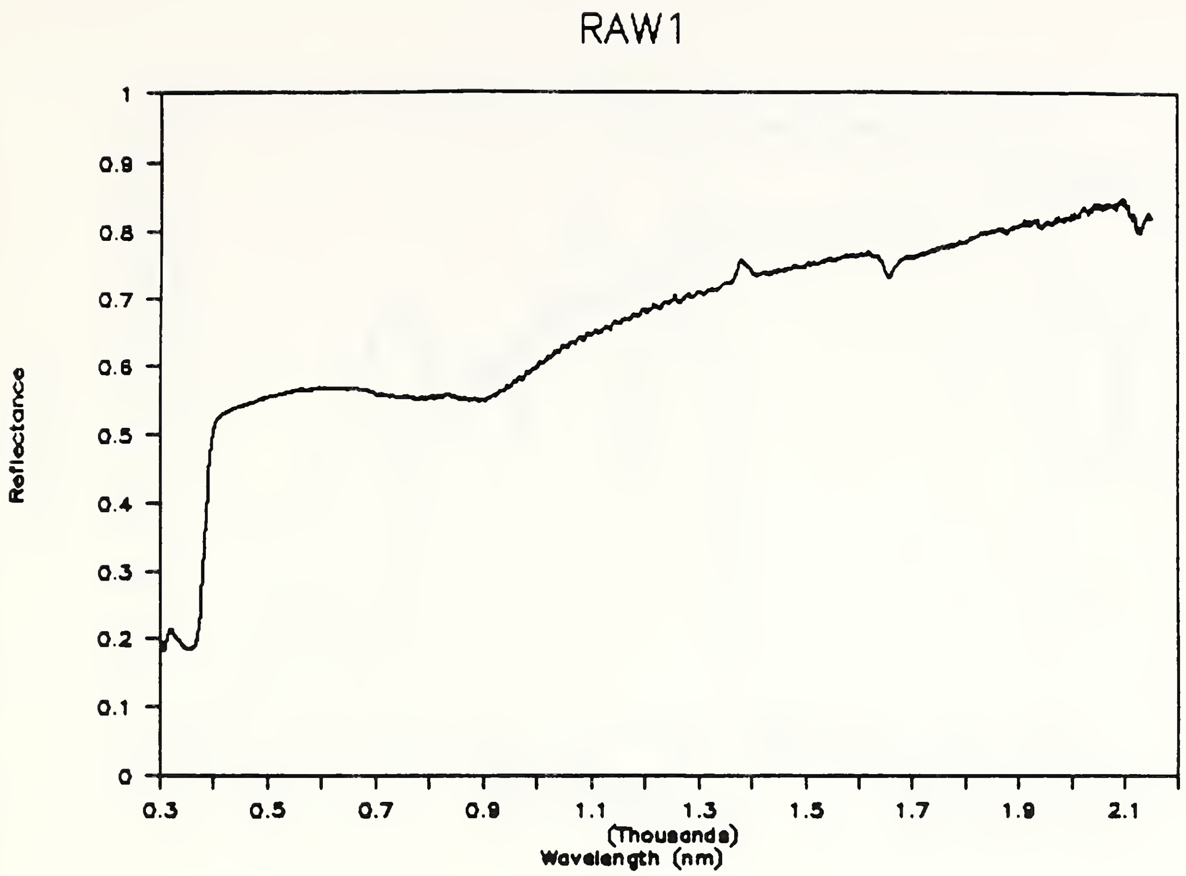


Figure 6.23c Sample AW, Visible specular reflectance

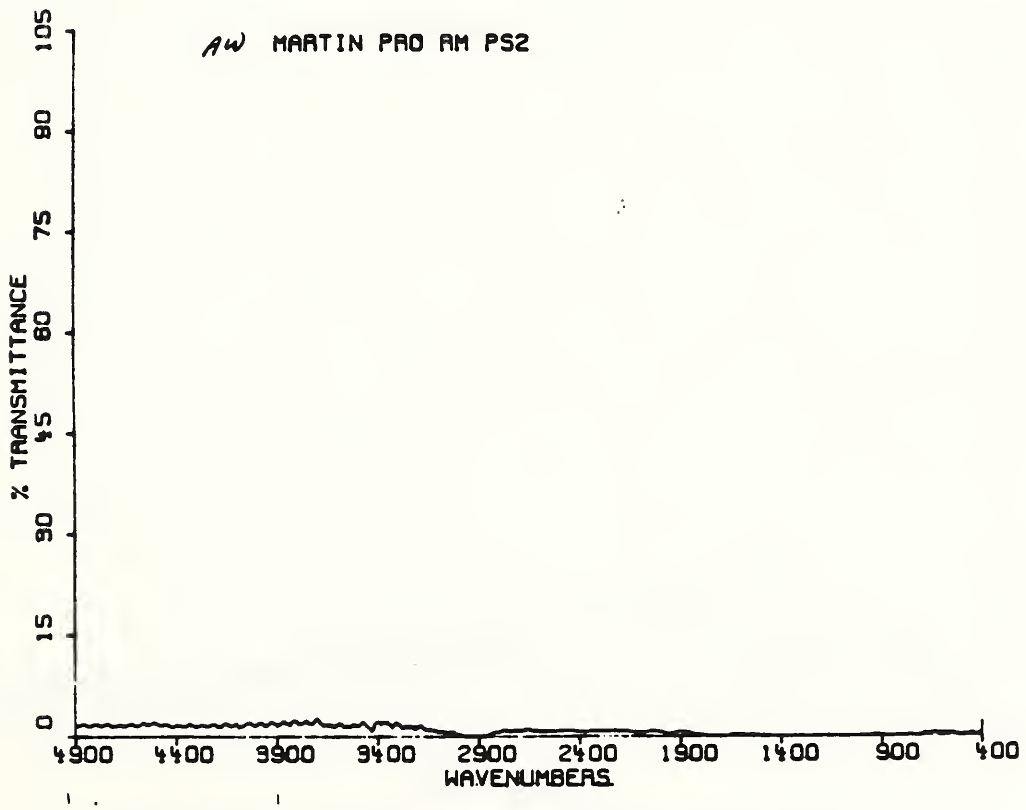


Figure 6.23d Sample AW, IR specular transmittance

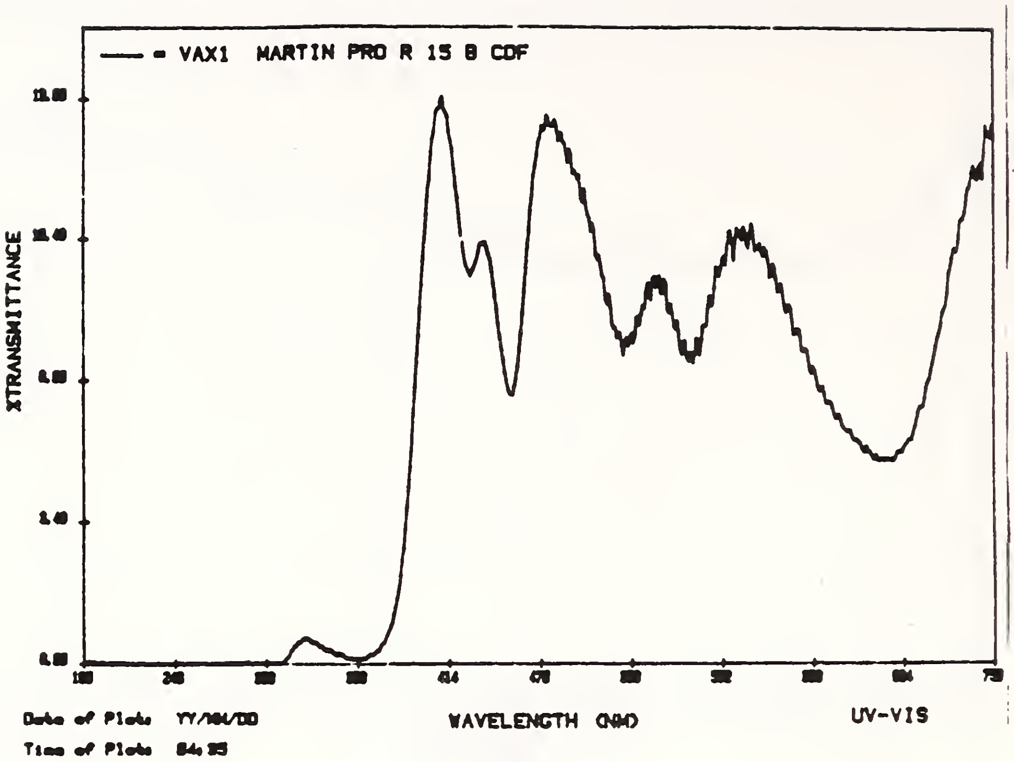


Figure 6.24a Sample AX, UV-visible total transmittance

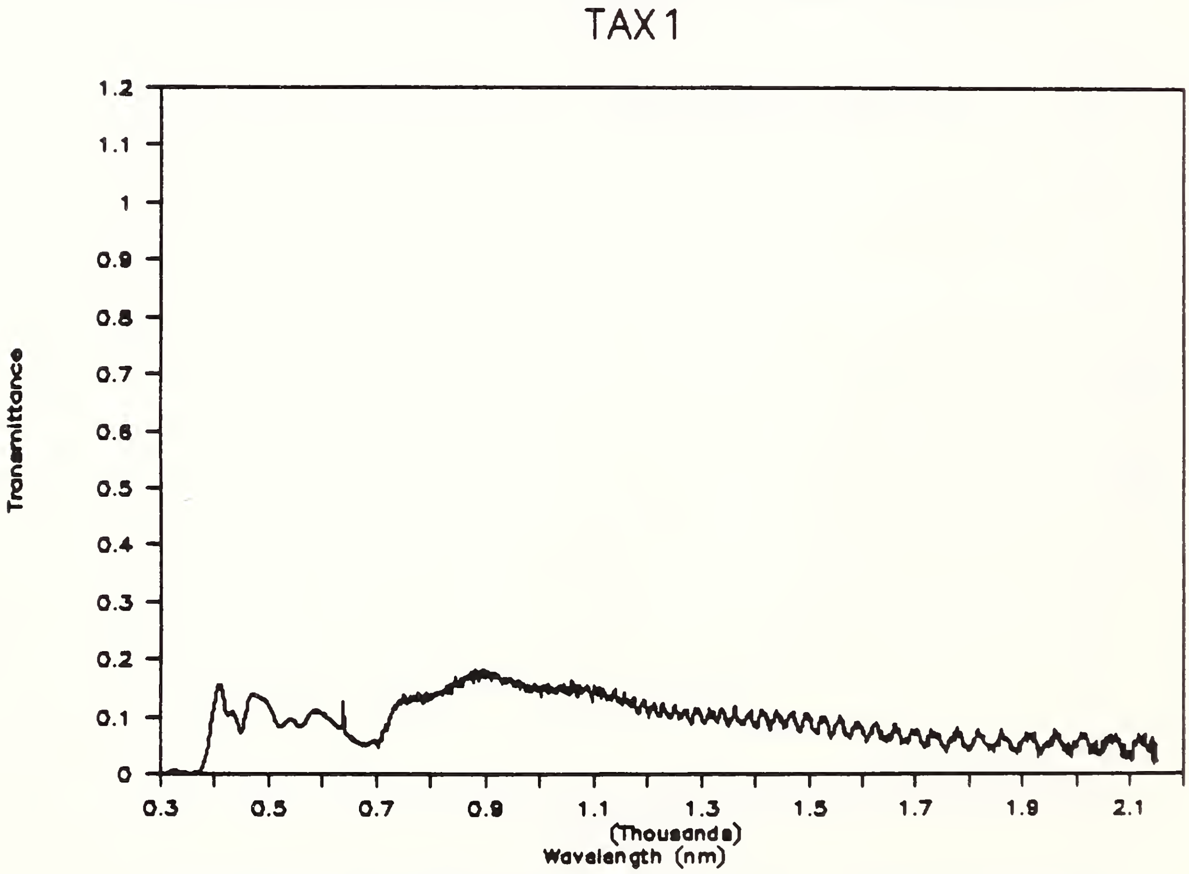


Figure 6.24b Sample AX, Visible specular transmittance

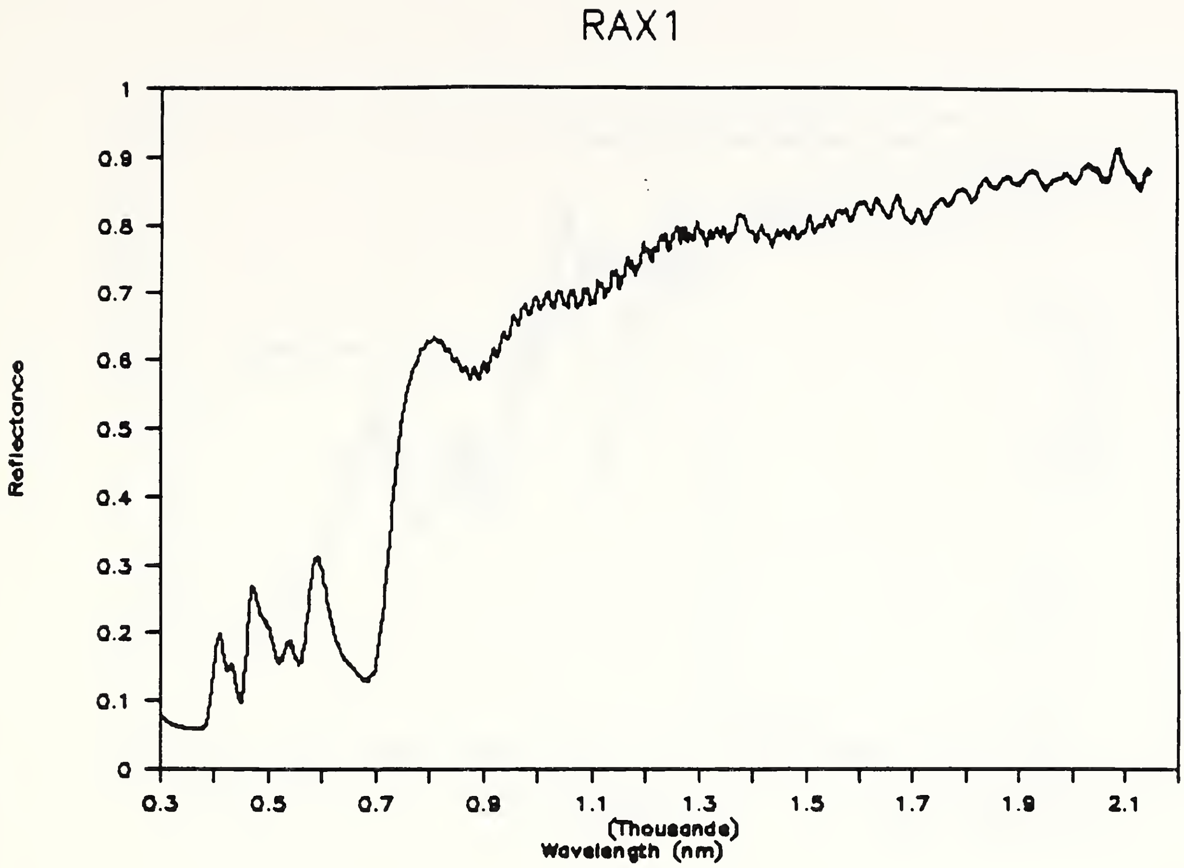


Figure 6.24c Sample AX, Visible specular reflectance

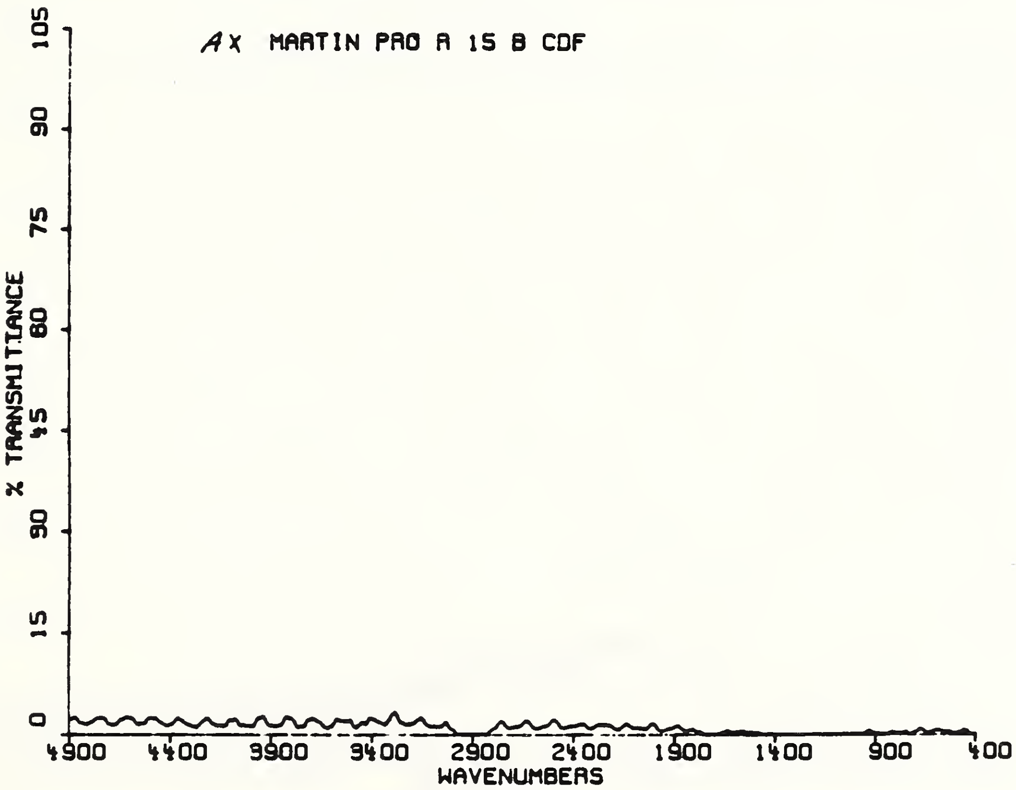


Figure 6.24d Sample AX, IR specular transmittance

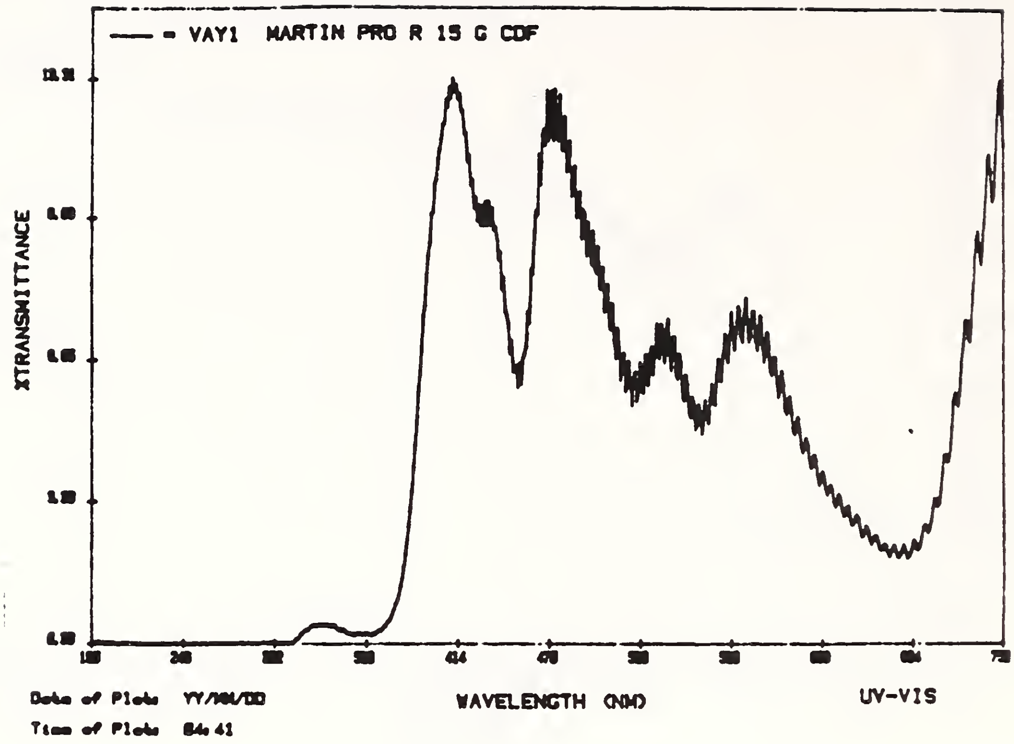


Figure 6.25a Sample AY, UV-visible total transmittance

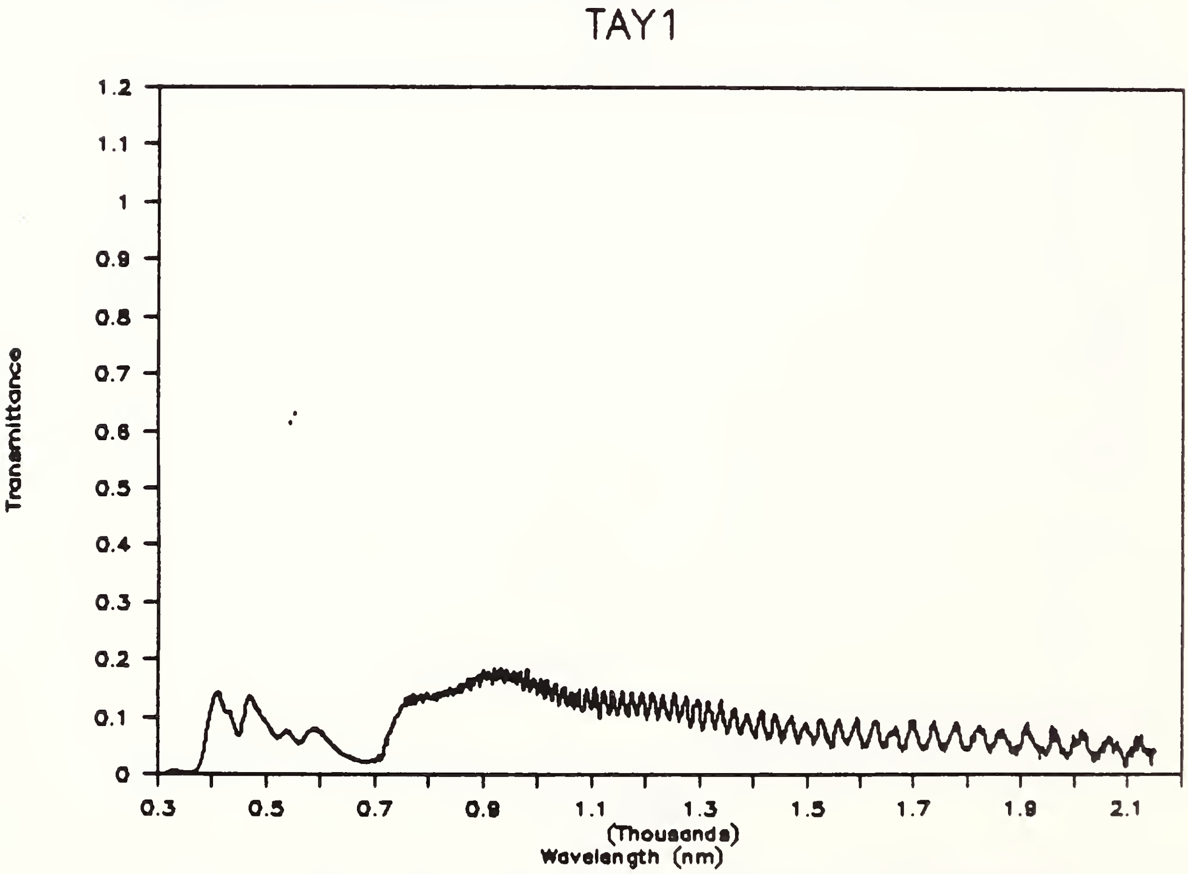


Figure 6.25b Sample AY, Visible specular transmittance

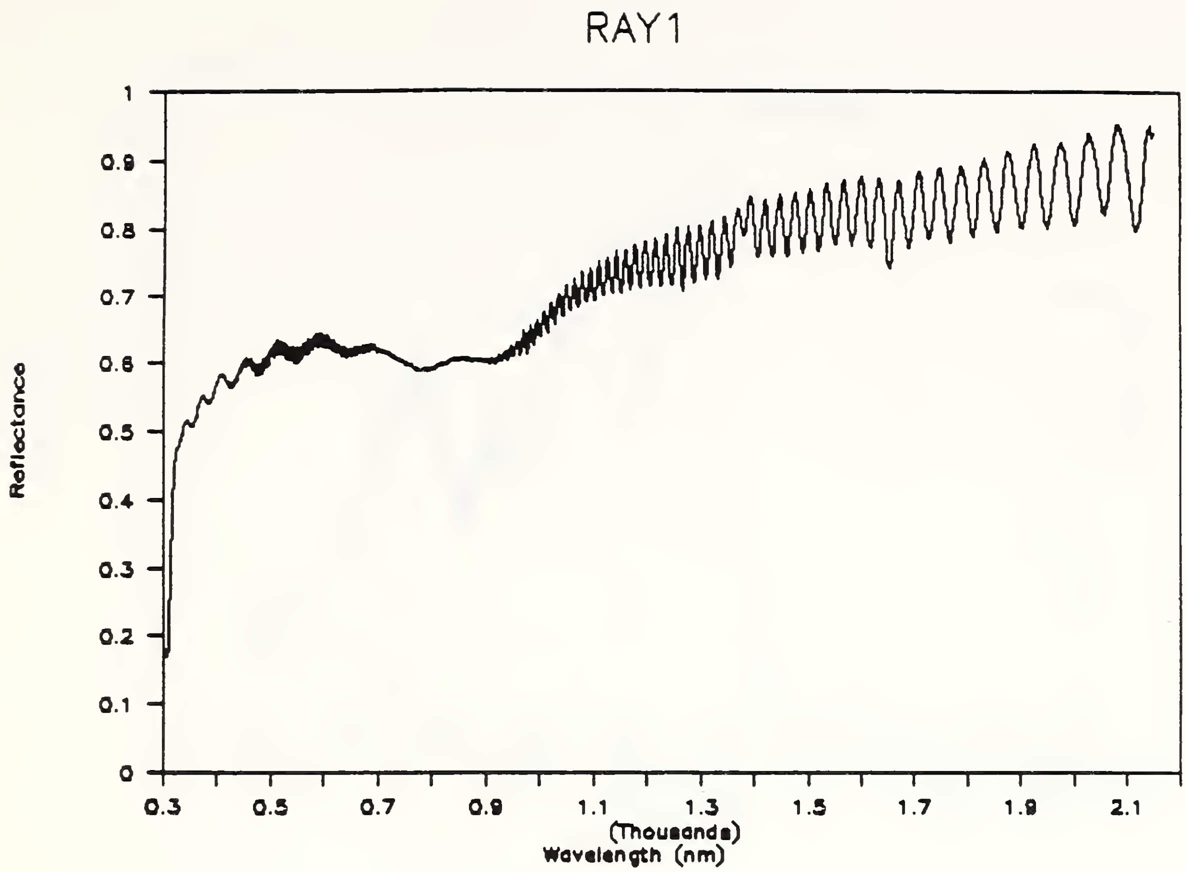


Figure 6.25c Sample AY, Visible specular reflectance

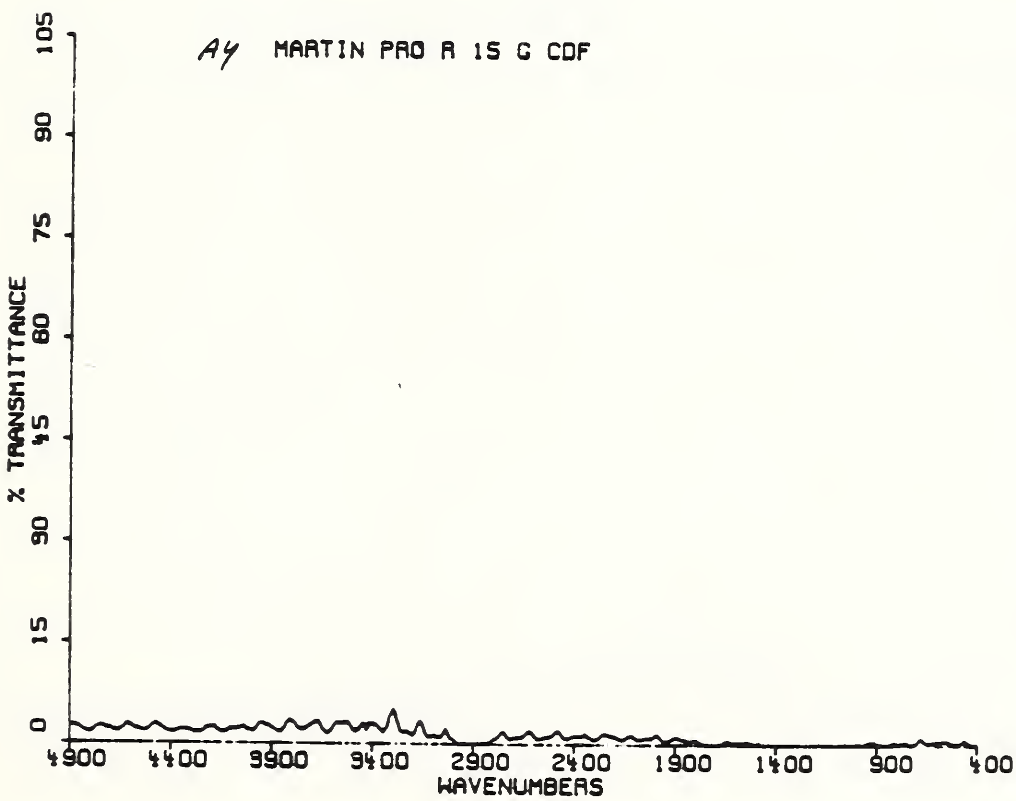


Figure 6.25d Sample AY, IR specular transmittance

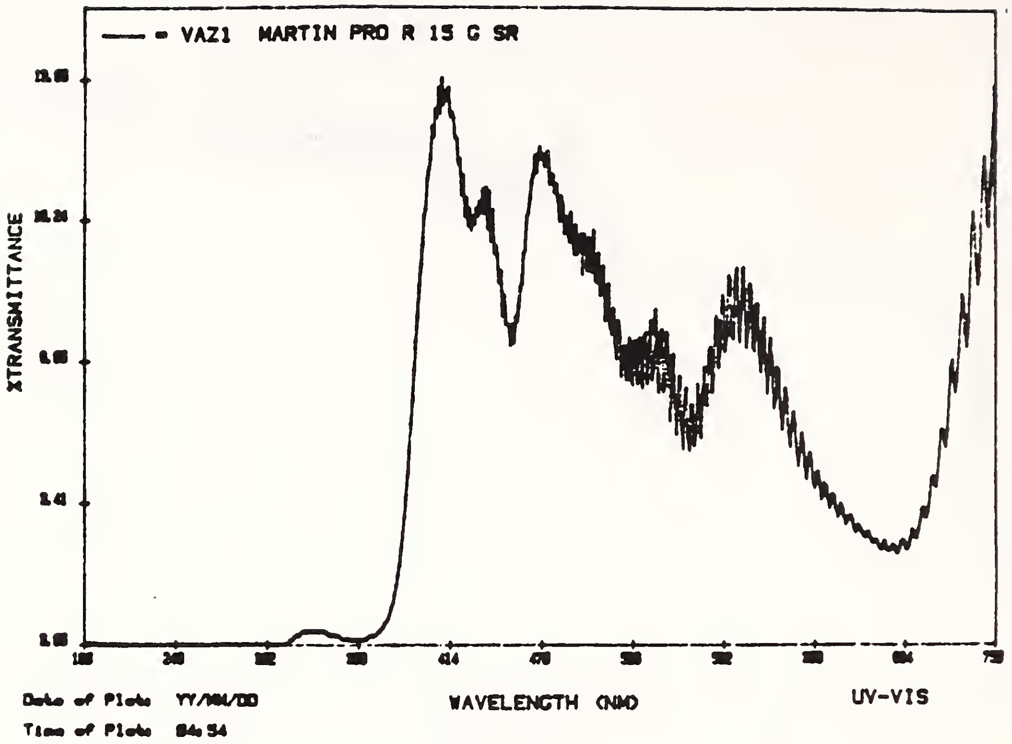


Figure 6.26a Sample AZ, UV-visible total transmittance

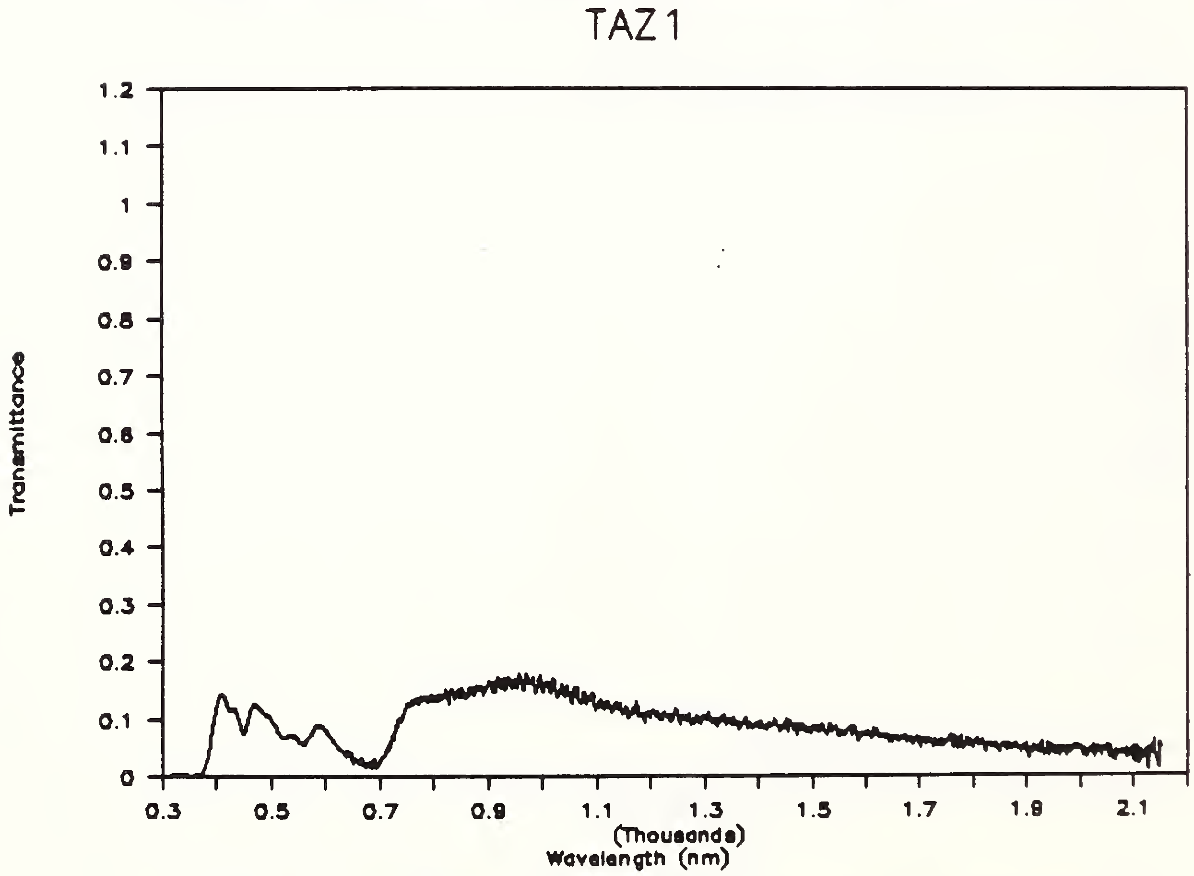


Figure 6.26b Sample AZ, Visible specular transmittance

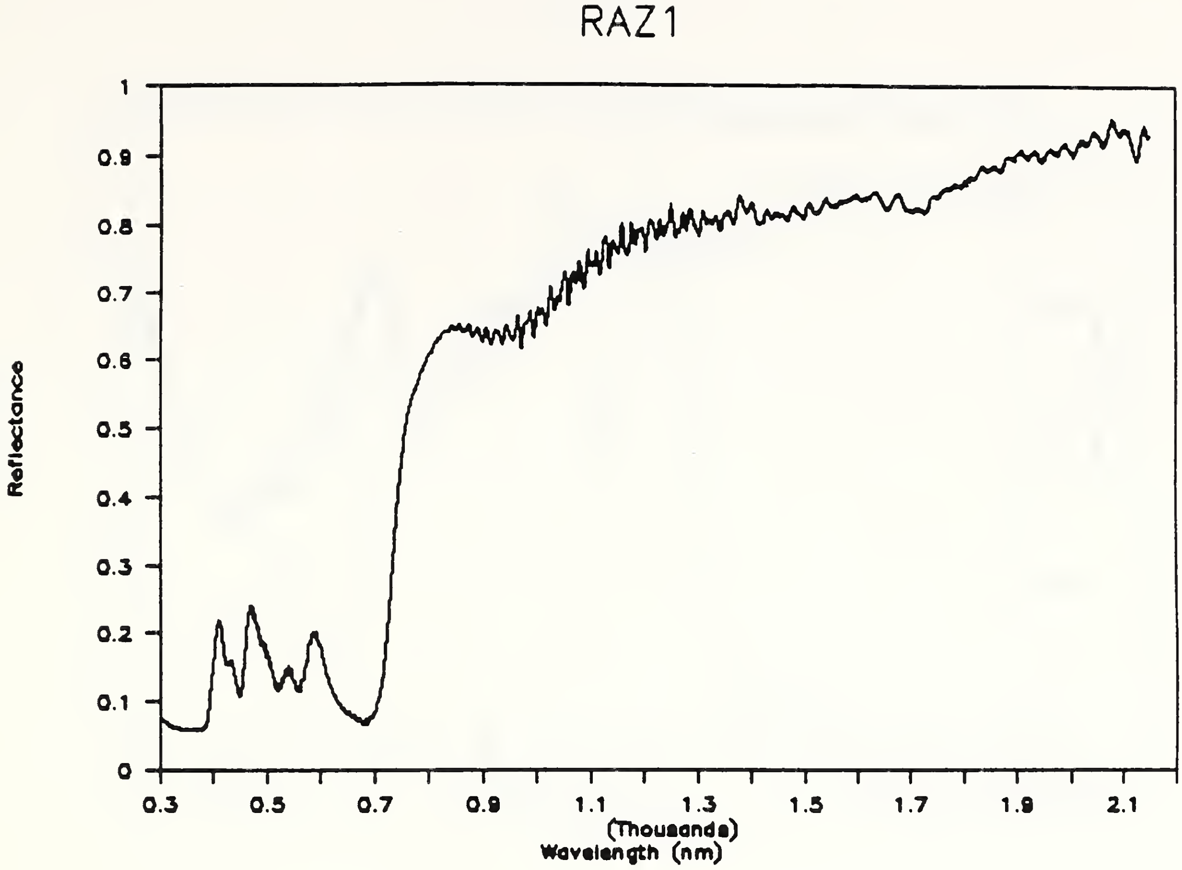


Figure 6.26c Sample AZ, Visible specular reflectance

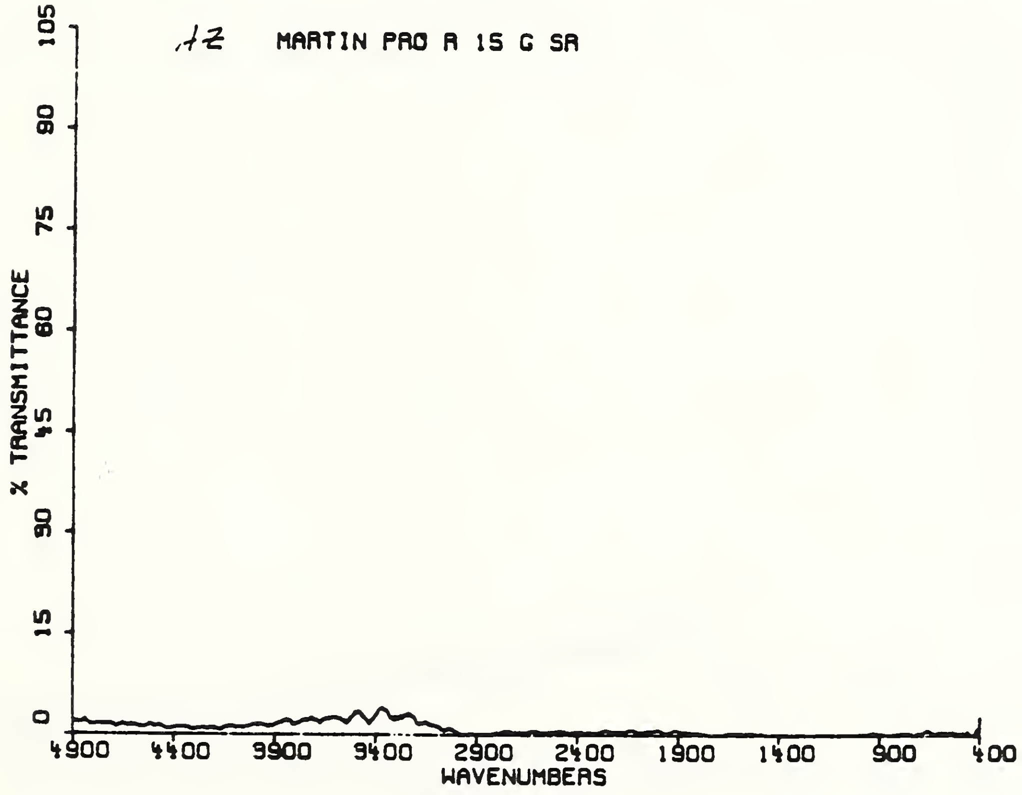


Figure 6.26d Sample AZ, IR specular transmittance

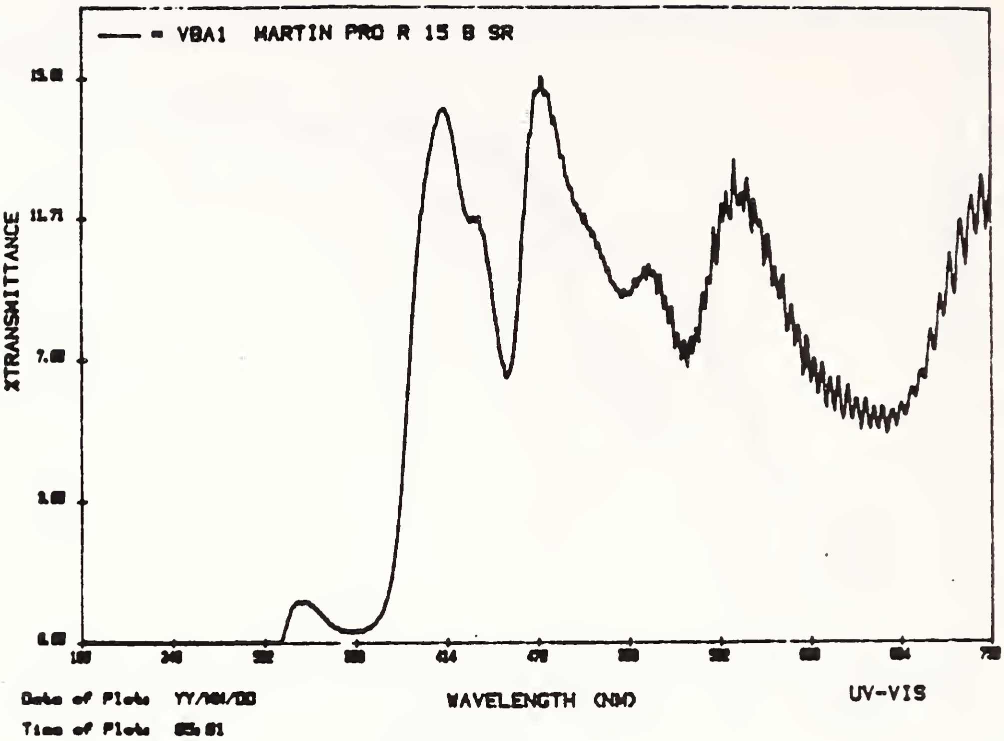


Figure 6.27a Sample BA, UV-visible total transmittance

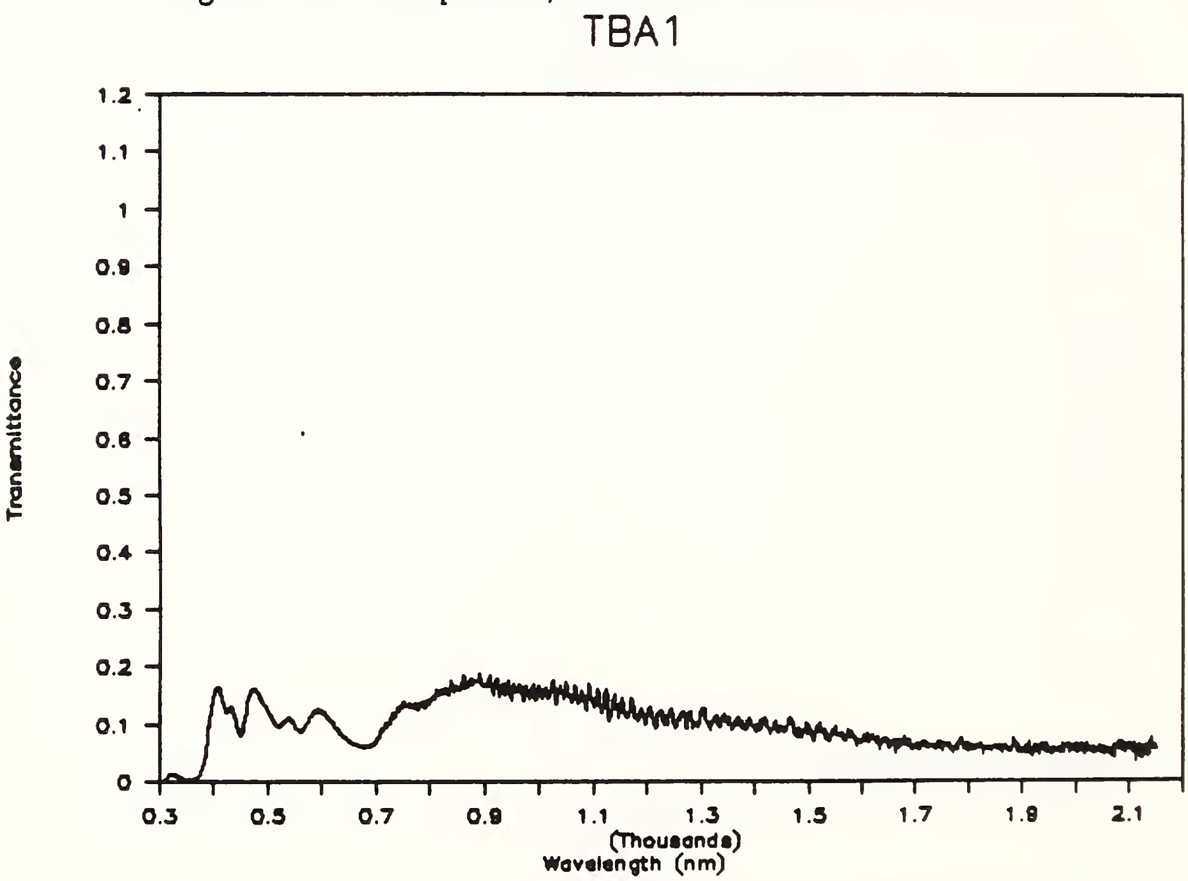


Figure 6.27b Sample BA, Visible specular transmittance

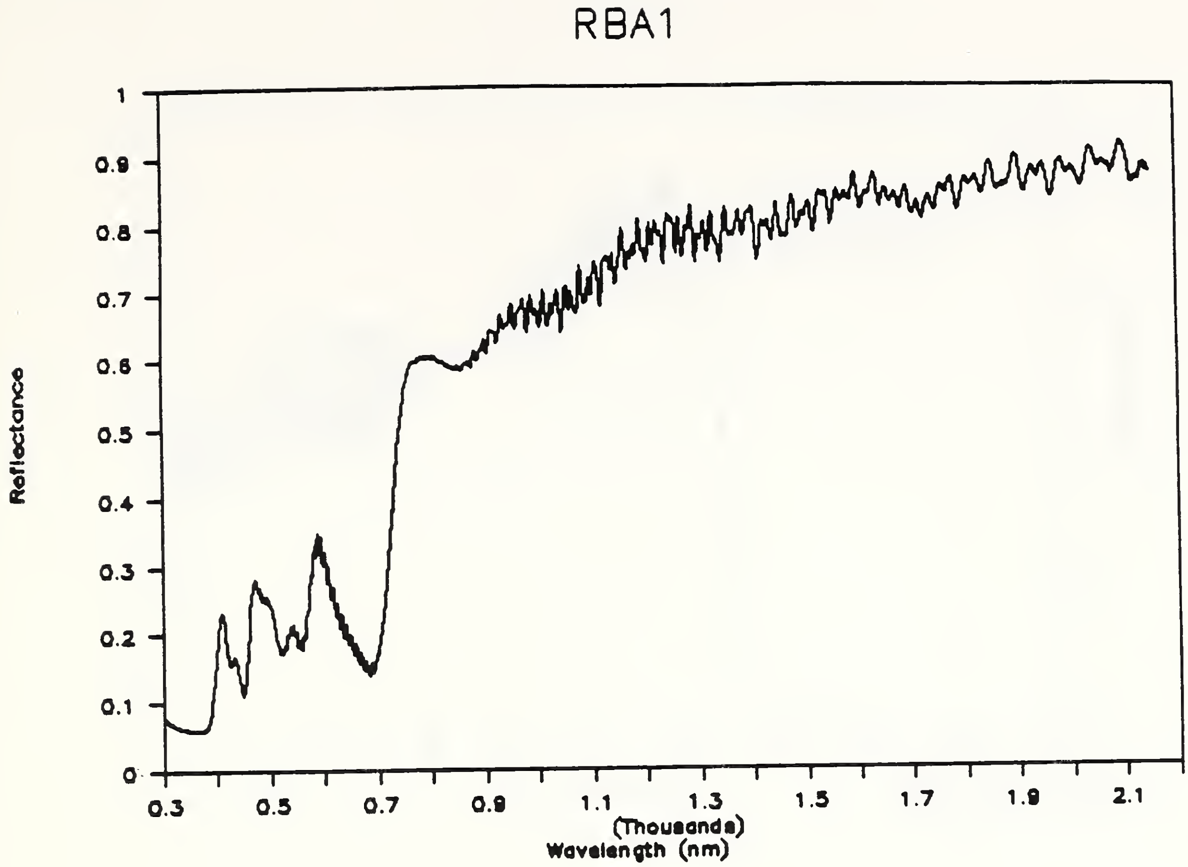


Figure 6.27c Sample BA, Visible specular reflectance

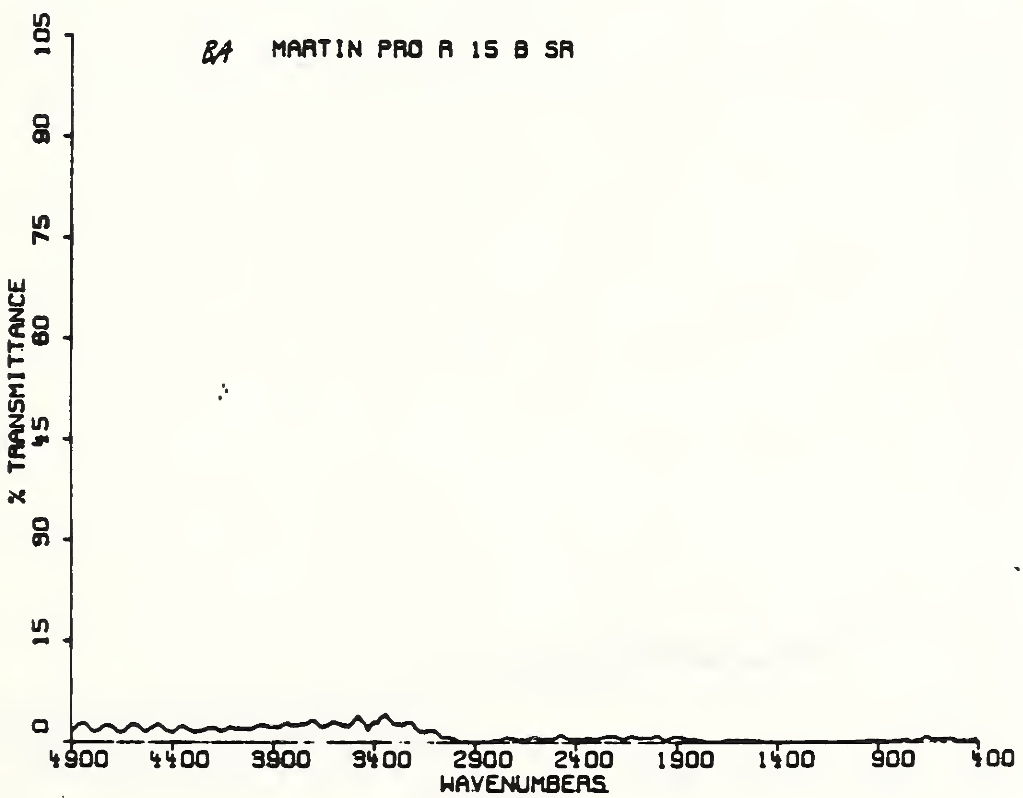


Figure 6.27d Sample BA, IR specular transmittance

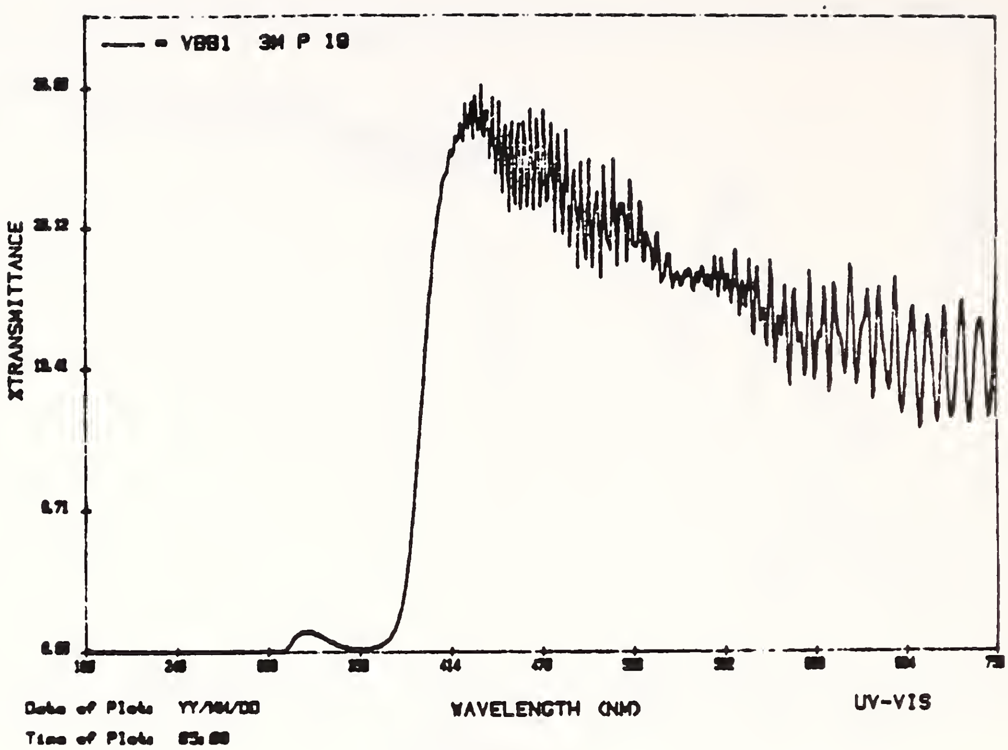


Figure 6.28a Sample BB, UV-visible total transmittance

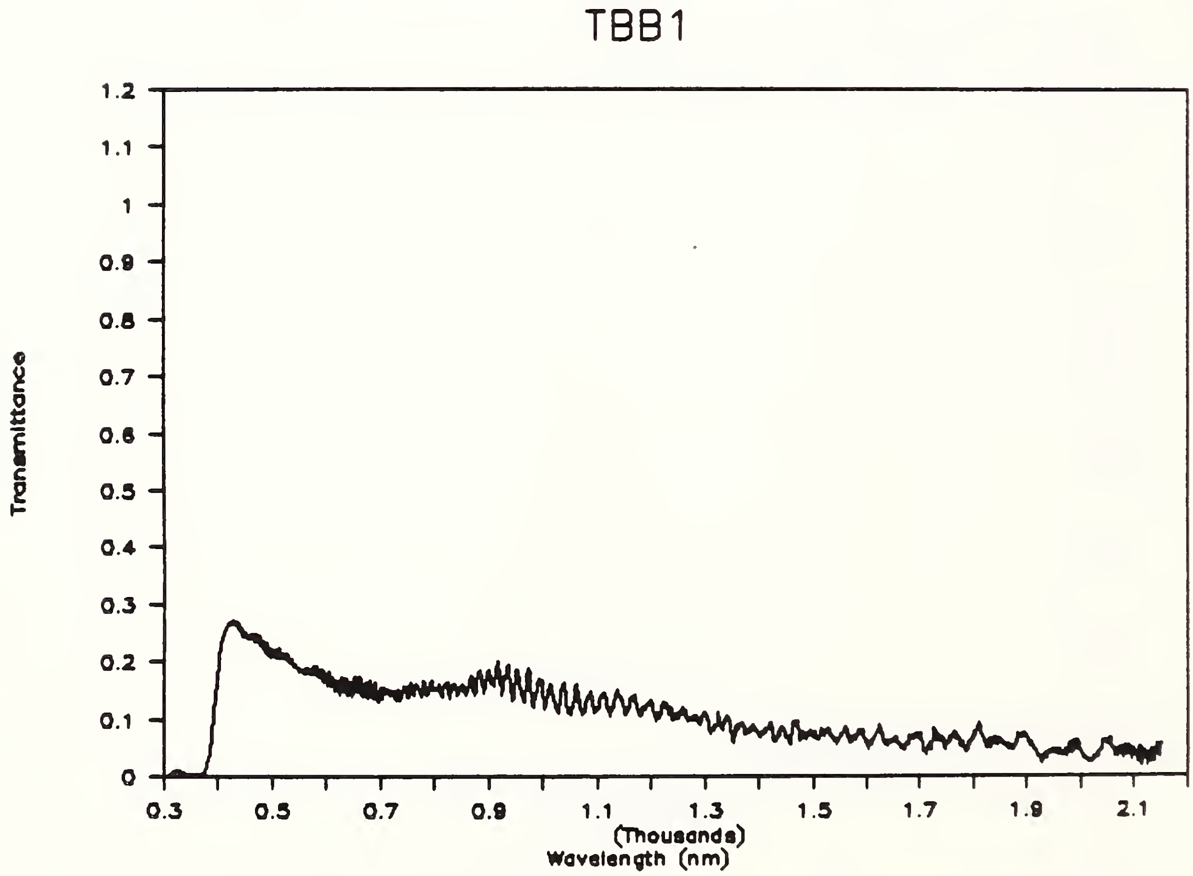


Figure 6.28b Sample BB, Visible specular transmittance

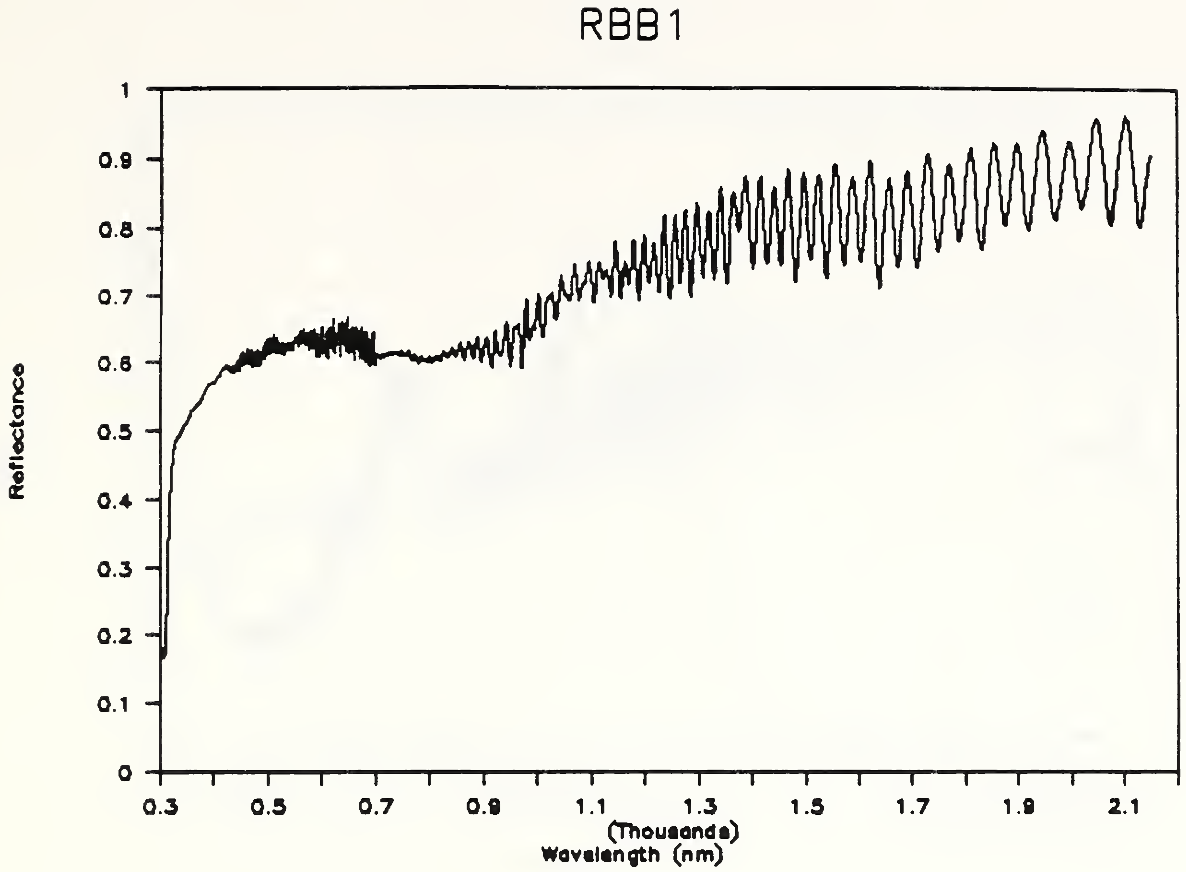


Figure 6.28c Sample BB, Visible specular reflectance

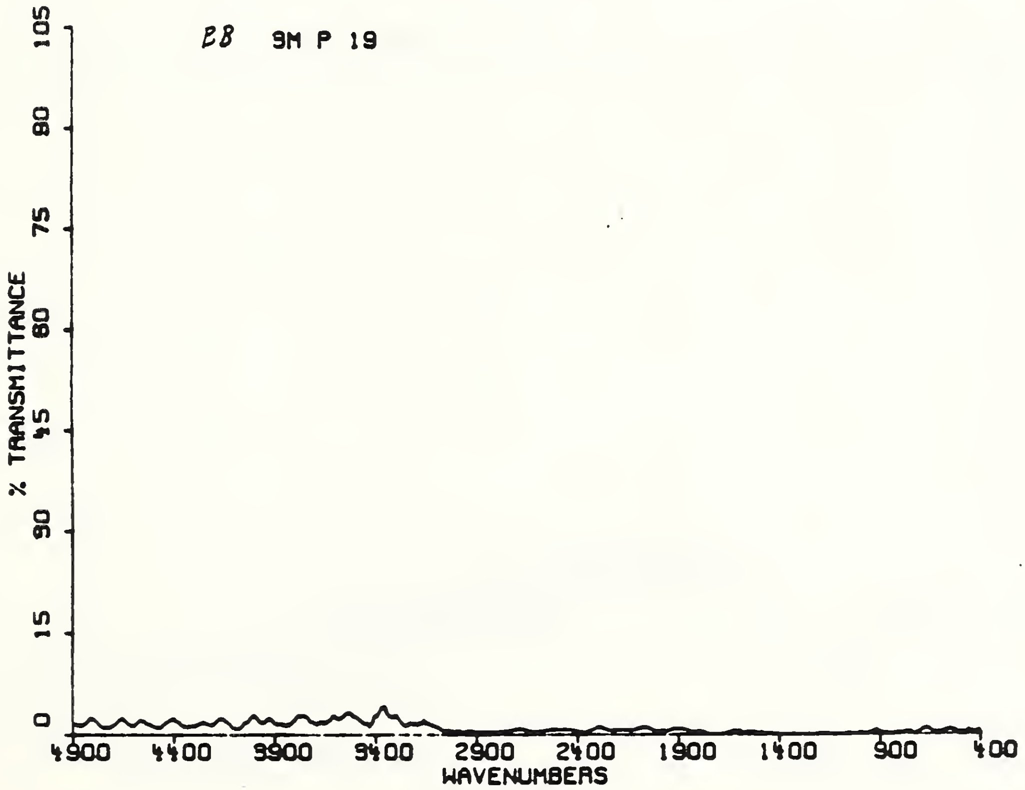


Figure 6.28d Sample BB, IR specular transmittance

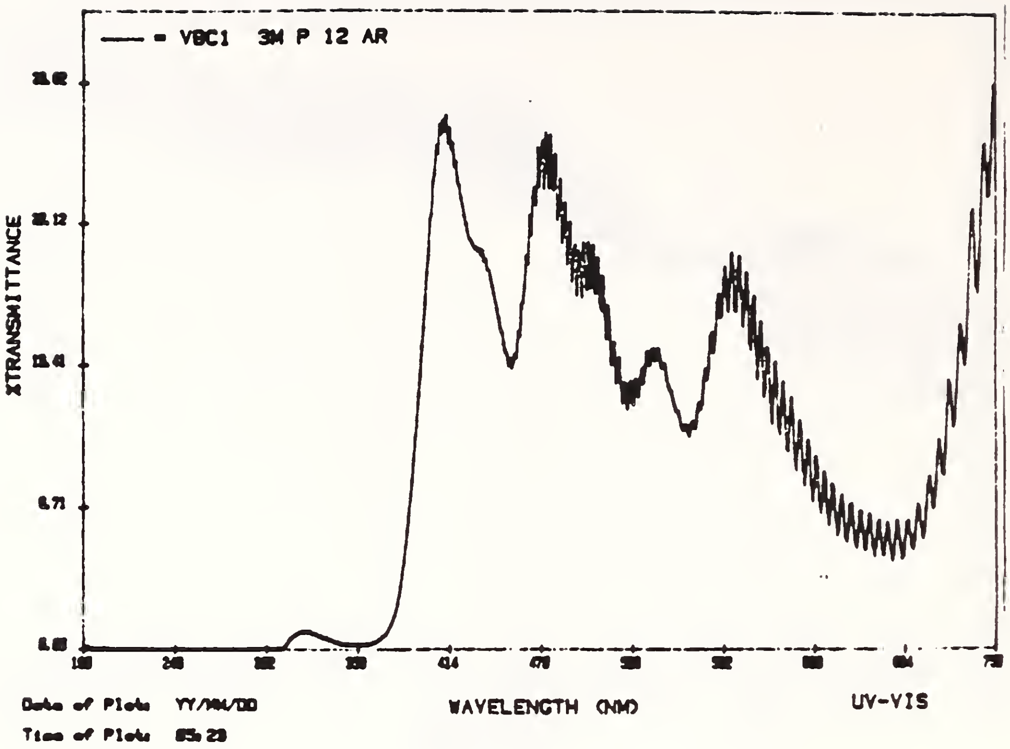


Figure 6.29a Sample BC, UV-visible total transmittance

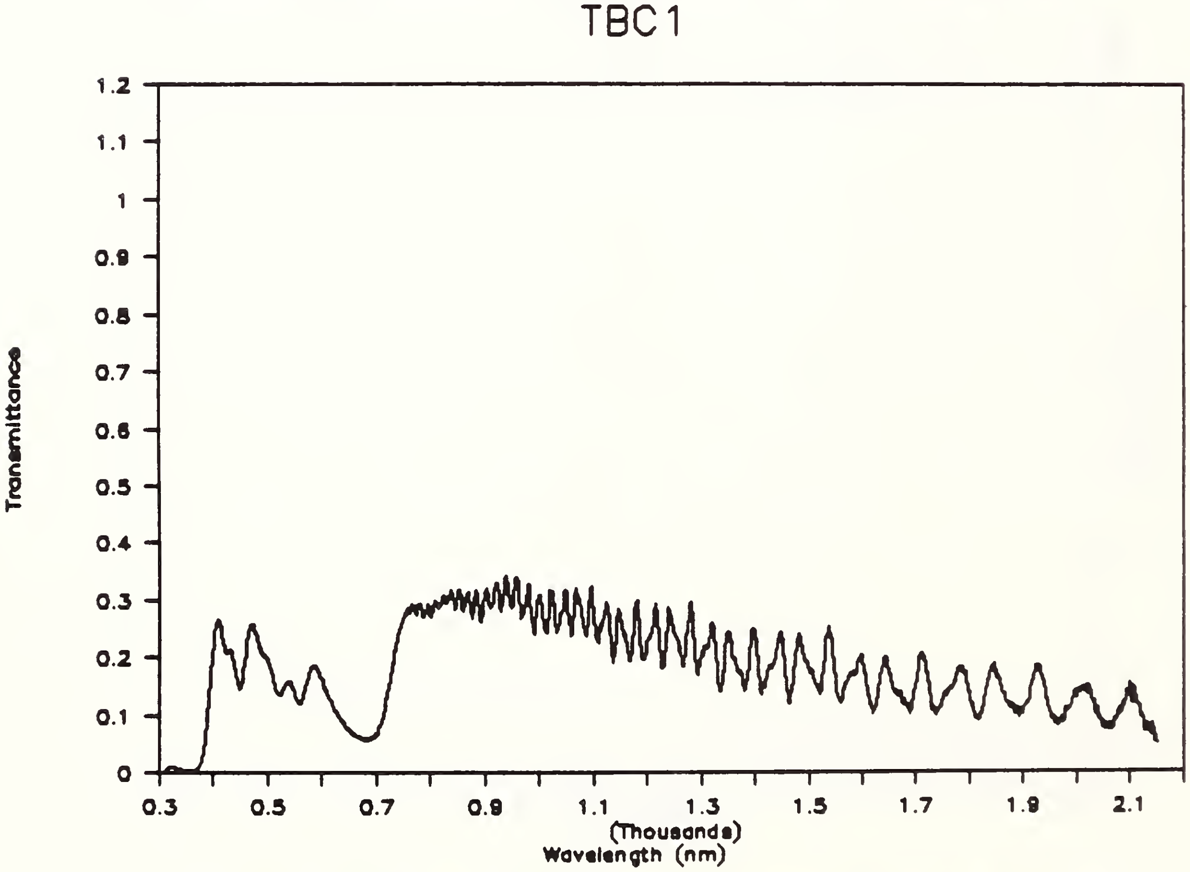


Figure 6.29b Sample BC, Visible specular transmittance

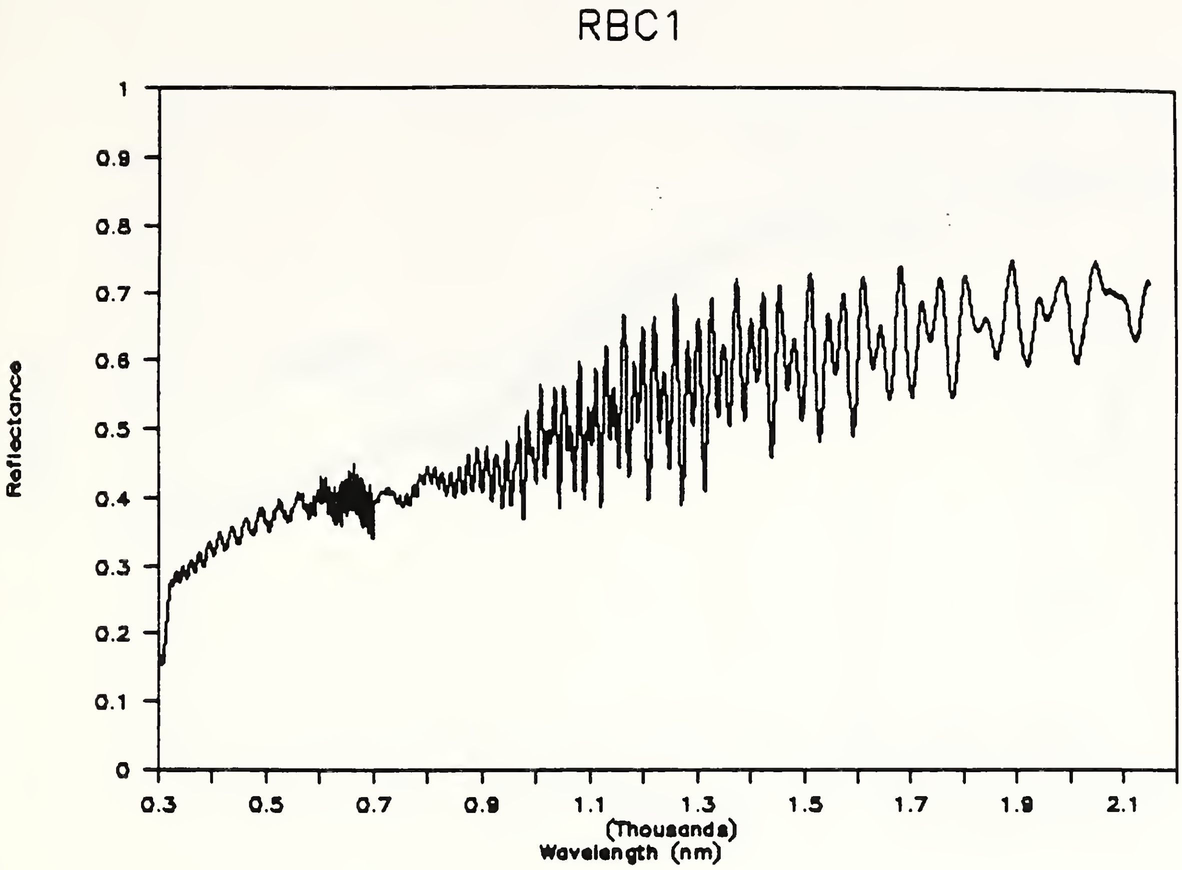


Figure 6.29c Sample BC, Visible specular reflectance

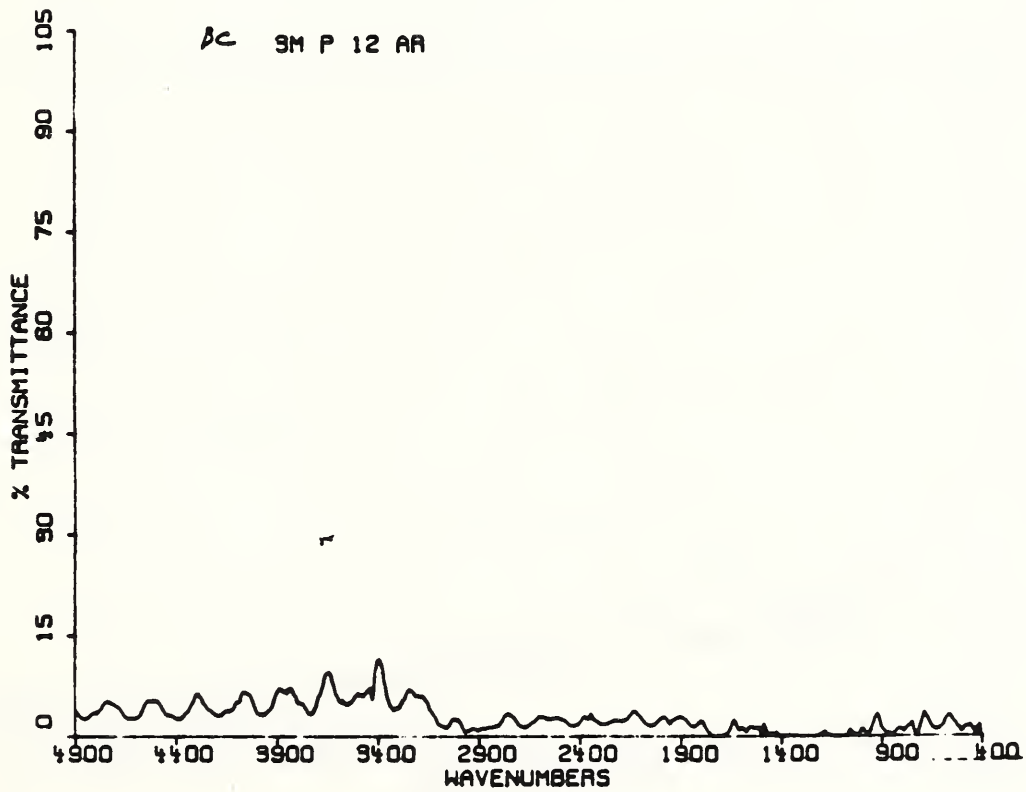


Figure 6.29d Sample BC, IR specular transmittance

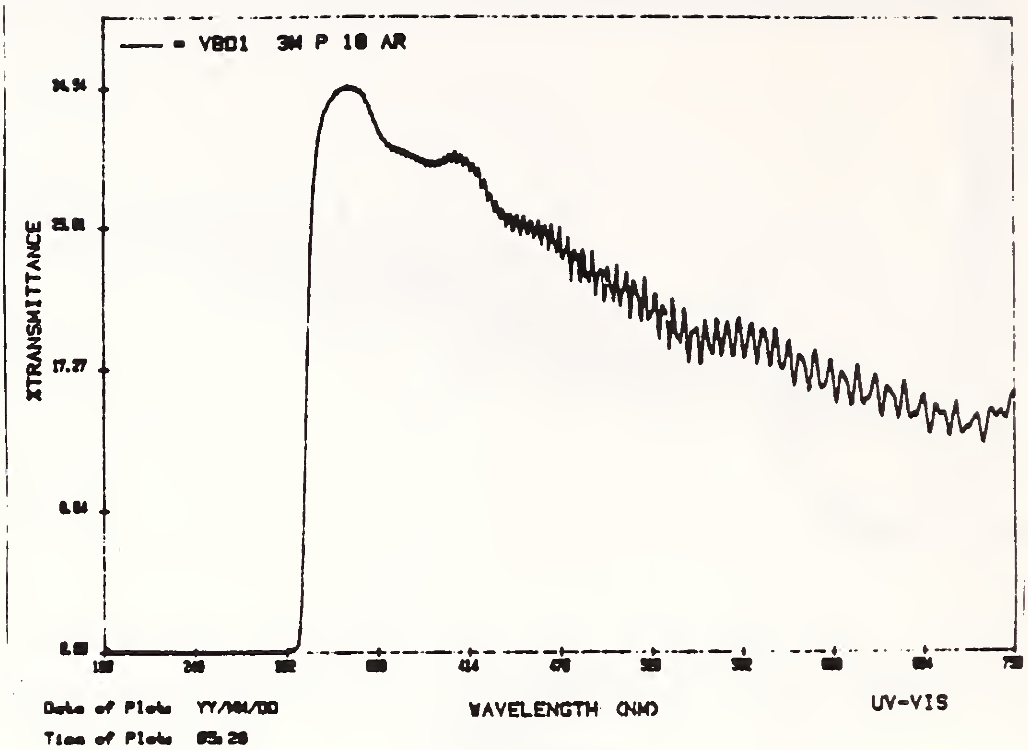


Figure 6.30a Sample BD, UV-visible total transmittance

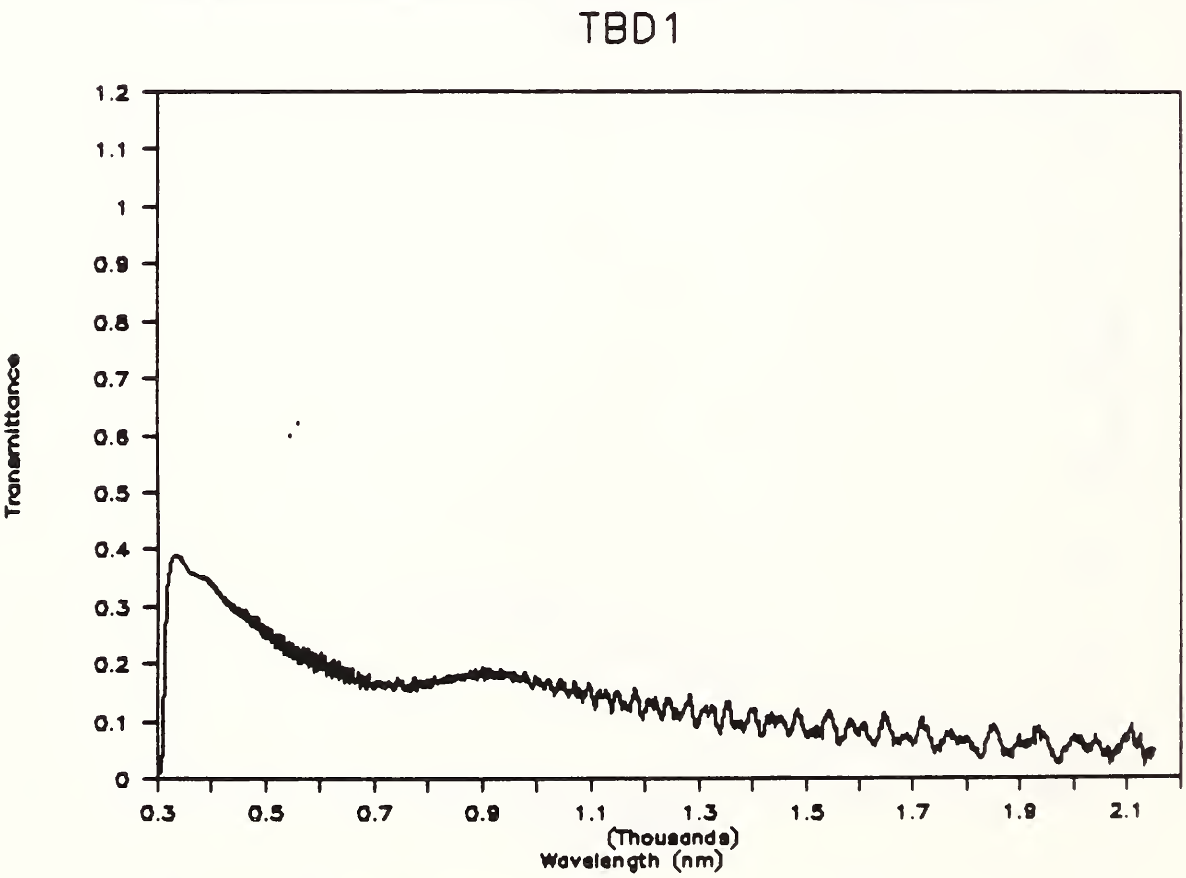


Figure 6.30b Sample BD, Visible specular transmittance

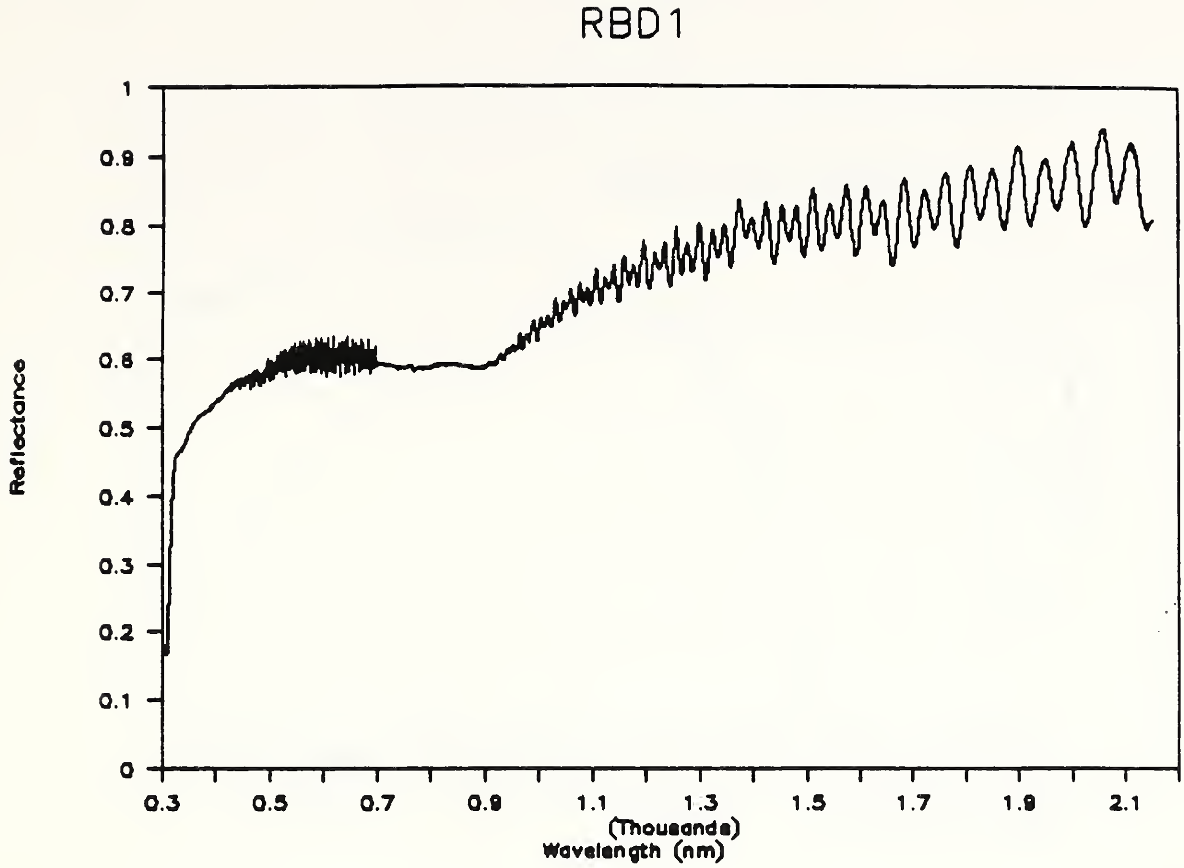


Figure 6.30c Sample BD, Visible specular reflectance

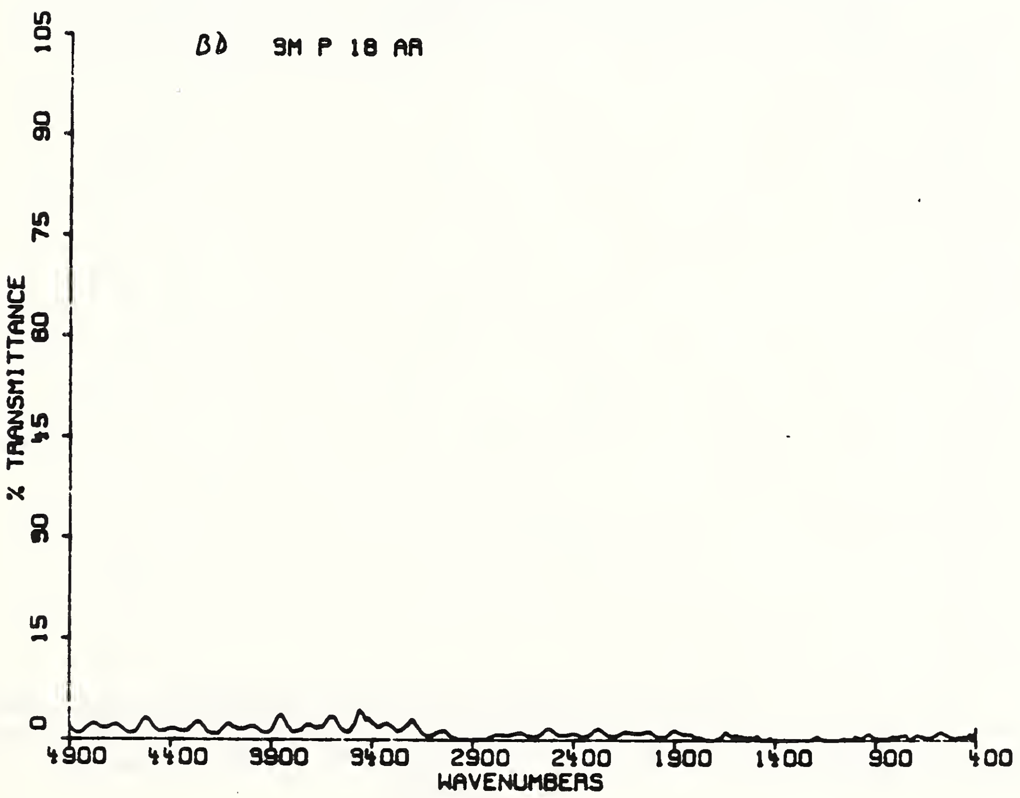


Figure 6.30d Sample BD, IR specular transmittance

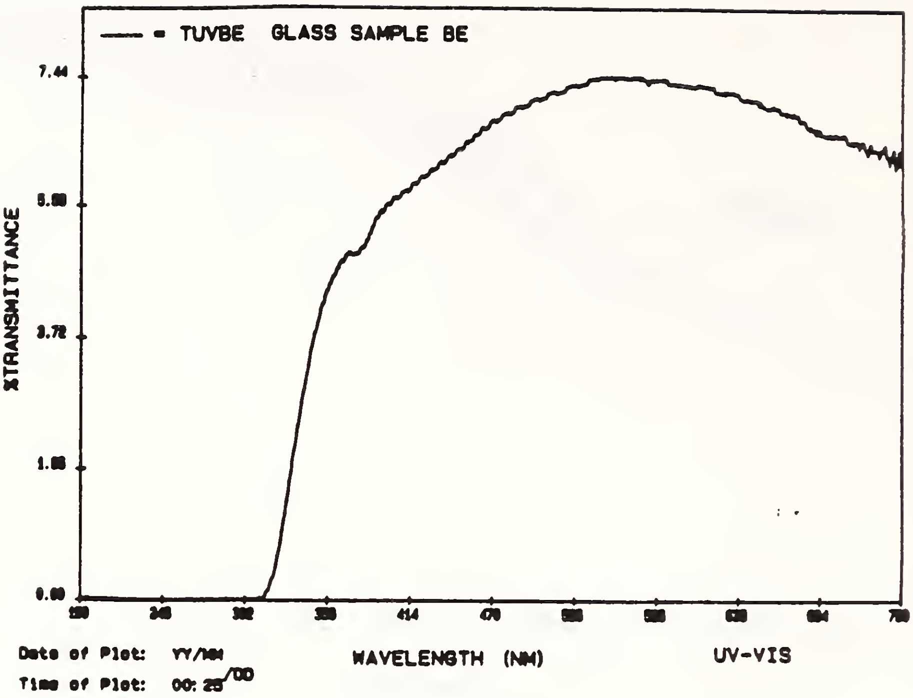


Figure 6.31a Sample BE, UV-visible total transmittance

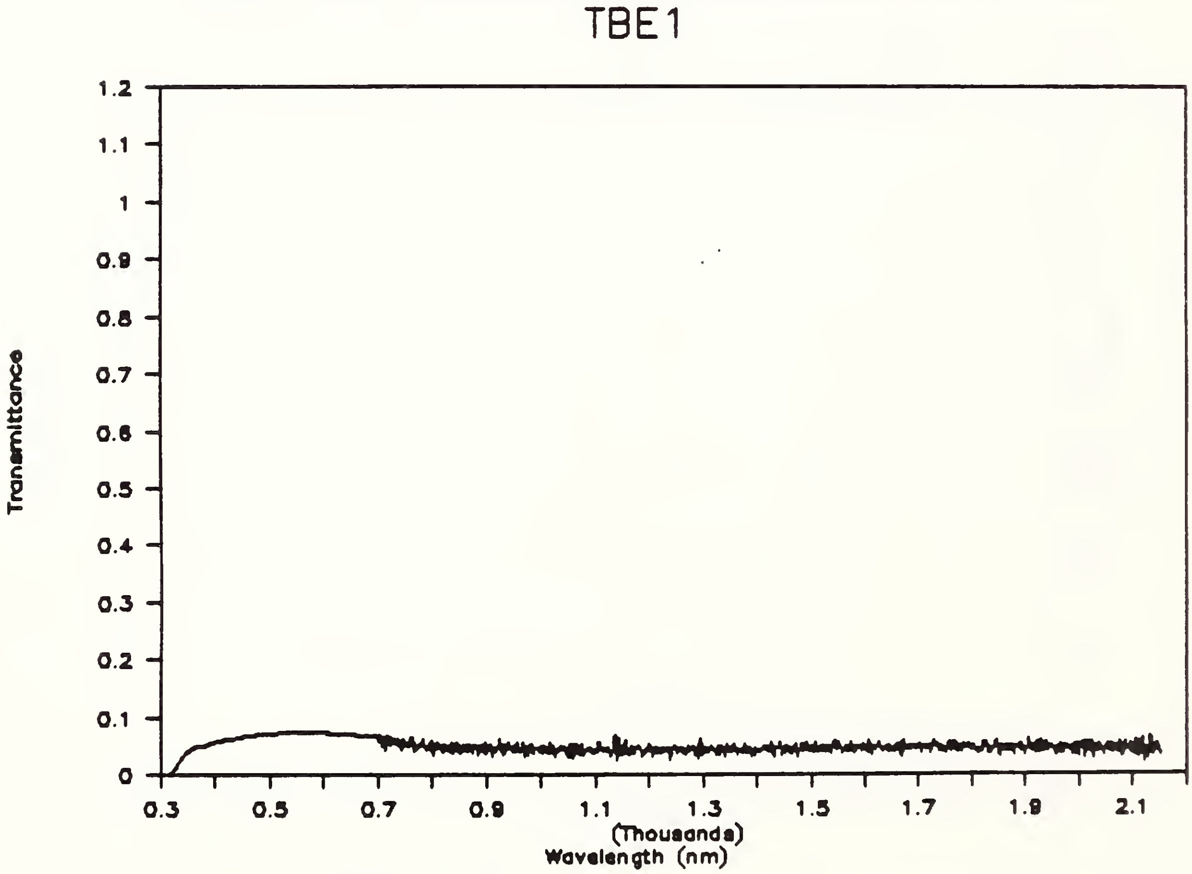


Figure 6.31b Sample BE, Visible specular transmittance

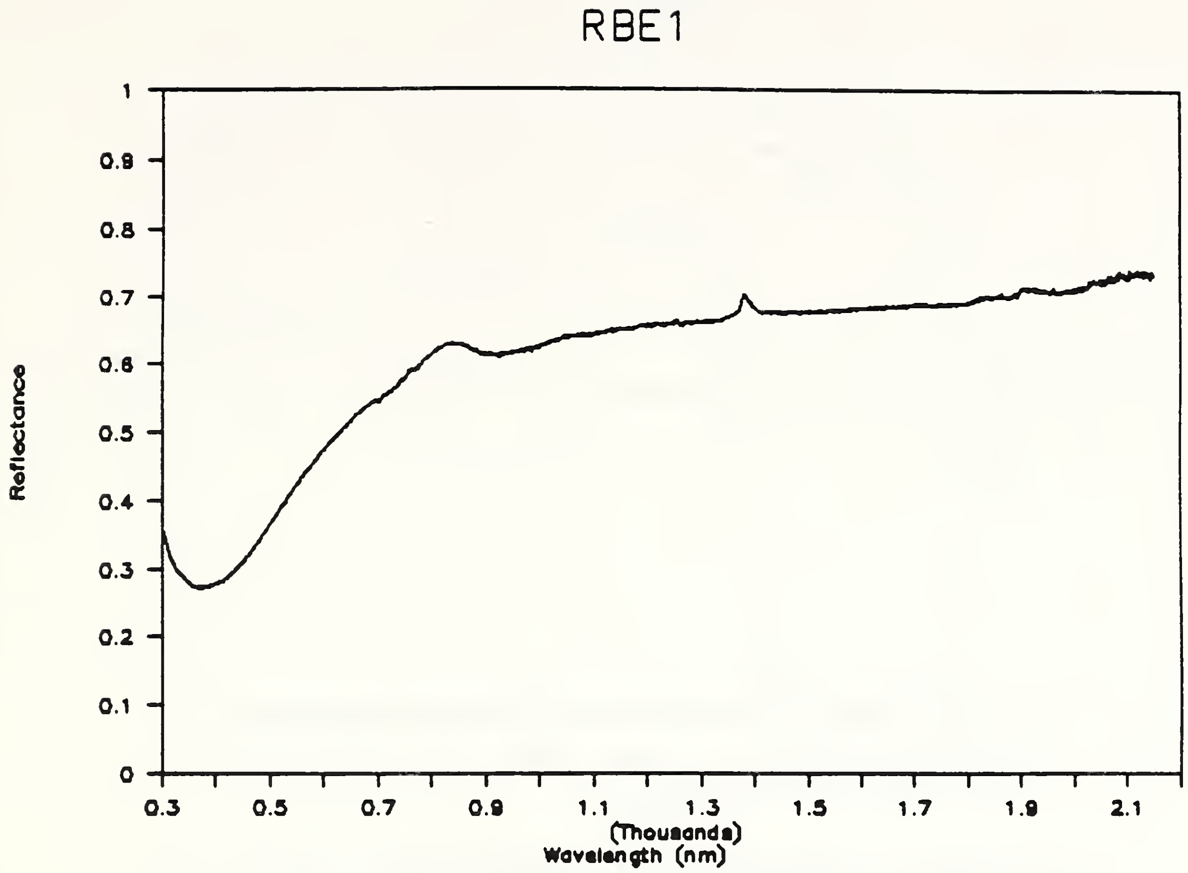


Figure 6.31c Sample BE, Visible specular reflectance

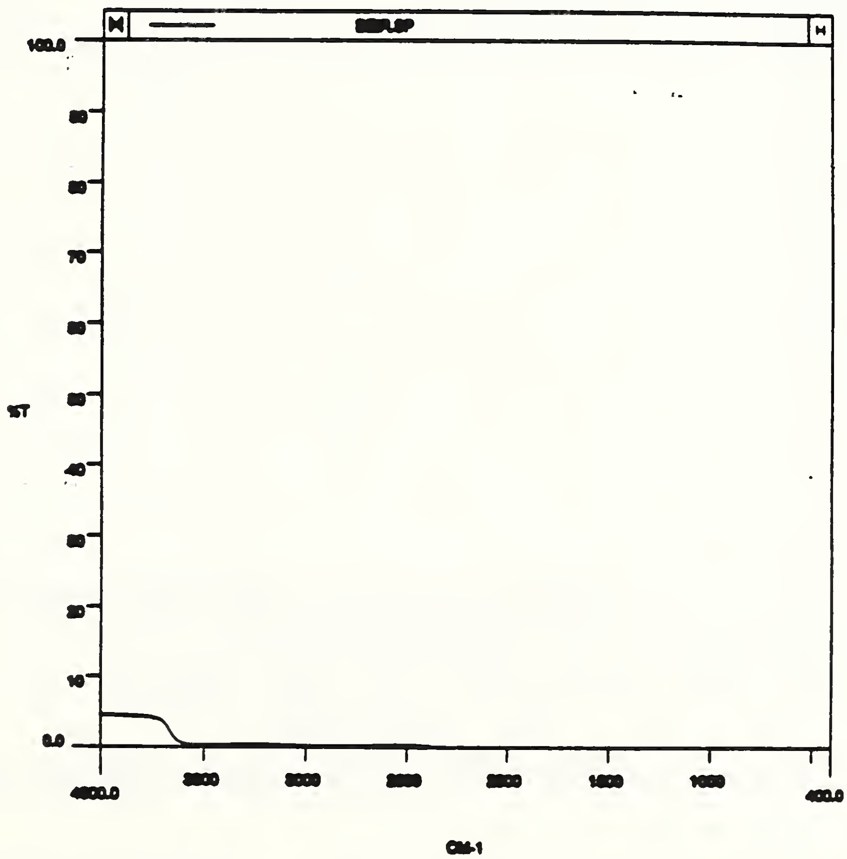


Figure 6.31d Sample BE, IR specular transmittance

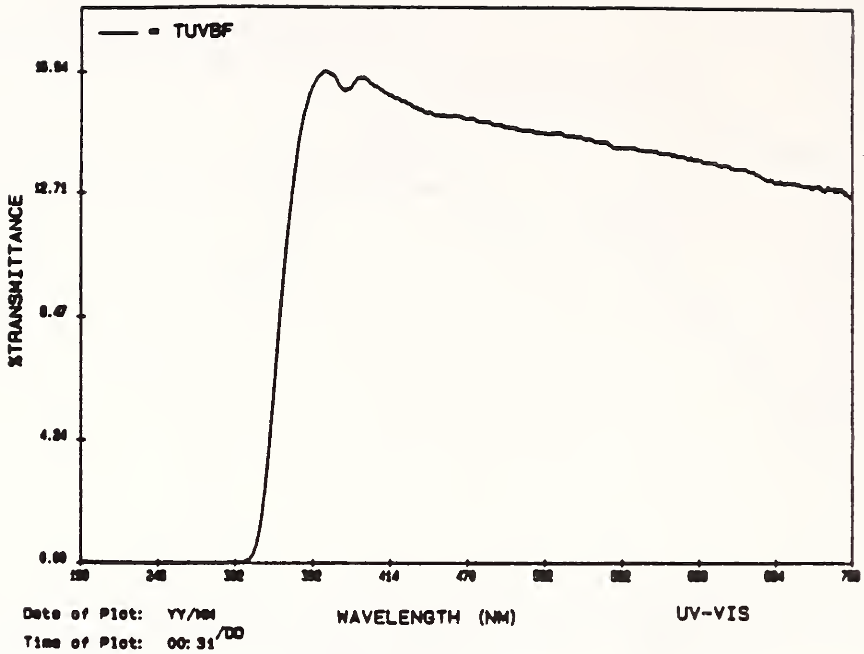


Figure 6.32a Sample BF, UV-visible total transmittance

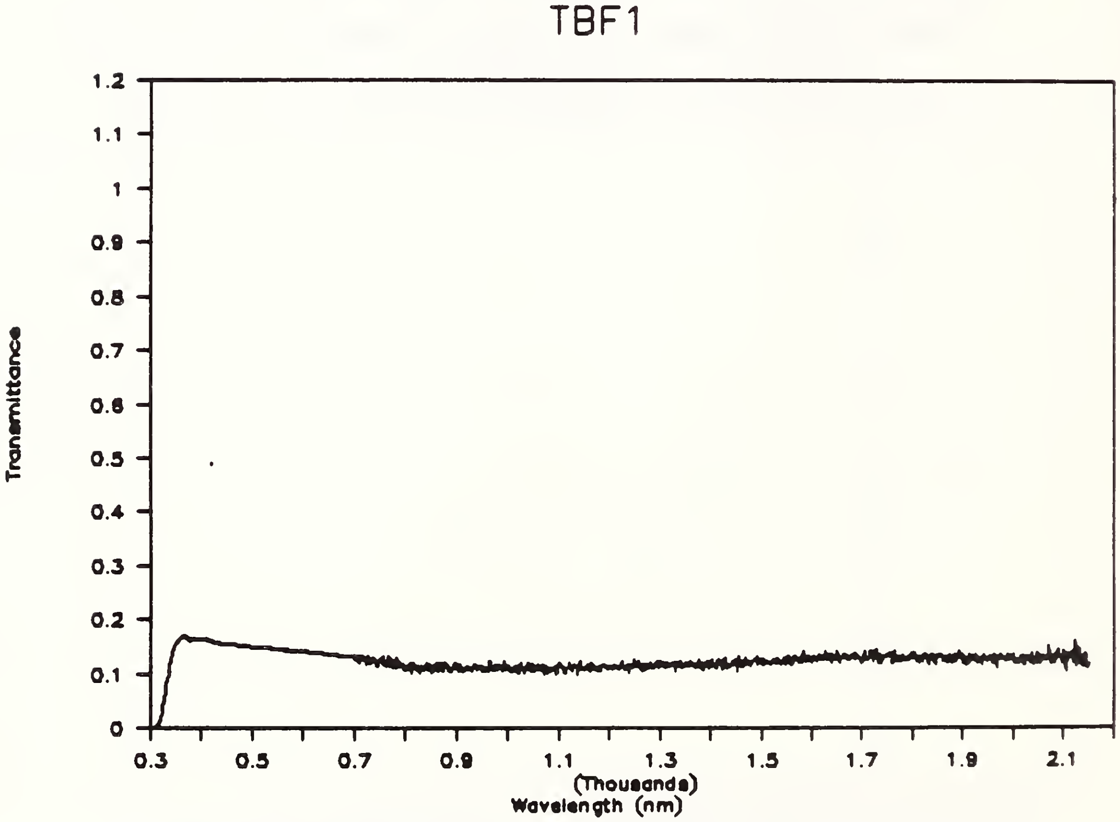


Figure 6.32b Sample BF, Visible specular transmittance

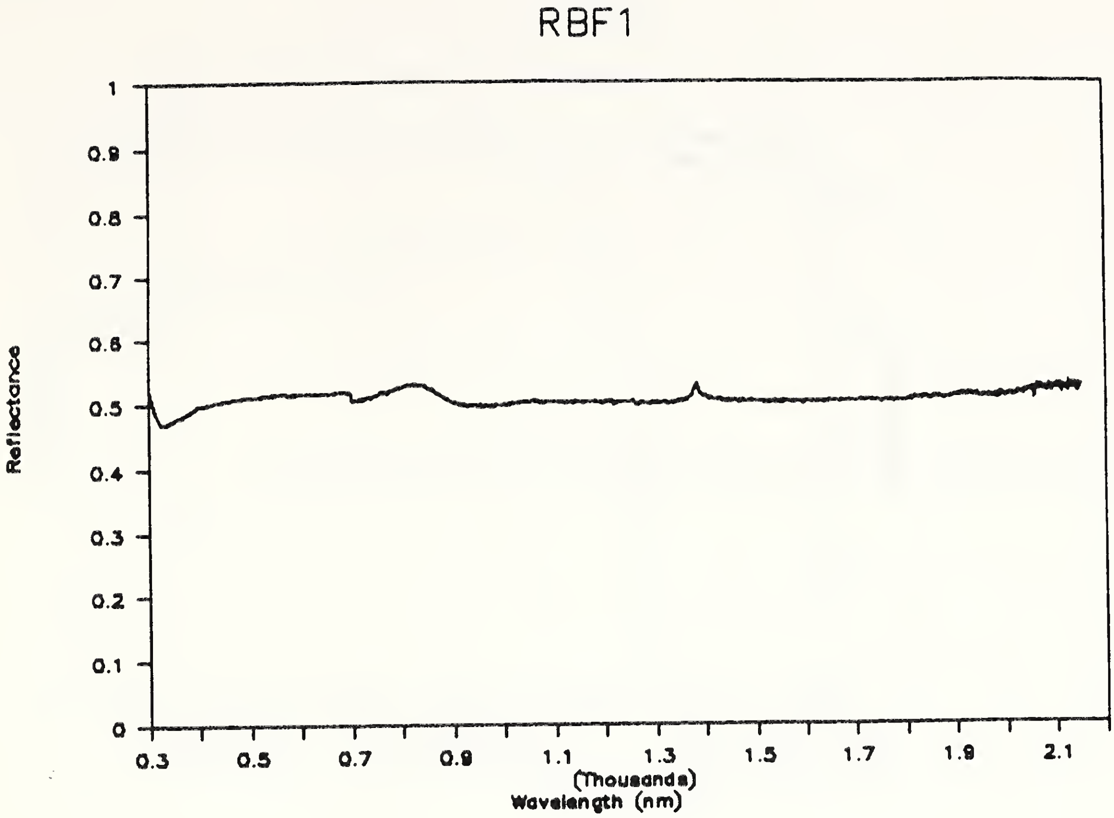


Figure 6.32c Sample BF, Visible specular reflectance

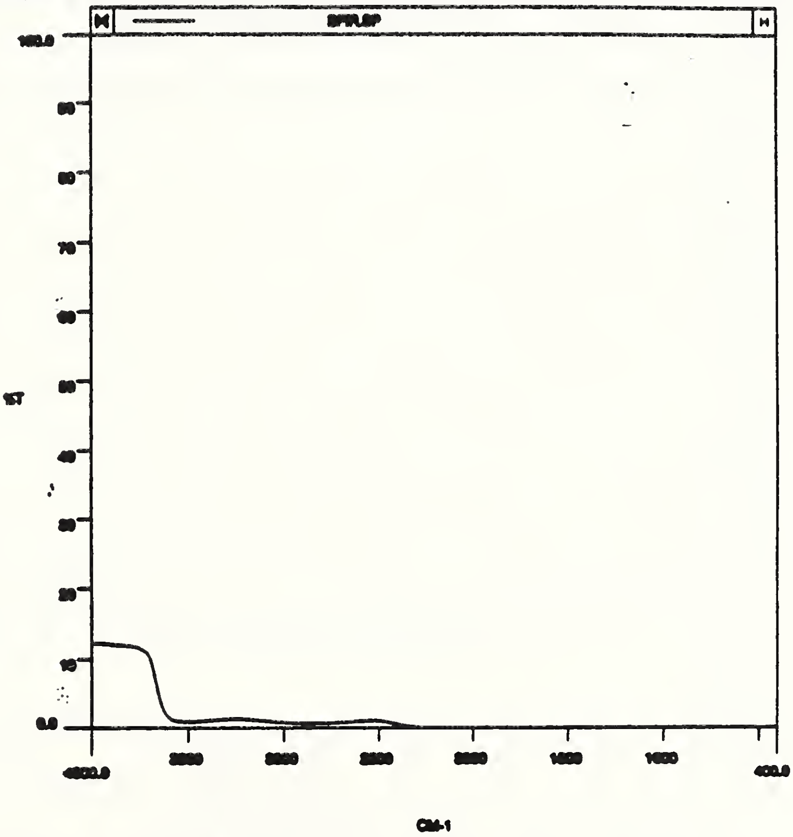


Figure 6.32d Sample BF, IR specular transmittance

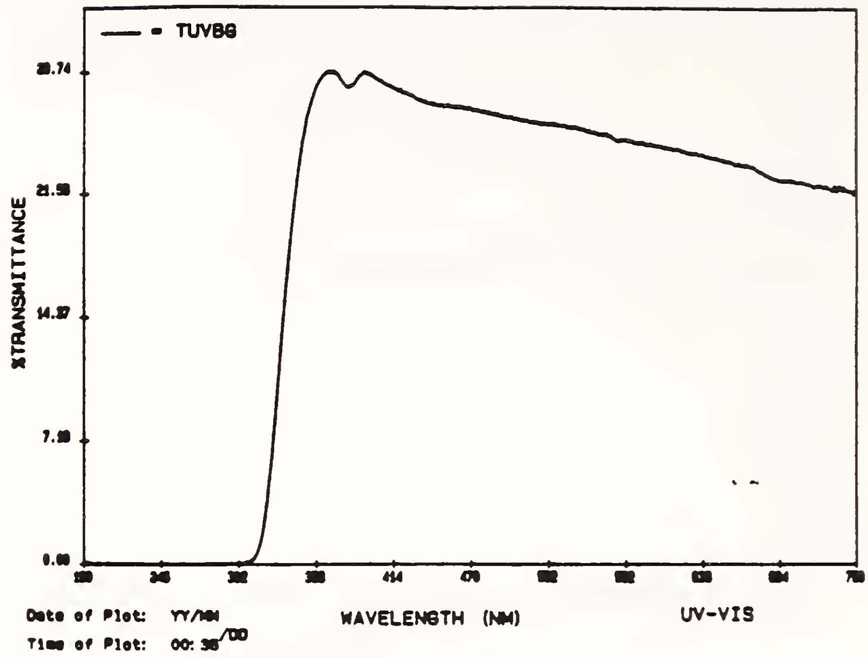


Figure 6.33a Sample BG, UV-visible total transmittance

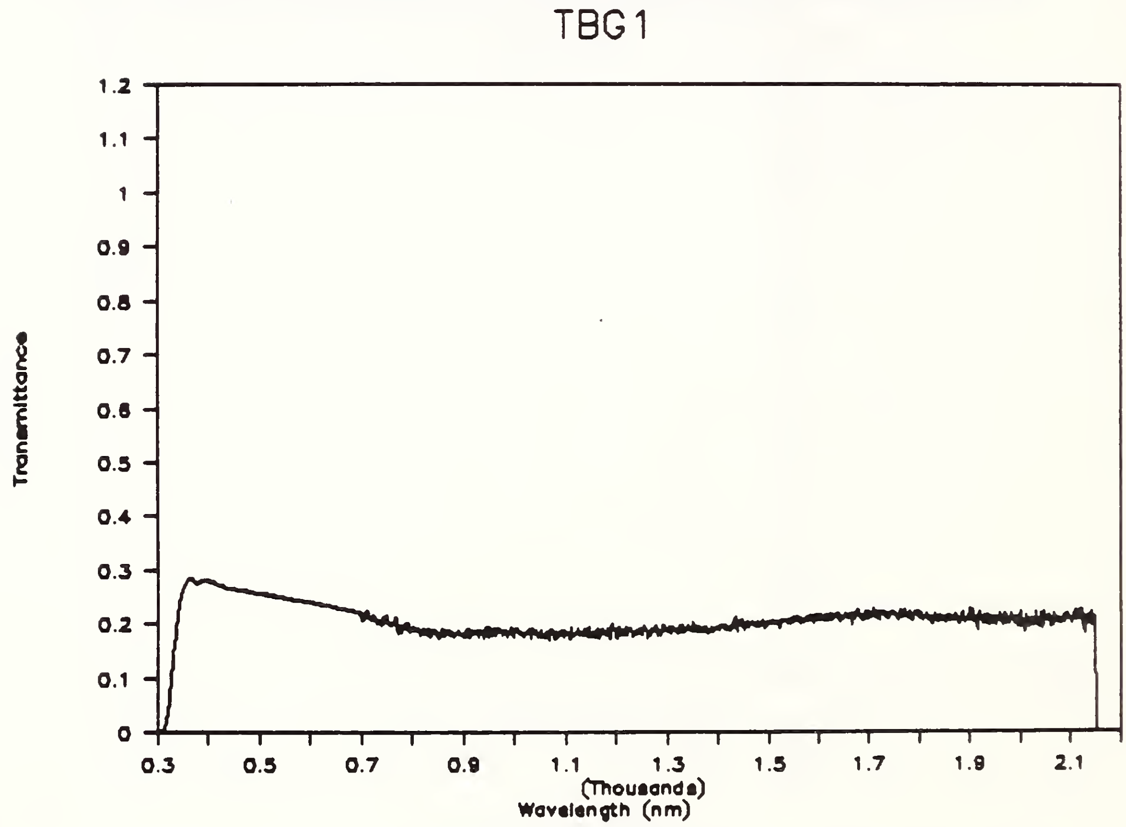


Figure 6.33b Sample BG, Visible specular transmittance

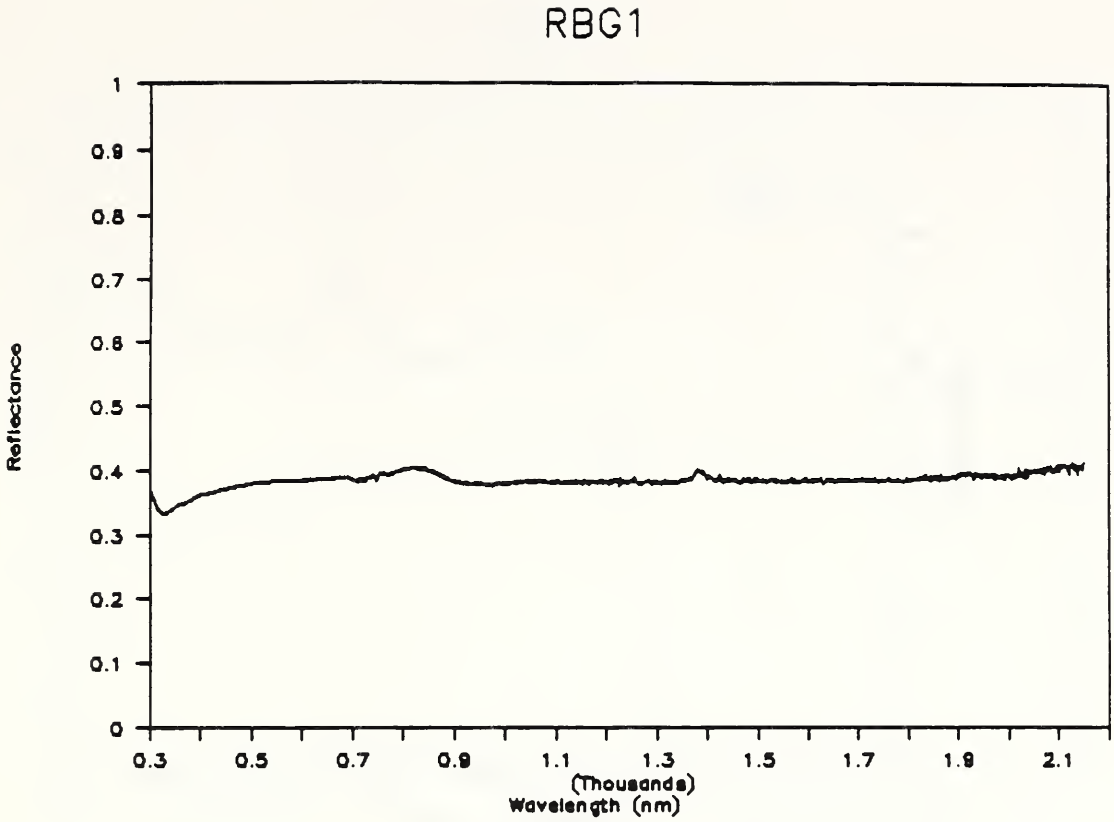


Figure 6.33c Sample BG, Visible specular reflectance

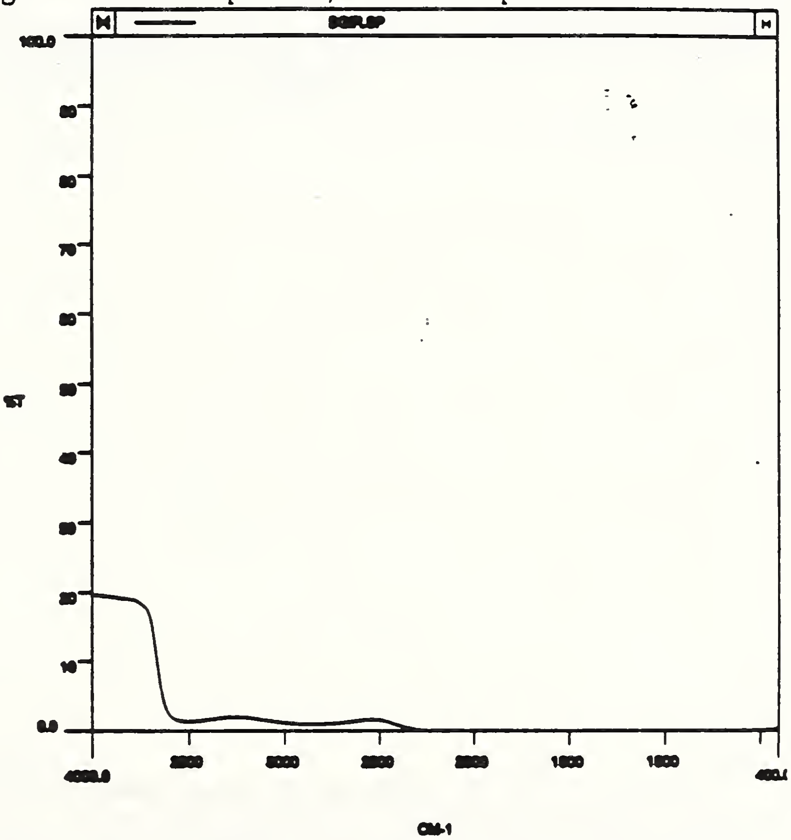


Figure 6.33d Sample BG, IR specular transmittance

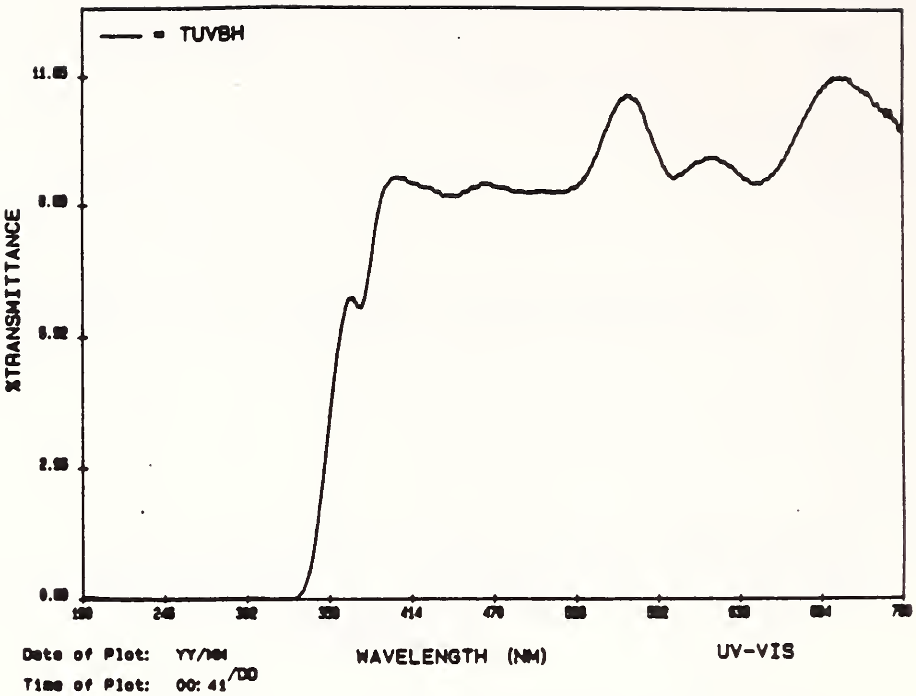


Figure 6.34a Sample BH, UV-visible total transmittance

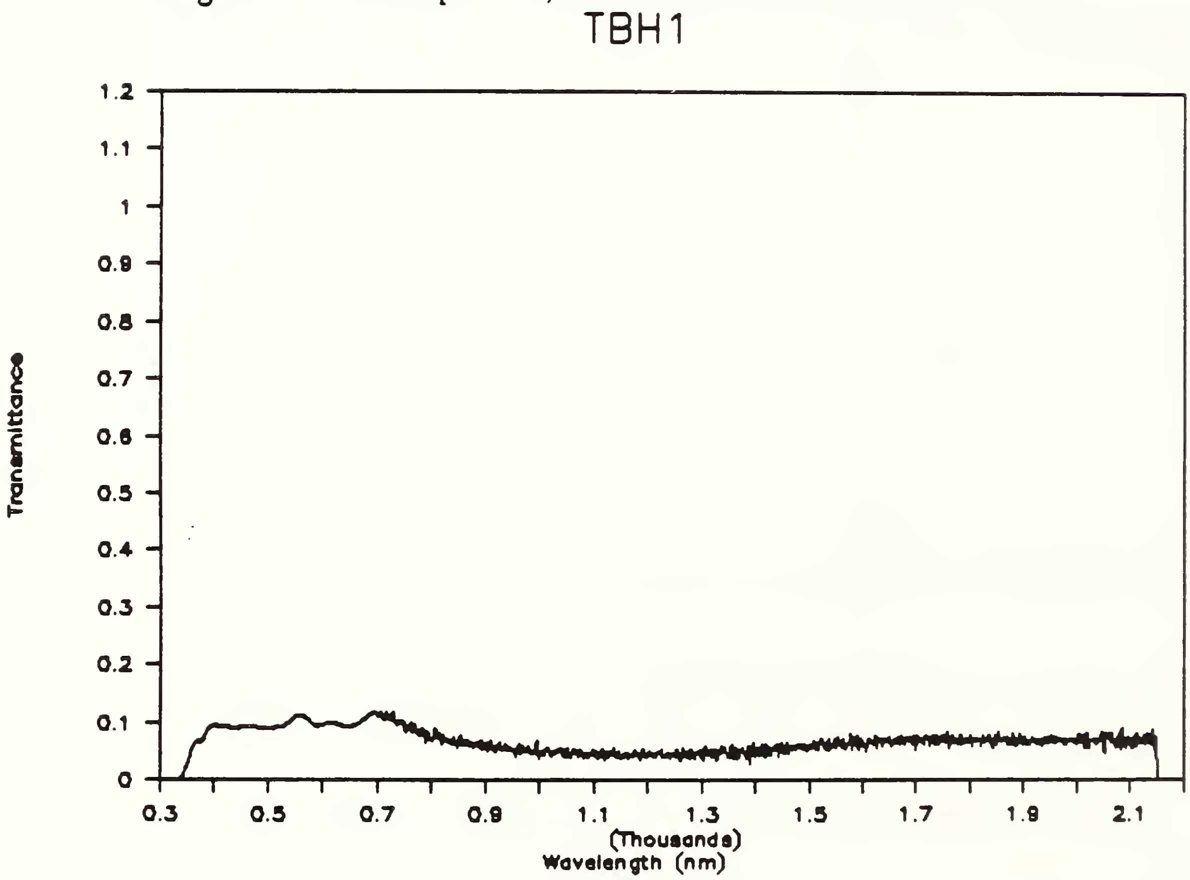


Figure 6.34b Sample BH, Visible specular transmittance

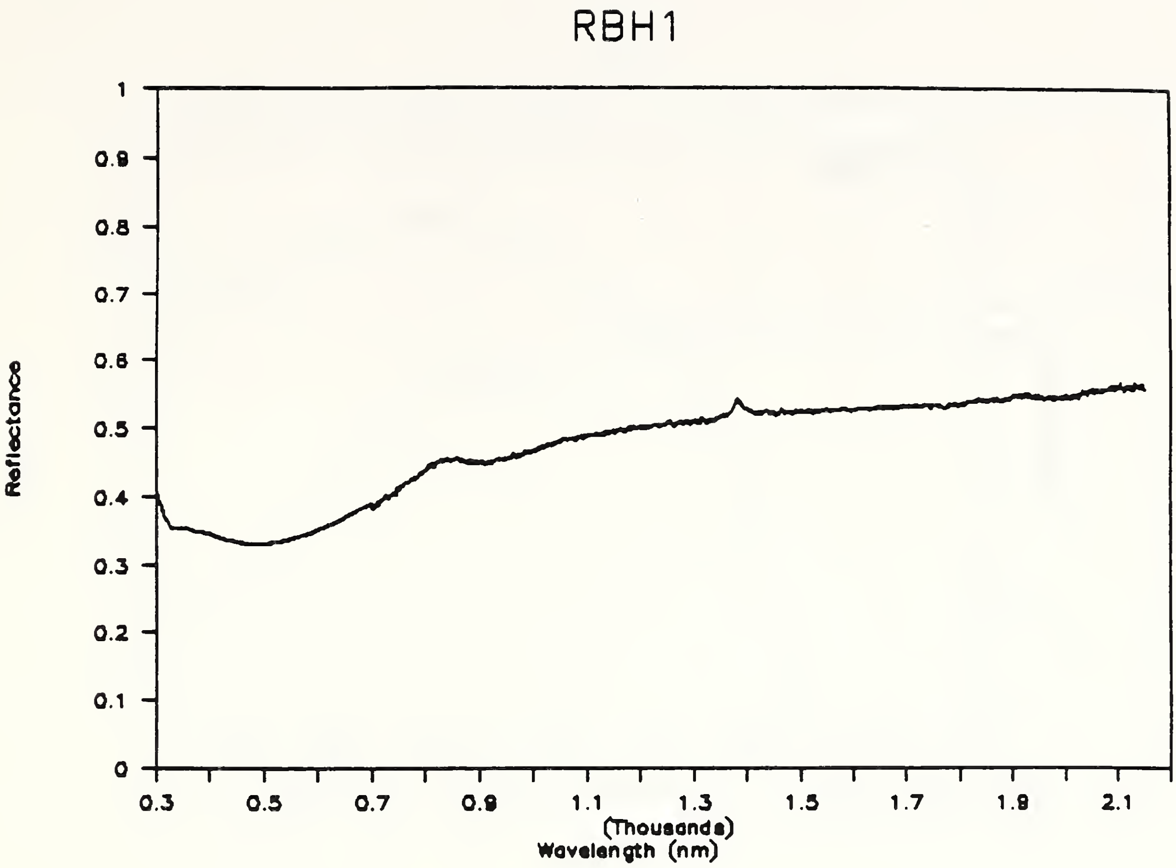


Figure 6.34c Sample BH, Visible specular reflectance

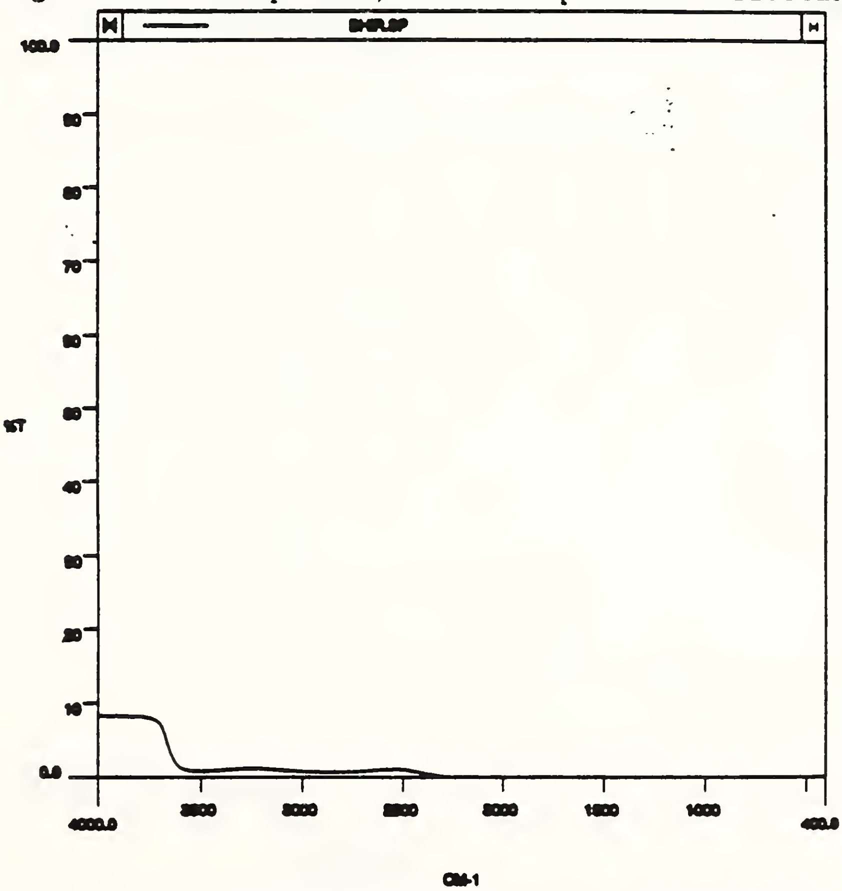


Figure 6.34d Sample BH, IR specular transmittance

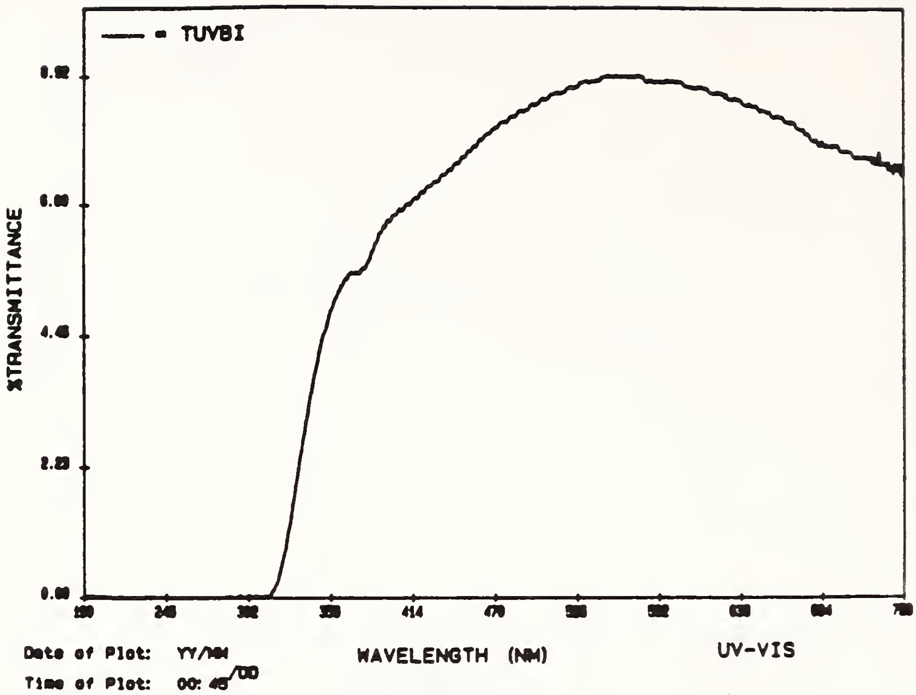


Figure 6.35a Sample BI, UV-visible total transmittance

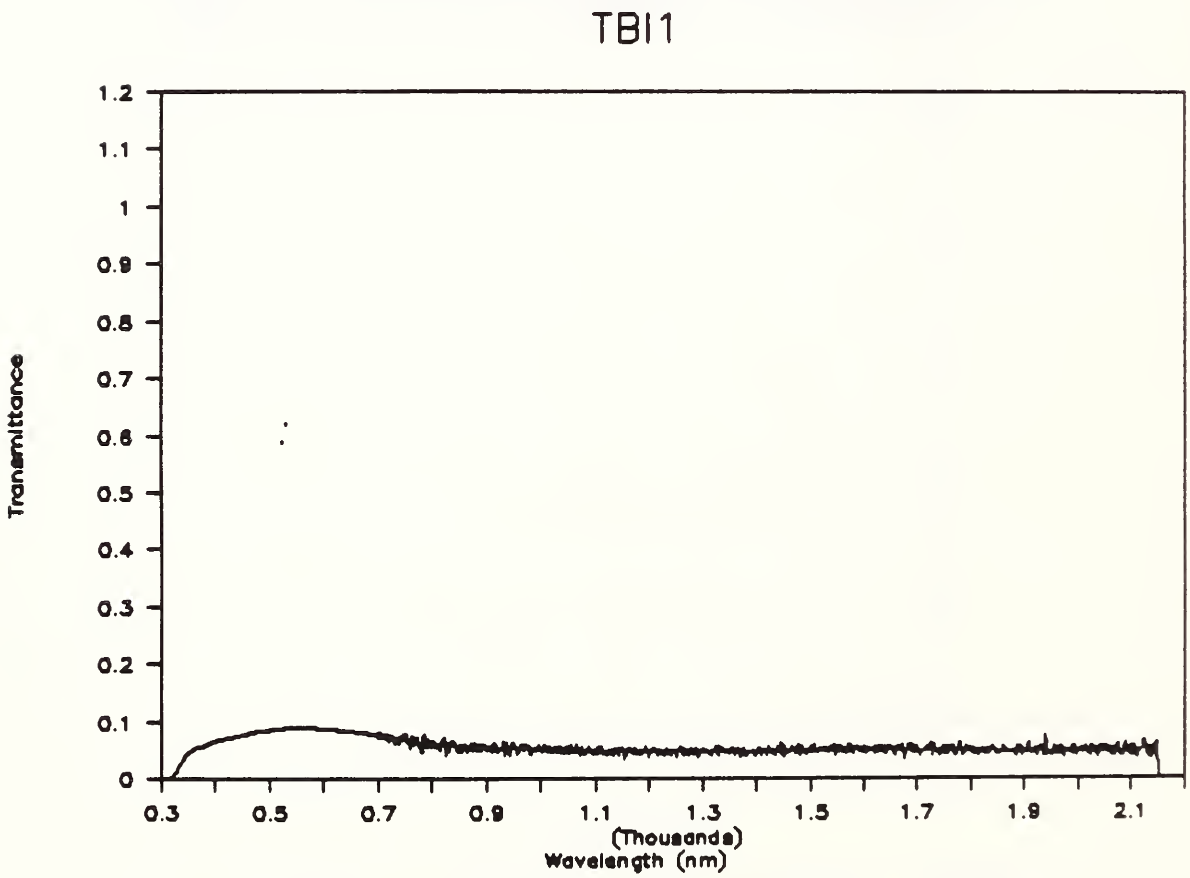


Figure 6.35b Sample BI, Visible specular transmittance

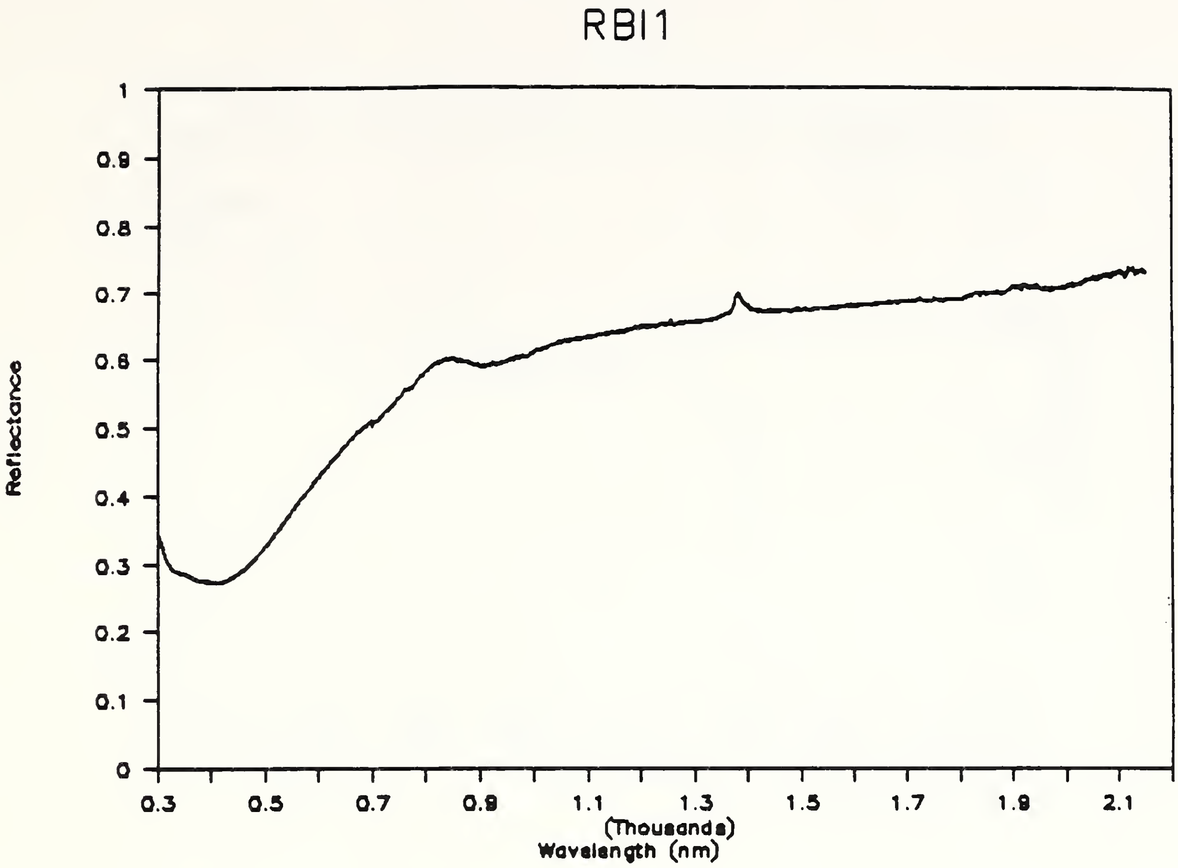


Figure 6.35c Sample BI, Visible specular reflectance

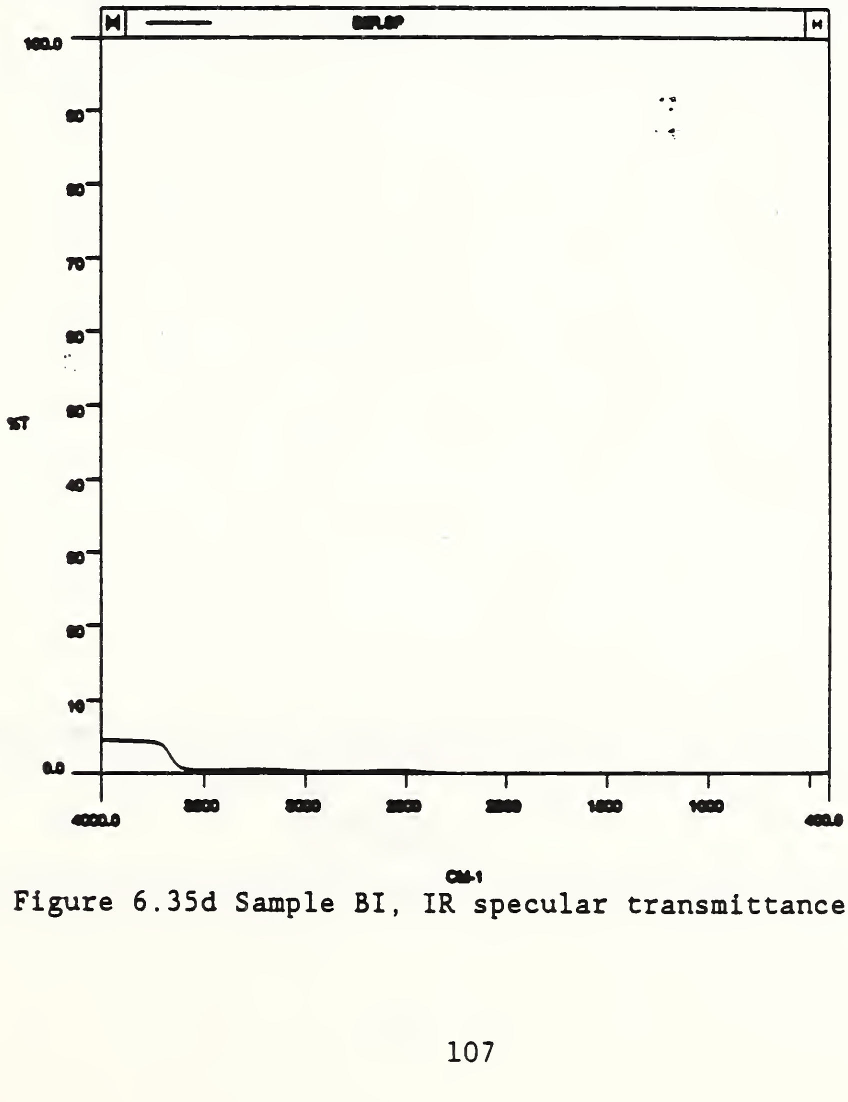


Figure 6.35d Sample BI, IR specular transmittance

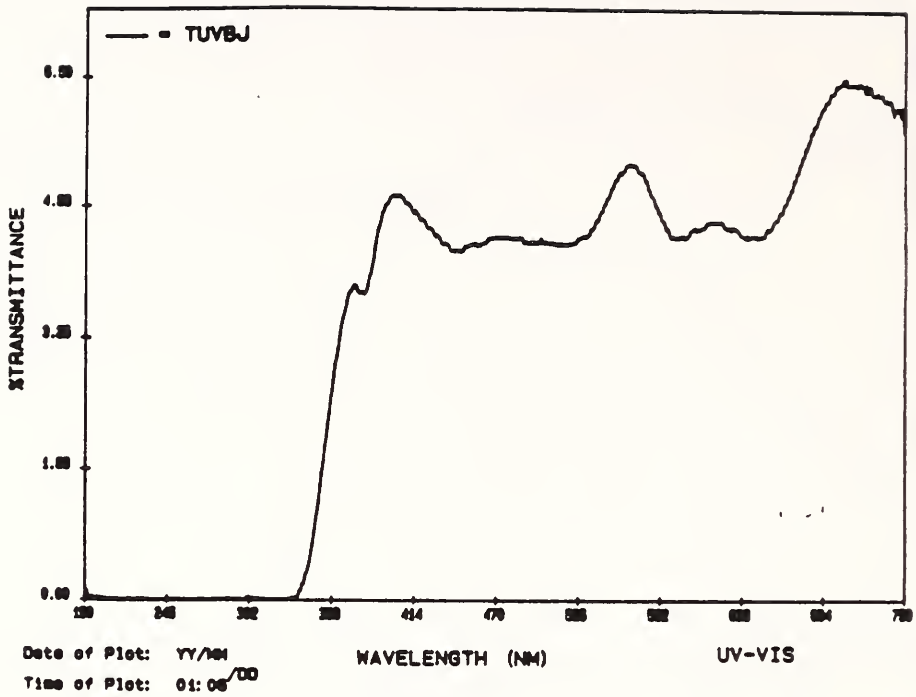


Figure 6.36a Sample BJ, UV-visible total transmittance

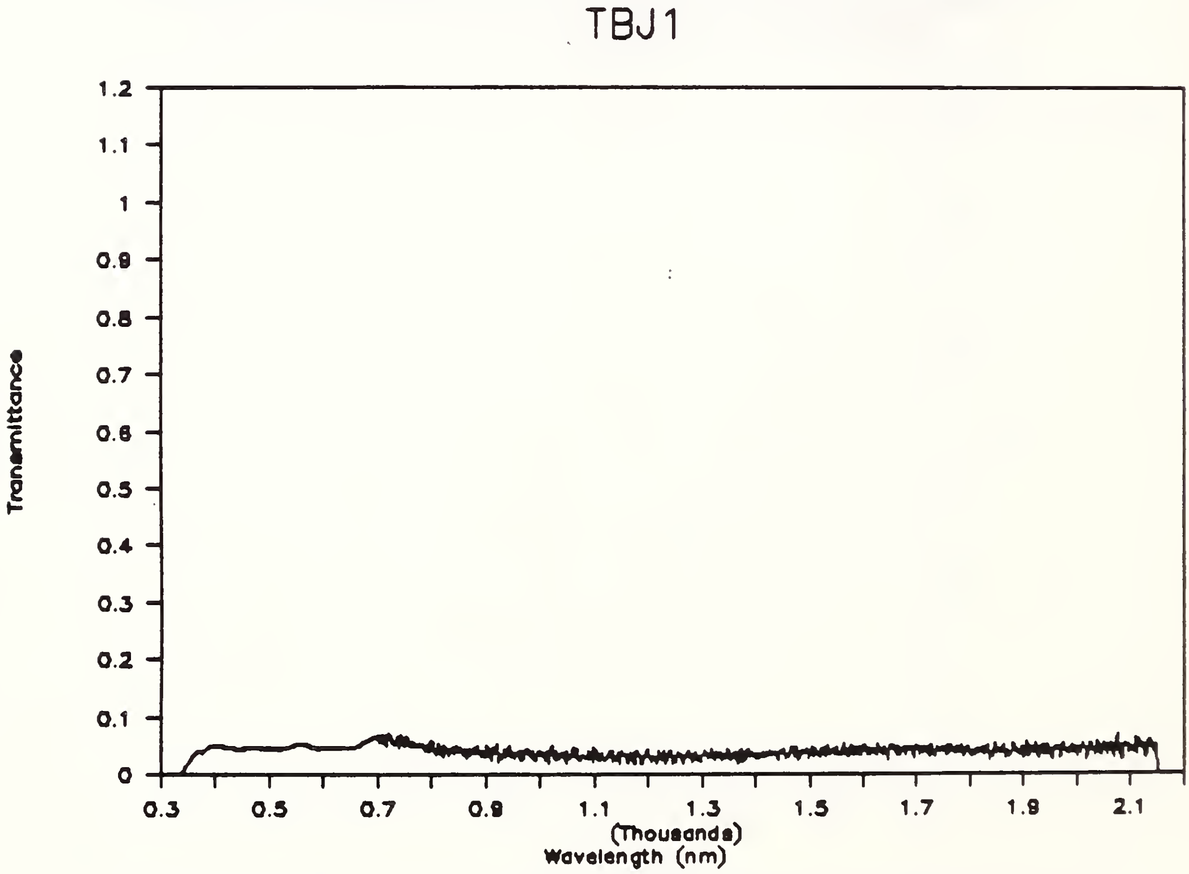


Figure 6.36b Sample BJ, Visible specular transmittance

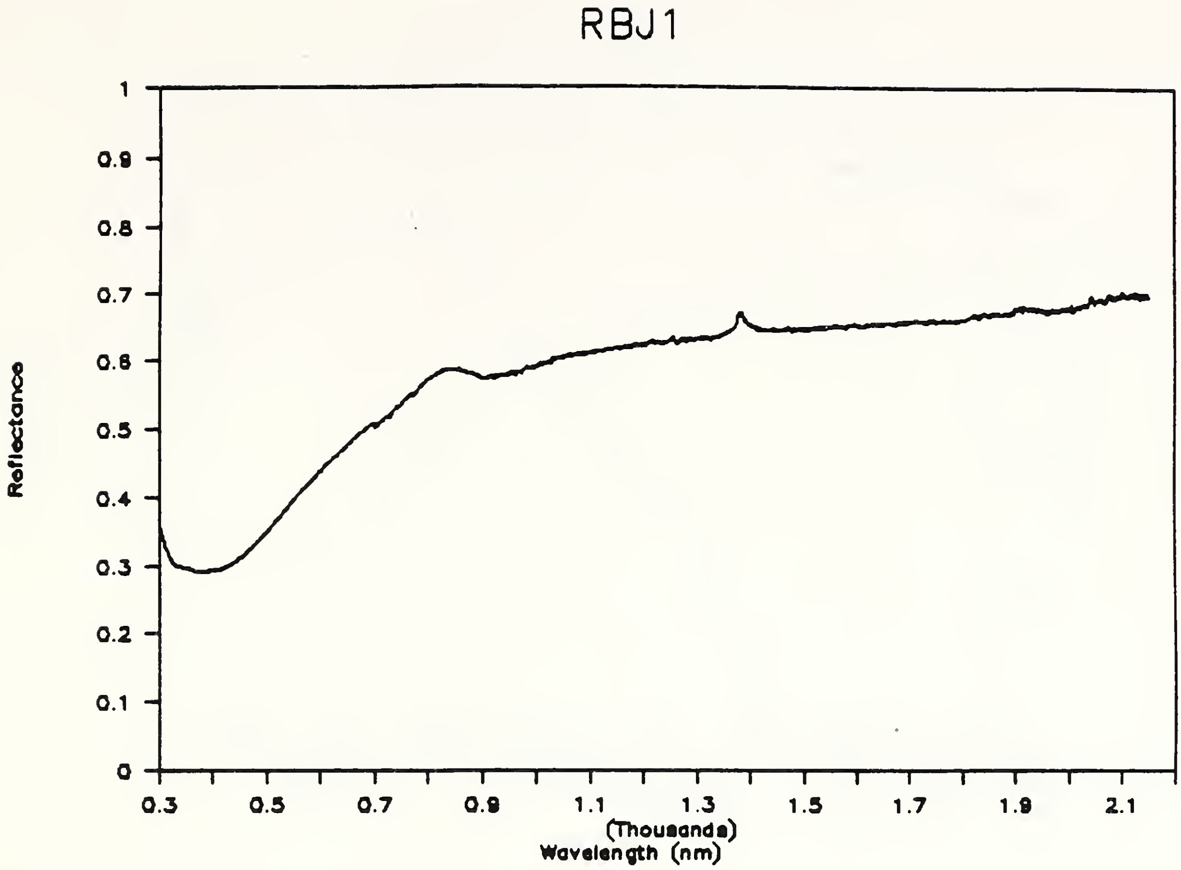


Figure 6.36c Sample BJ, Visible specular reflectance

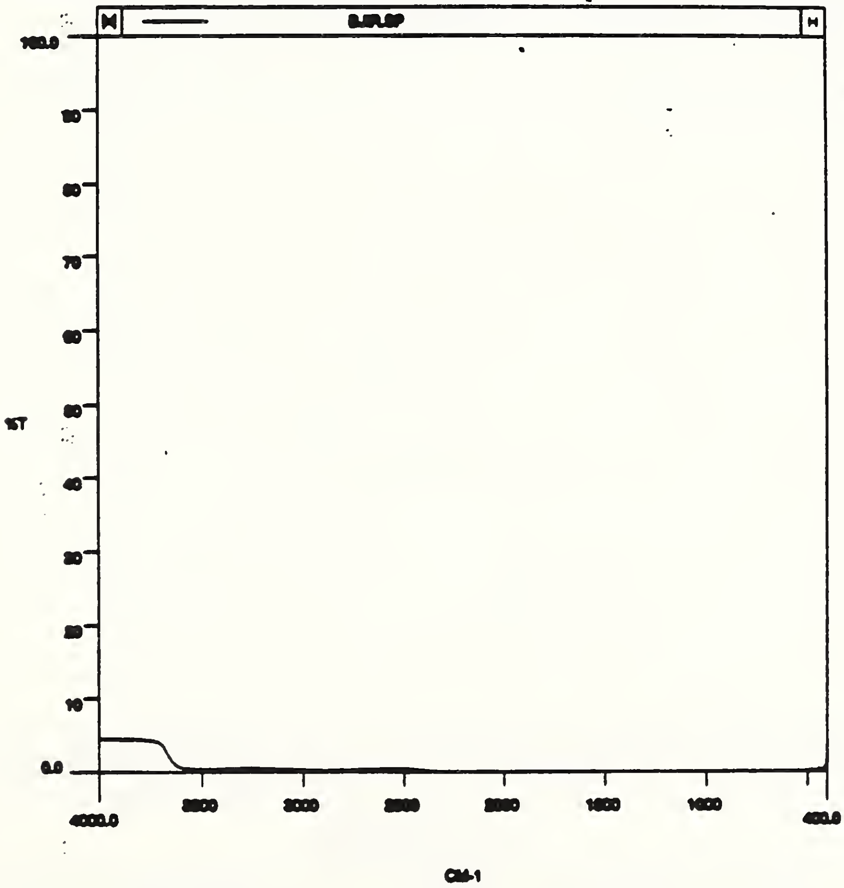


Figure 6.36d Sample BJ, IR specular transmittance

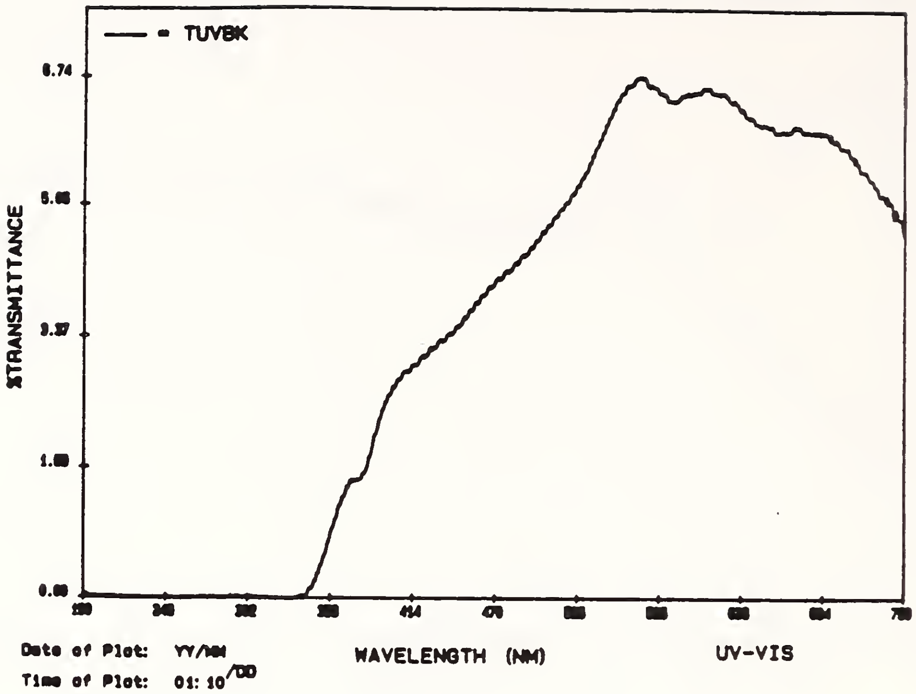


Figure 6.37a Sample BK, UV-visible total transmittance

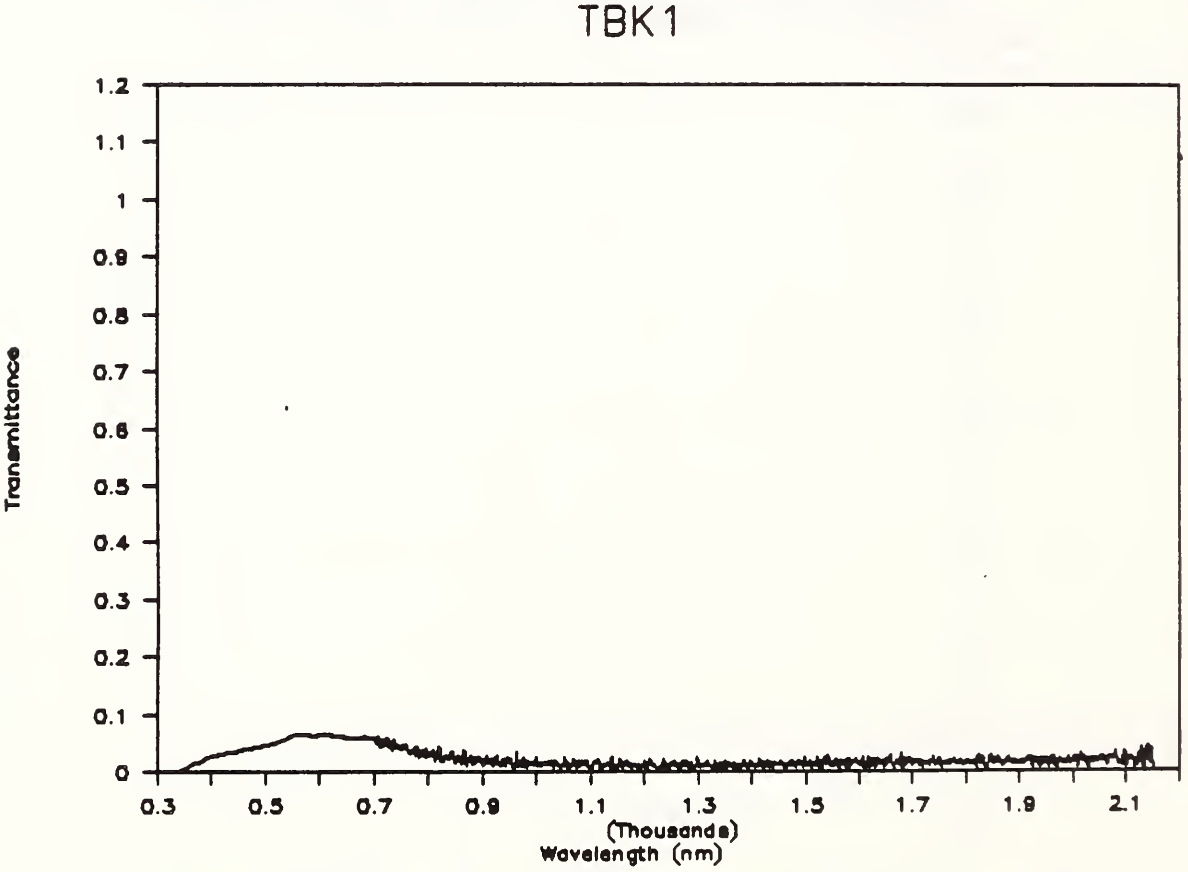


Figure 6.37b Sample BK, Visible specular transmittance

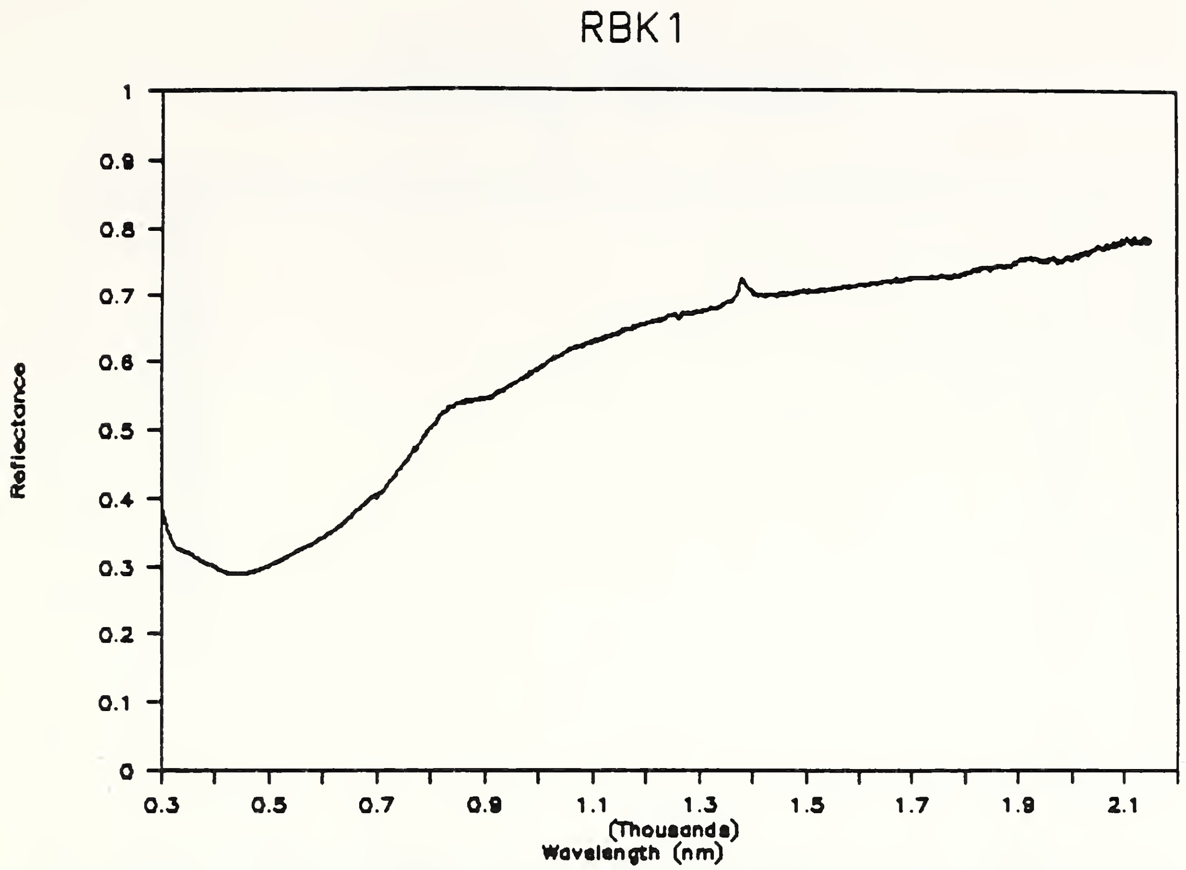


Figure 6.37c Sample BK, Visible specular reflectance

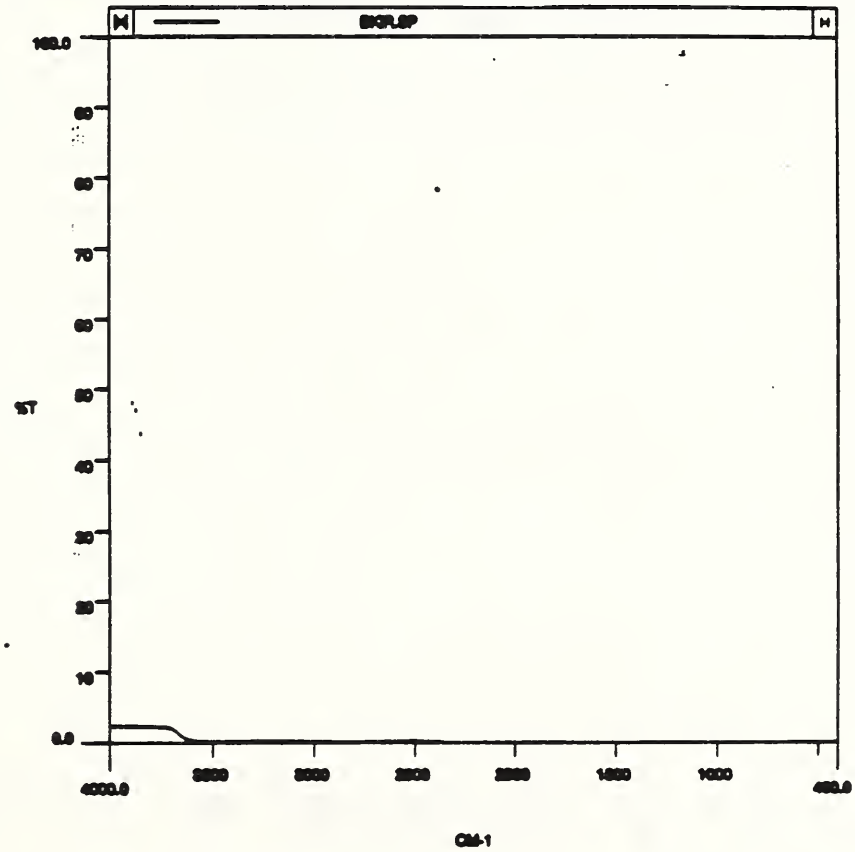


Figure 6.37d Sample BK, IR specular transmittance

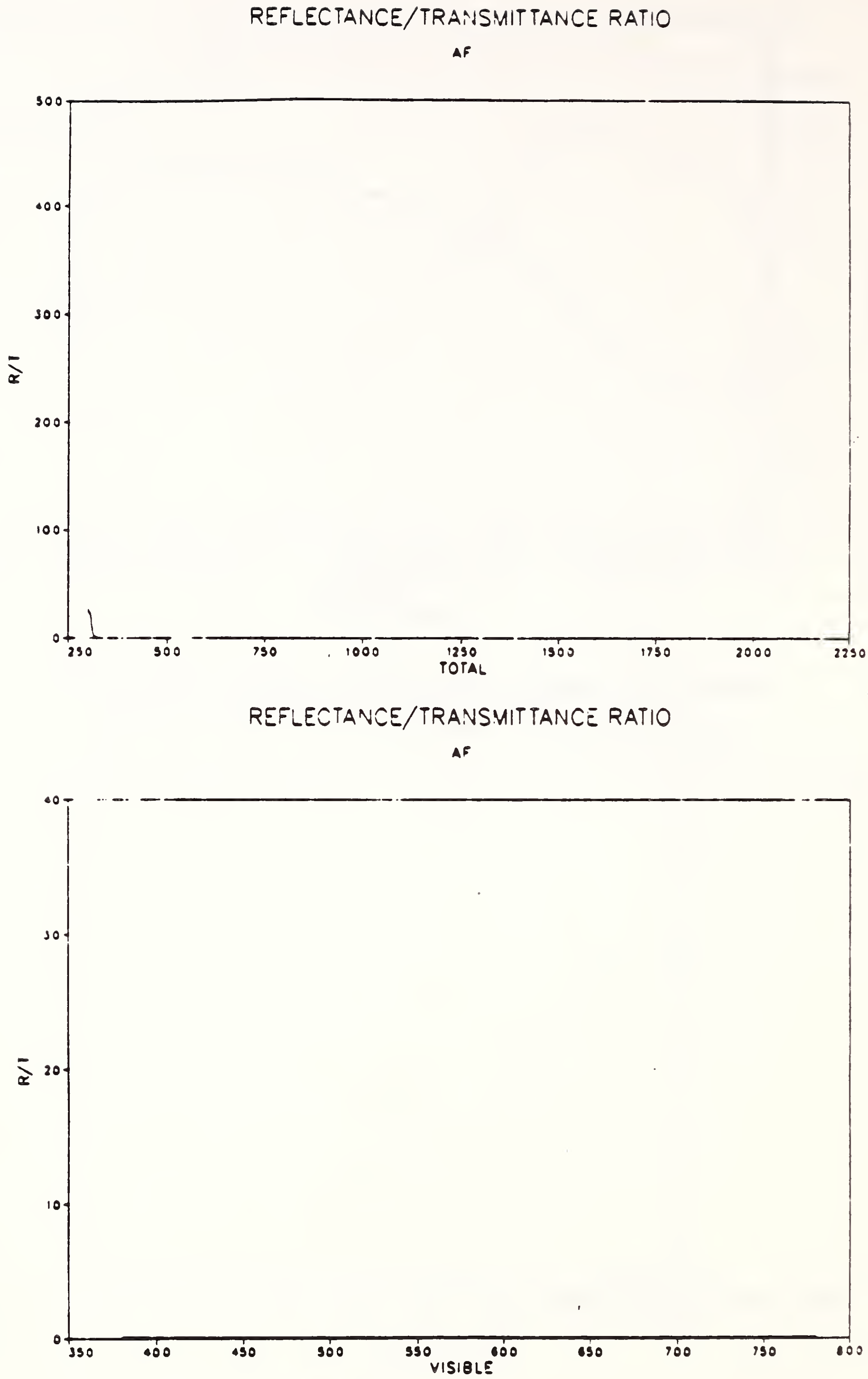
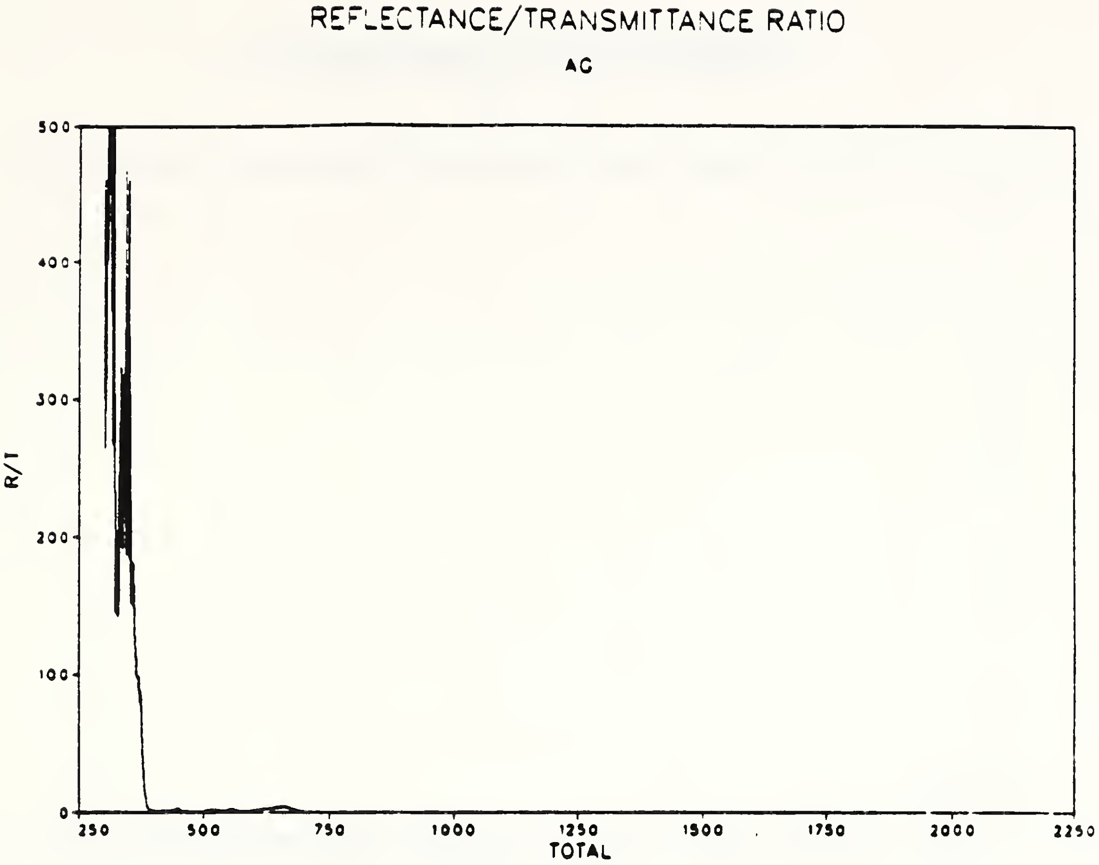


Figure 6.38 Sample AF, Total and visible ρ/τ versus wavelength



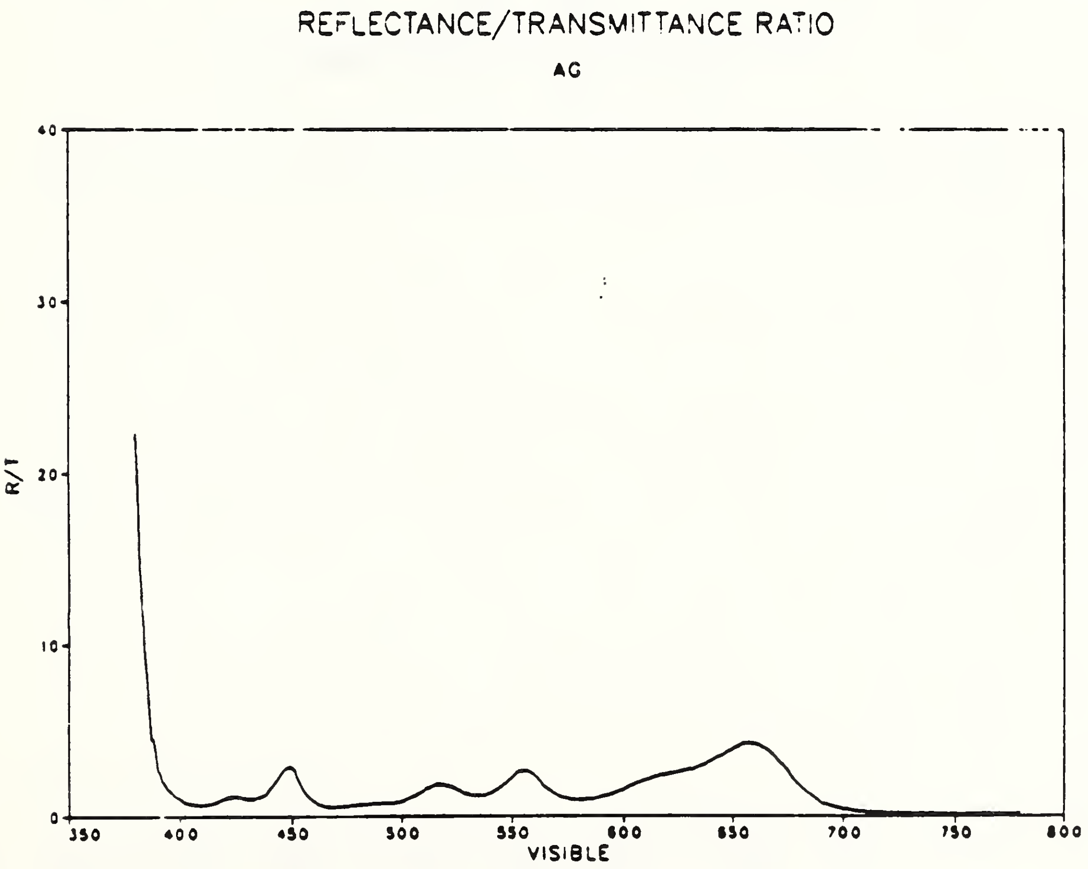
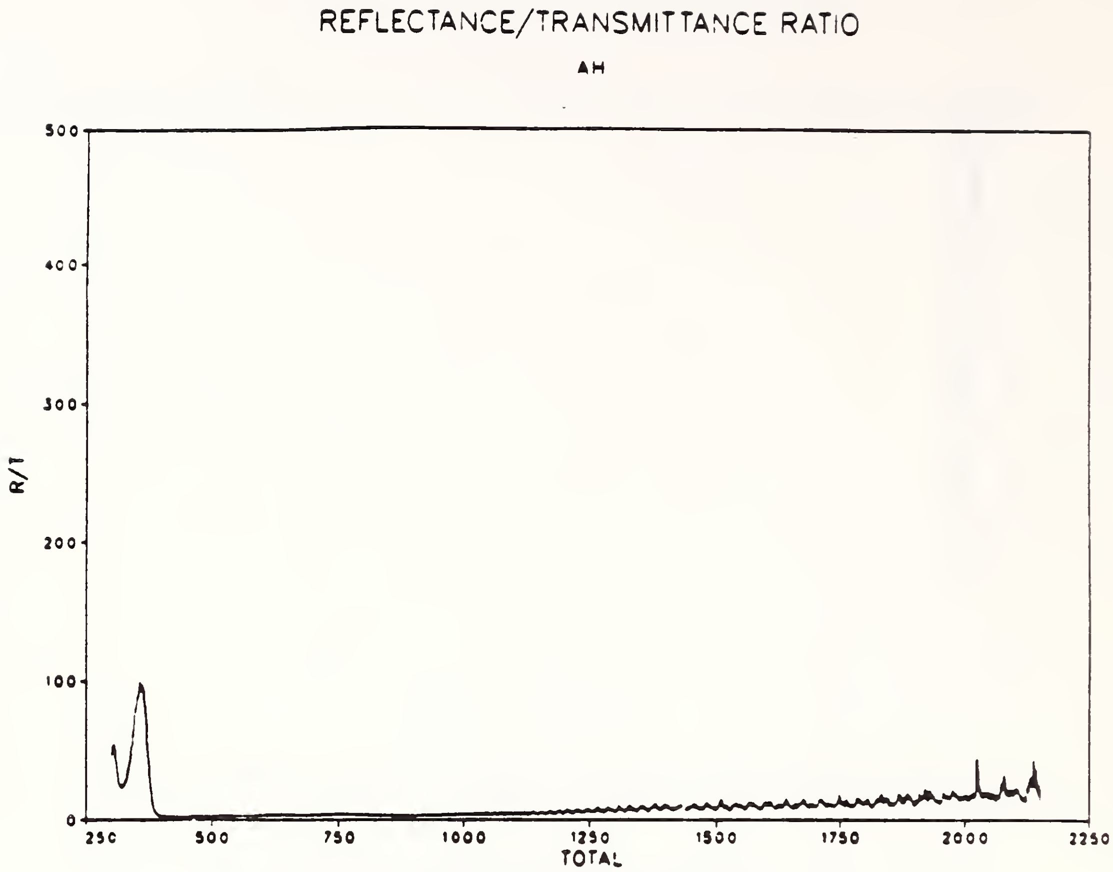


Figure 6.39 Sample AG, Total and visible ρ/τ versus wavelength



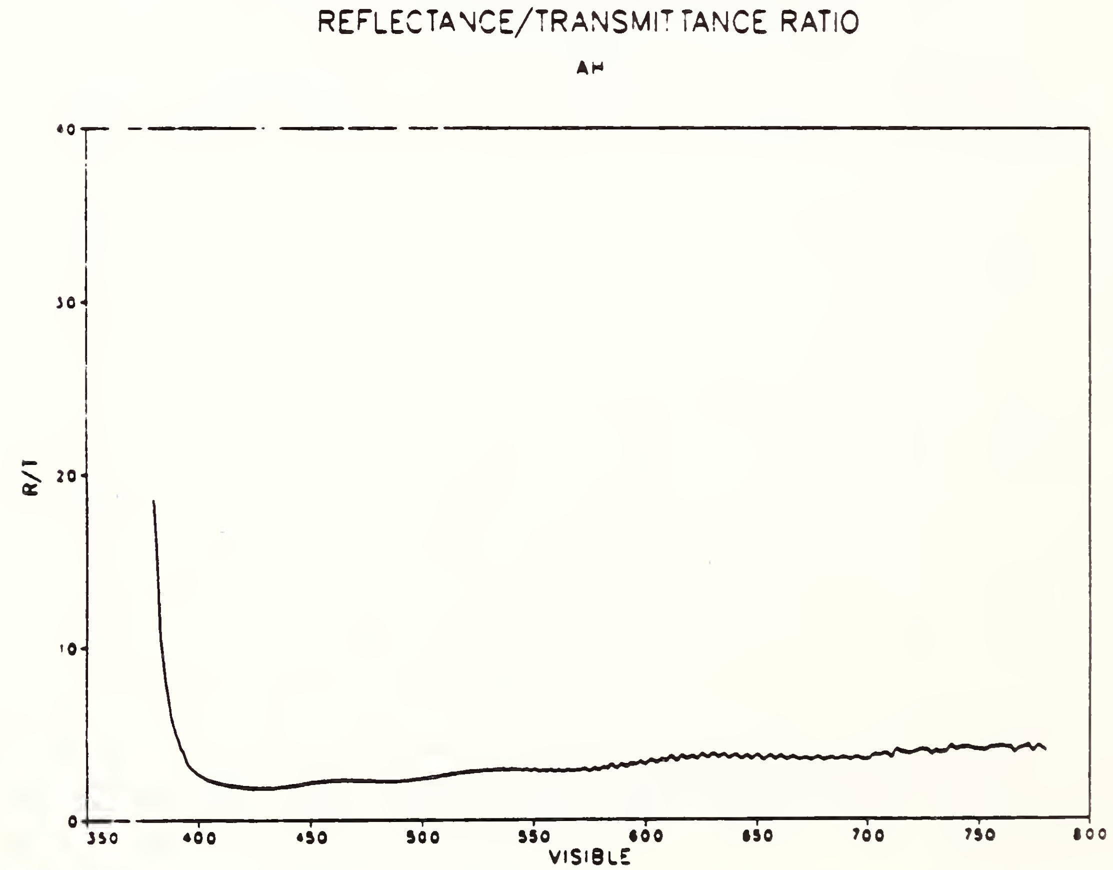


Figure 6.40 Sample AH, Total and visible ρ/τ versus wavelength

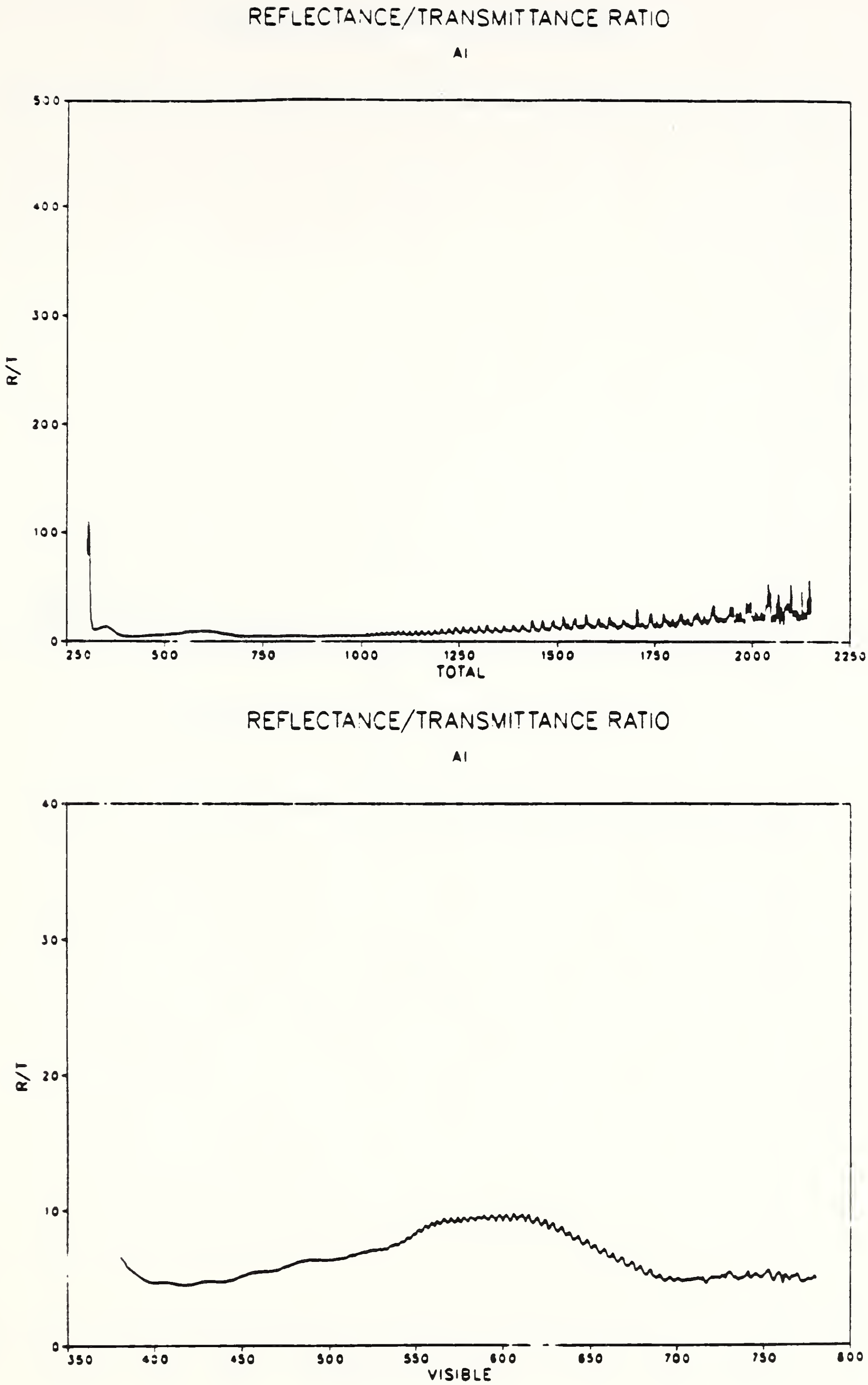
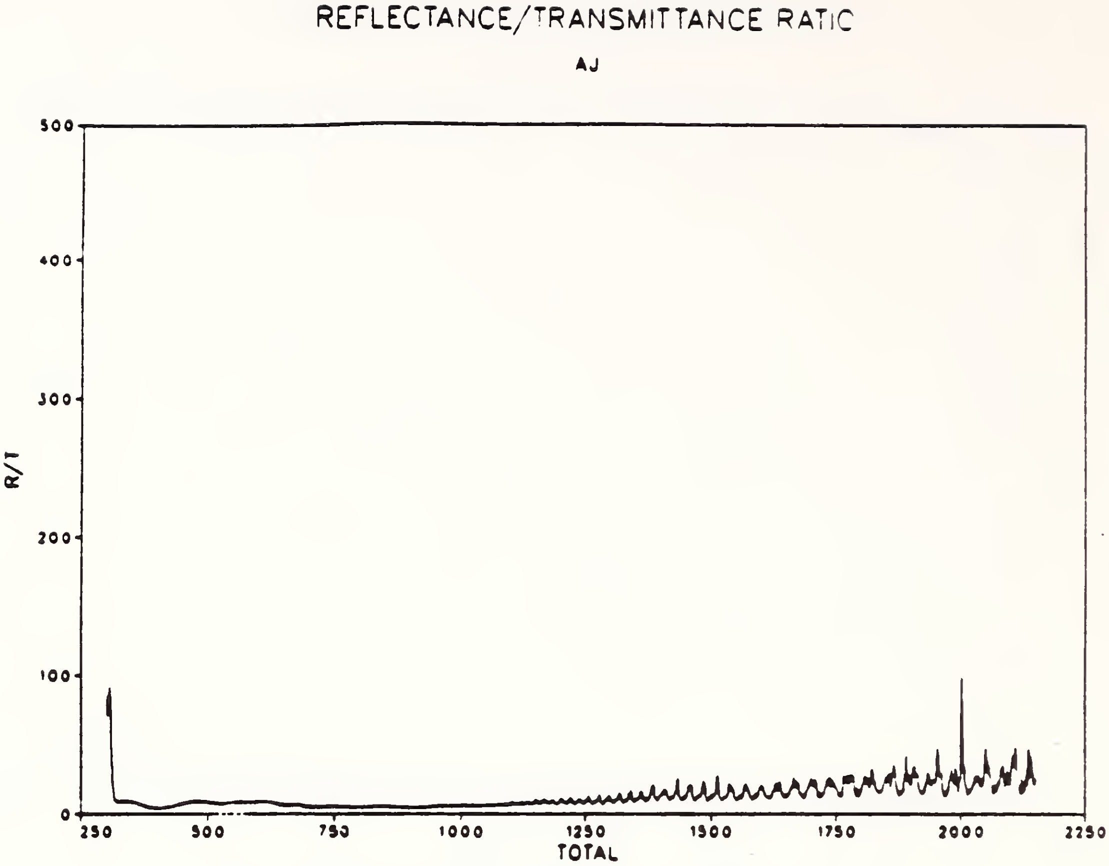


Figure 6.41 Sample AI, Total and visible ρ/τ versus wavelength



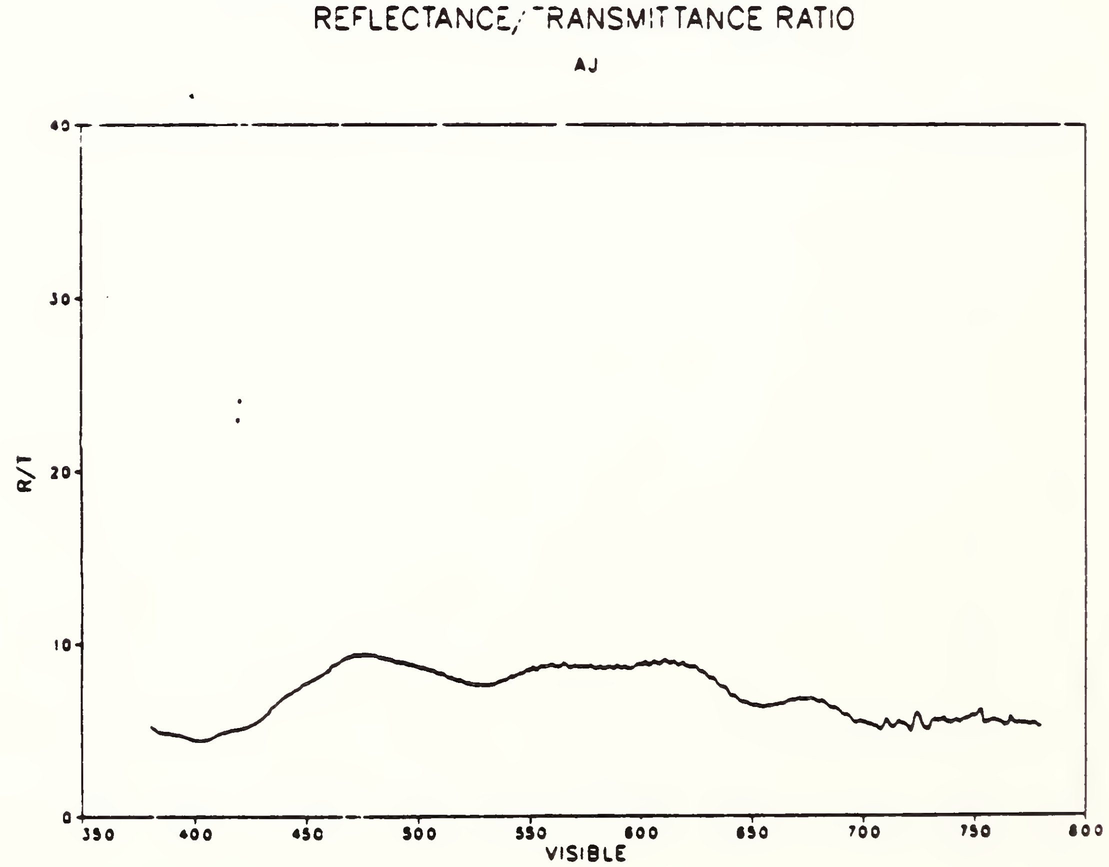


Figure 6.42 Sample AJ, Total and visible ρ/τ versus wavelength

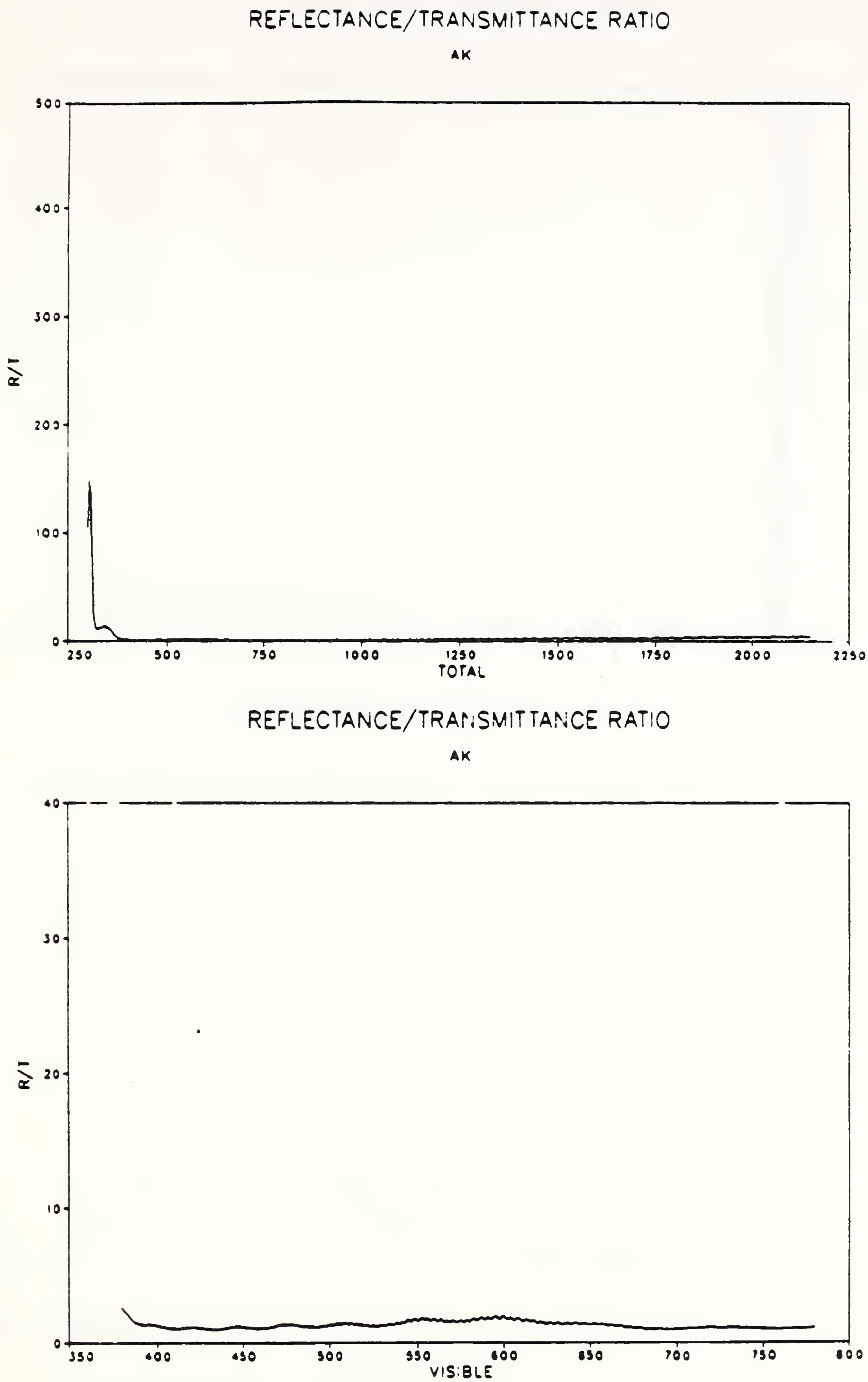


Figure 6.43 Sample AK, Total and visible ρ/τ versus wavelength

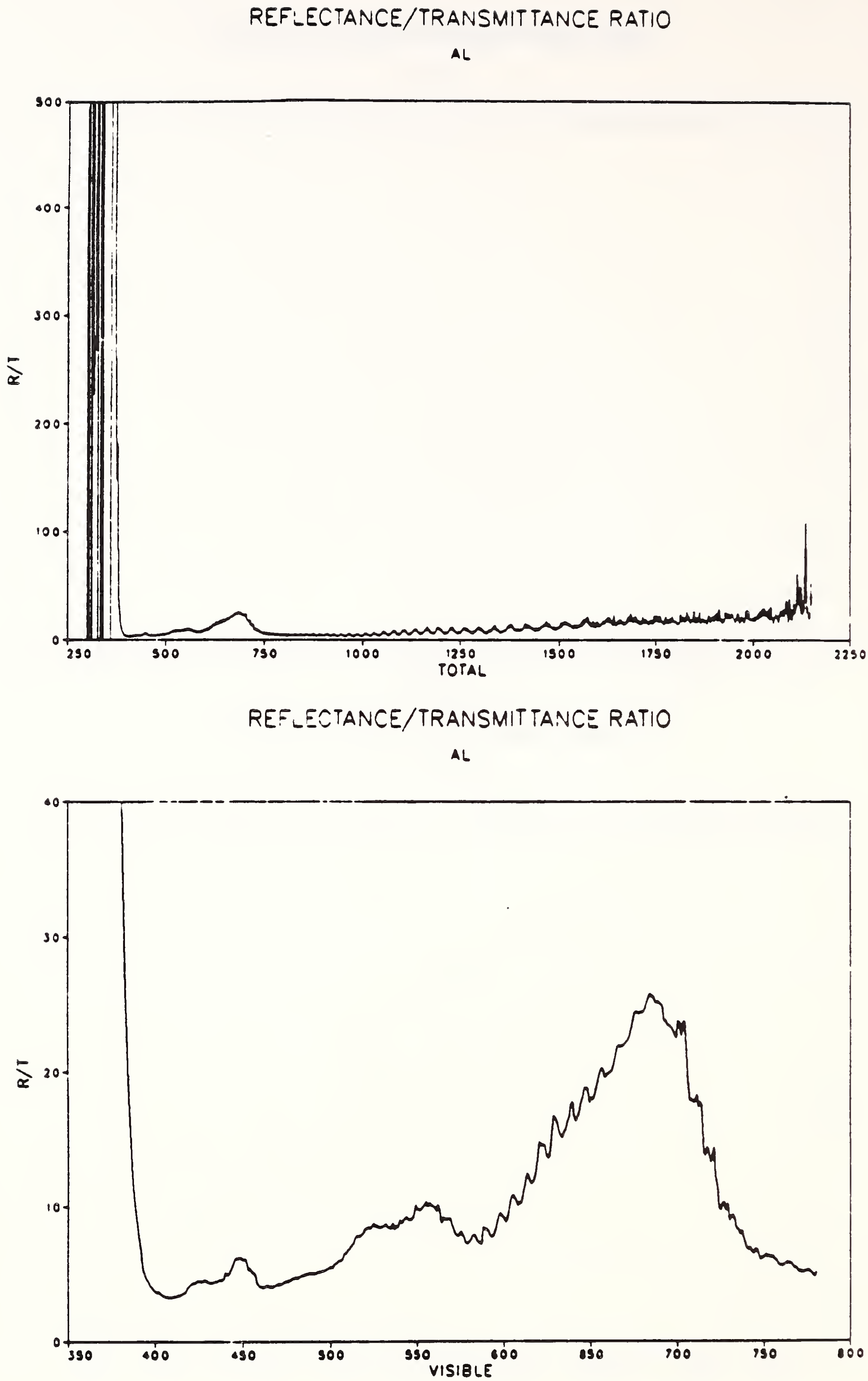


Figure 6.44 Sample AL, Total and visible ρ/τ versus wavelength

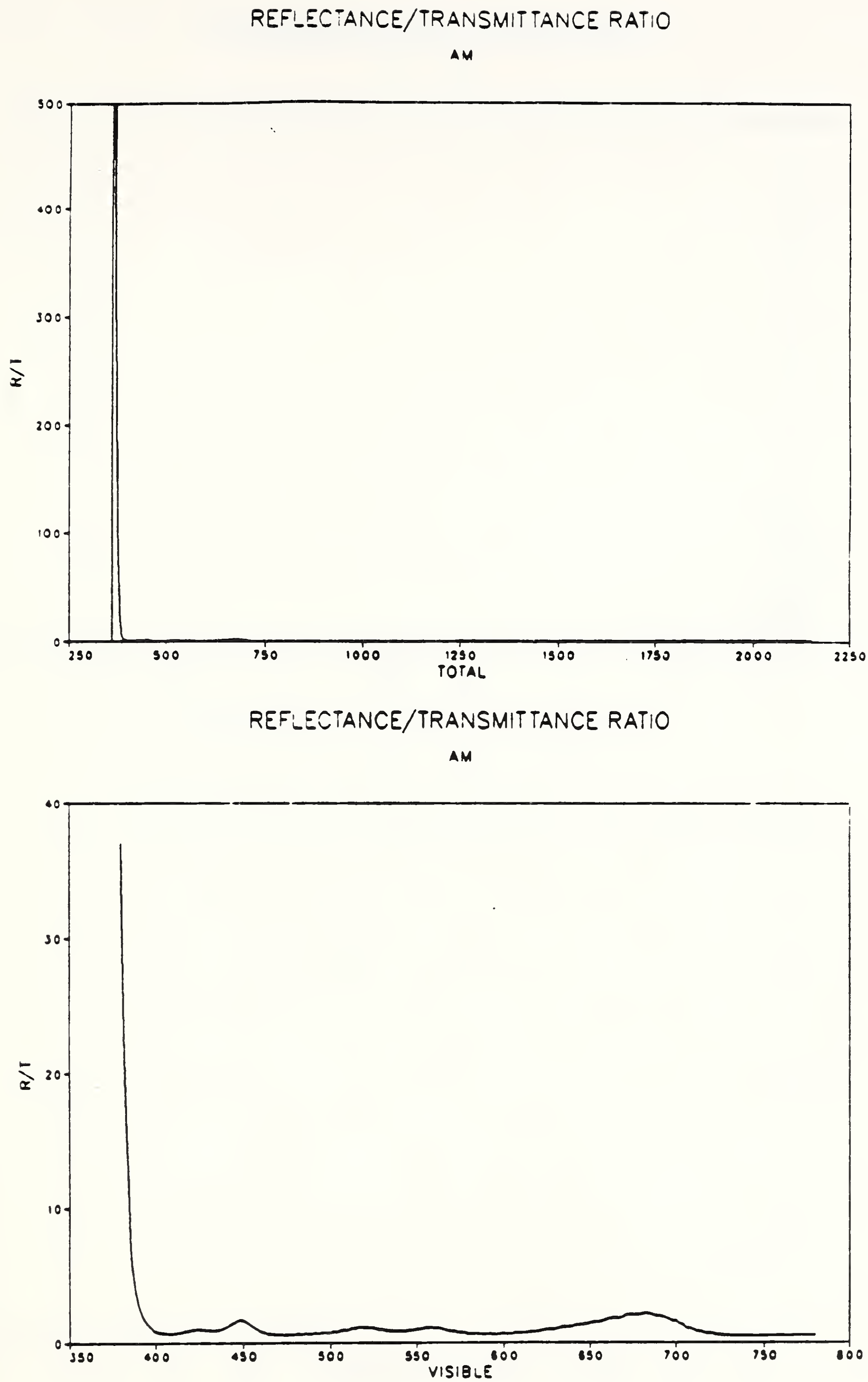
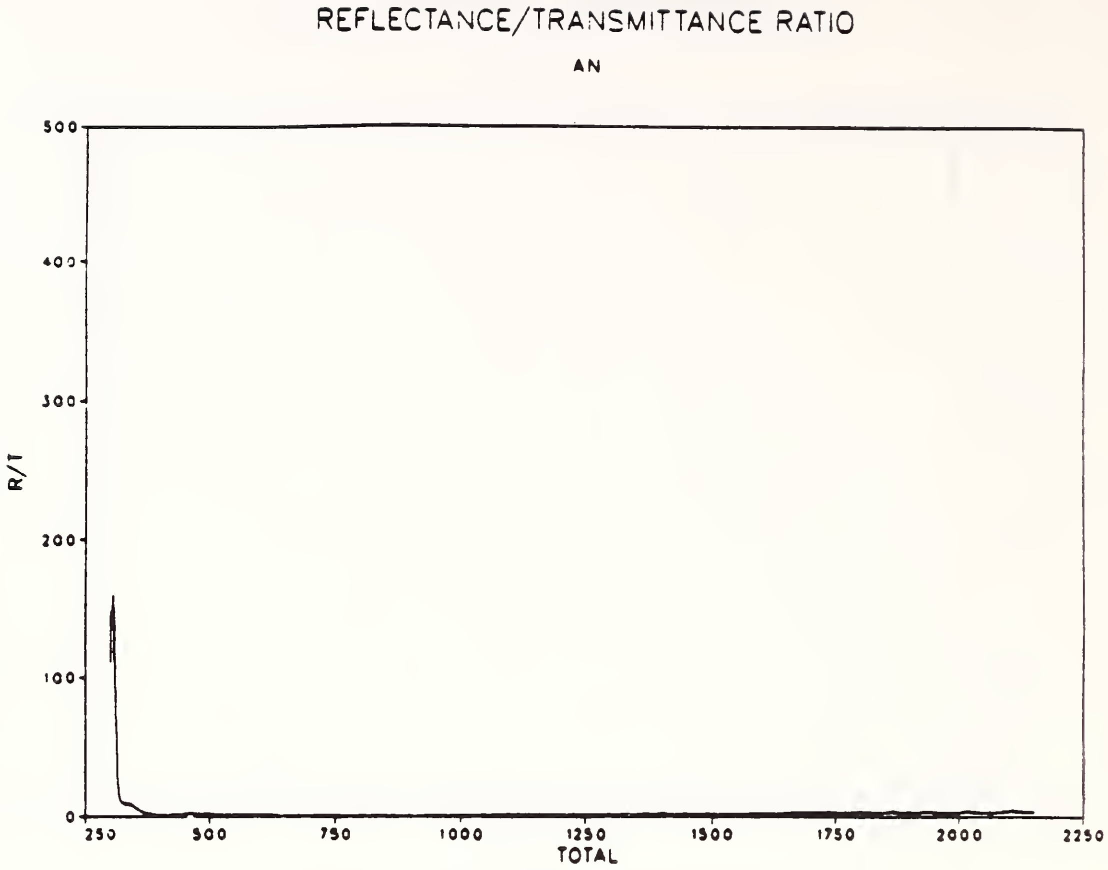


Figure 6.45 Sample AM, Total and visible ρ/τ versus wavelength



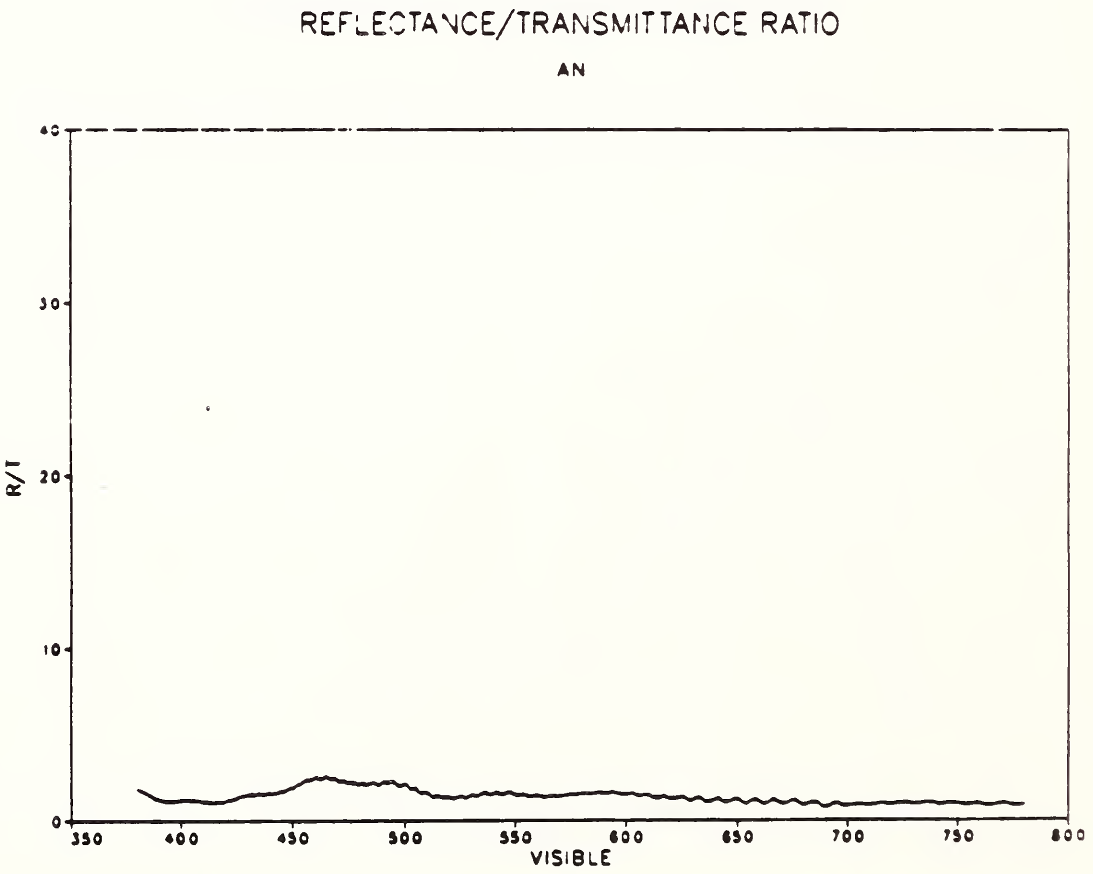


Figure 6.46 Sample AN, Total and visible ρ/τ versus wavelength

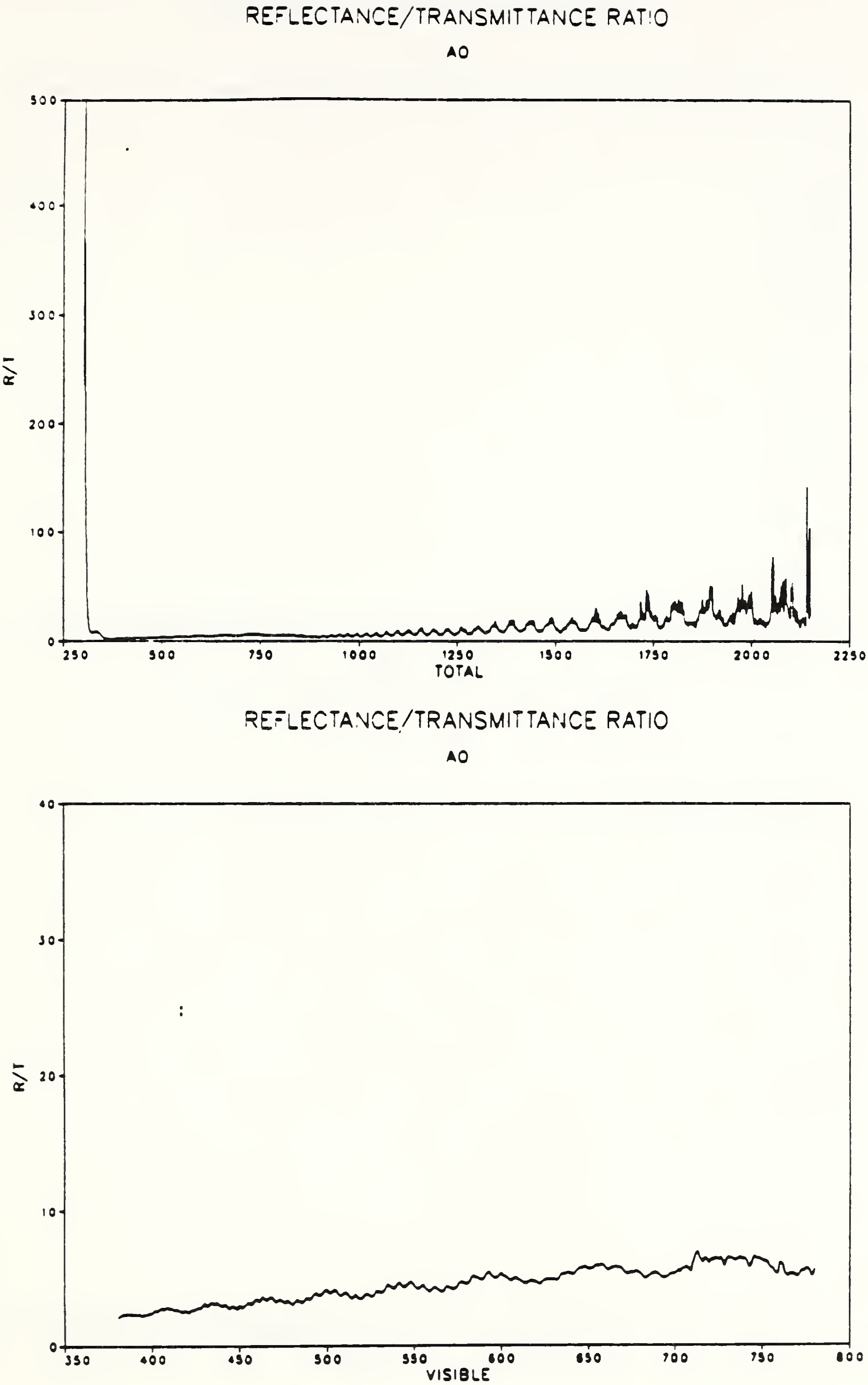


Figure 6.47 Sample AO, Total and visible ρ/τ versus wavelength

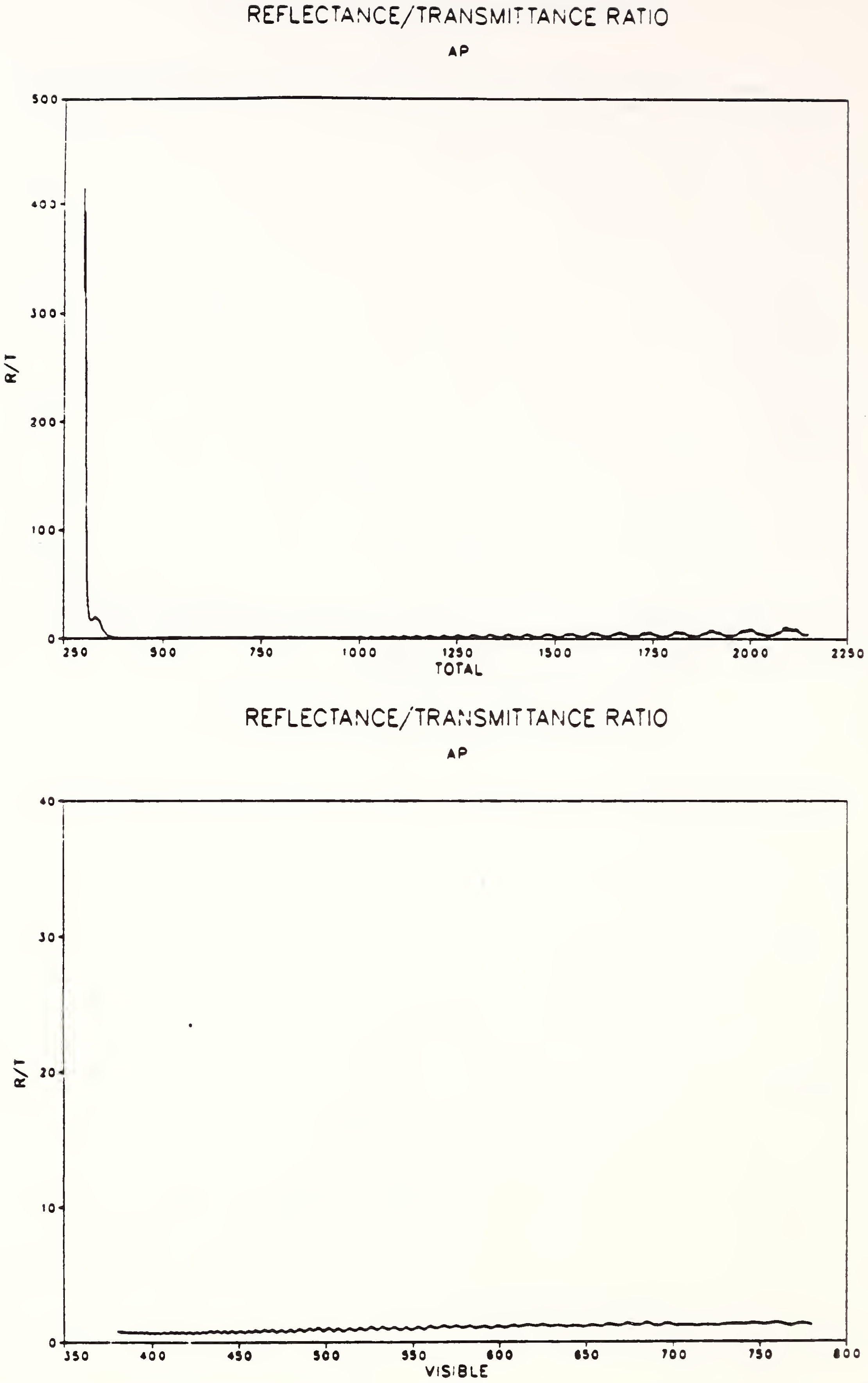
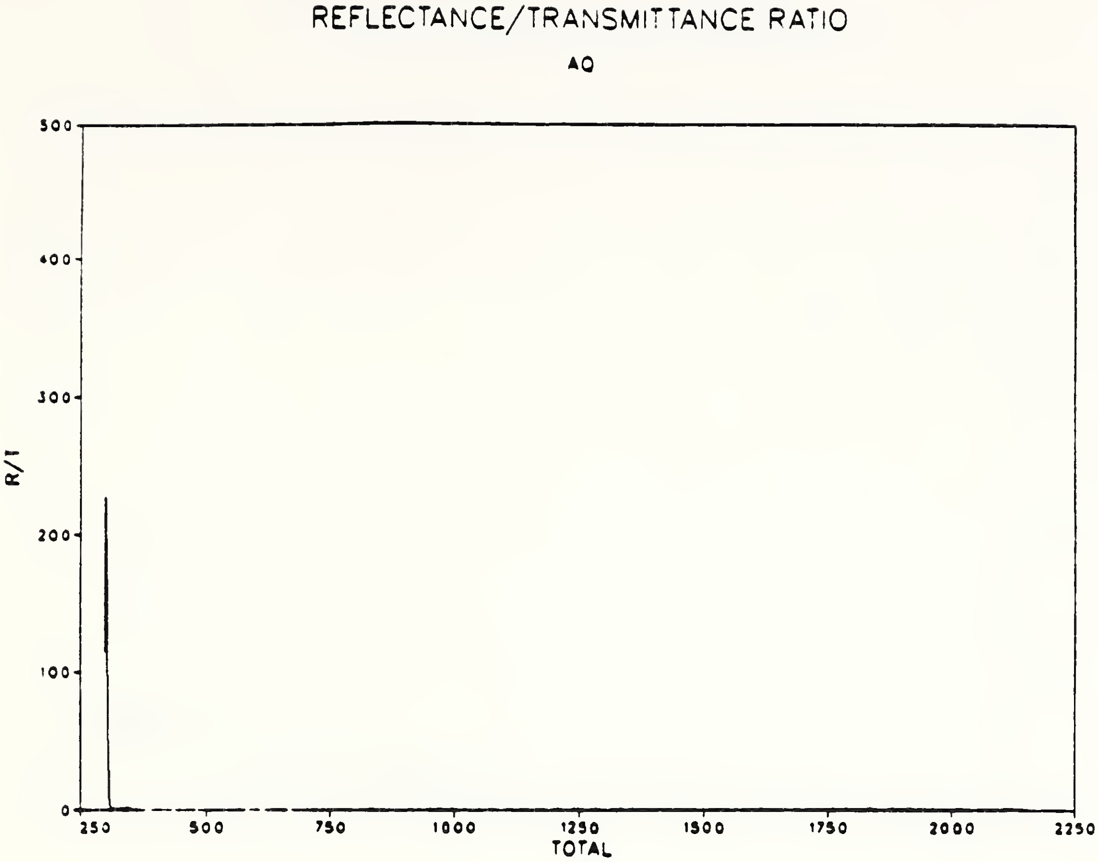


Figure 6.48 Sample AP, Total and visible ρ/τ versus wavelength



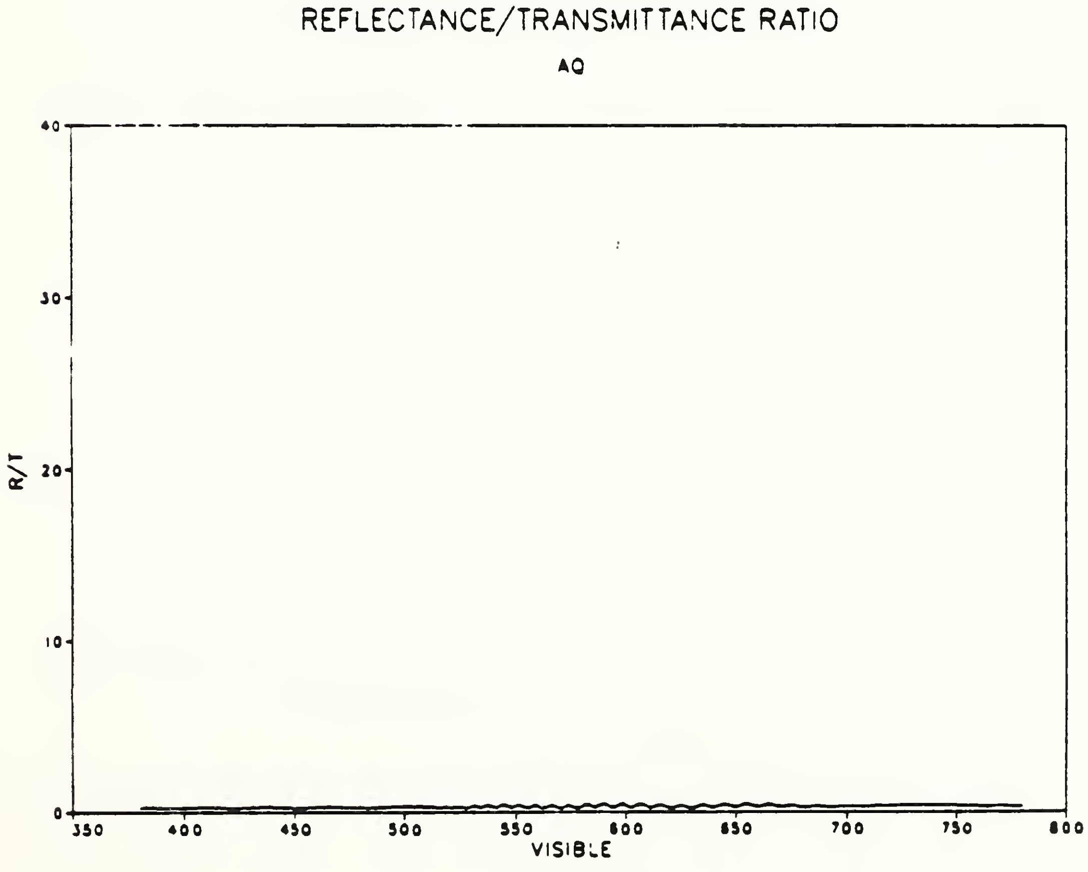
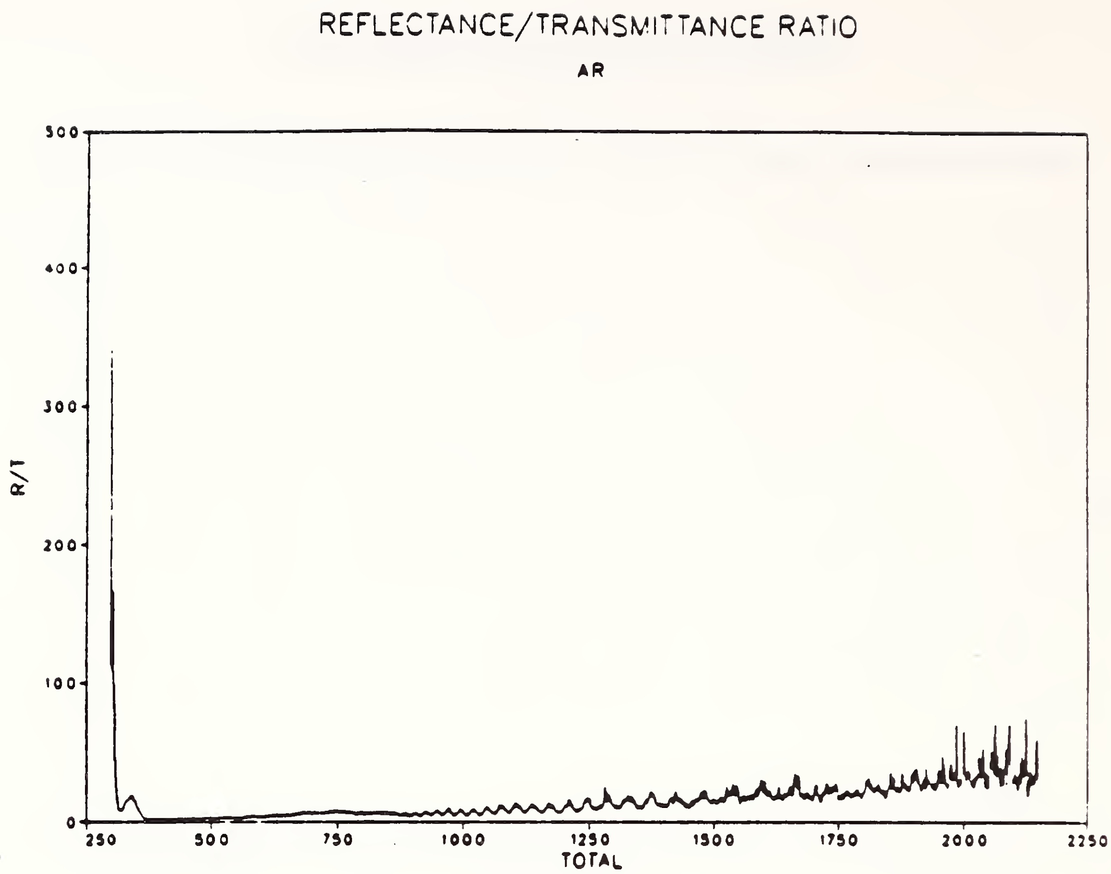


Figure 6.49 Sample AQ, Total and visible ρ/τ versus wavelength



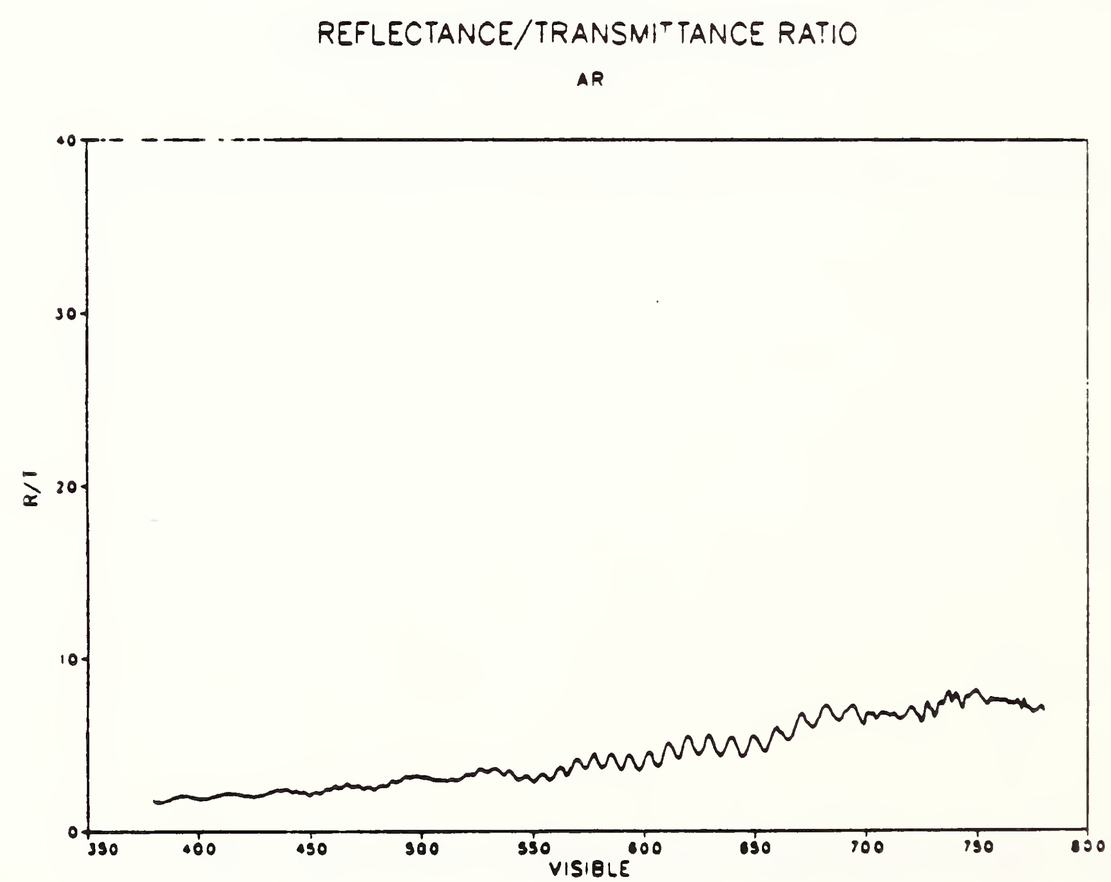
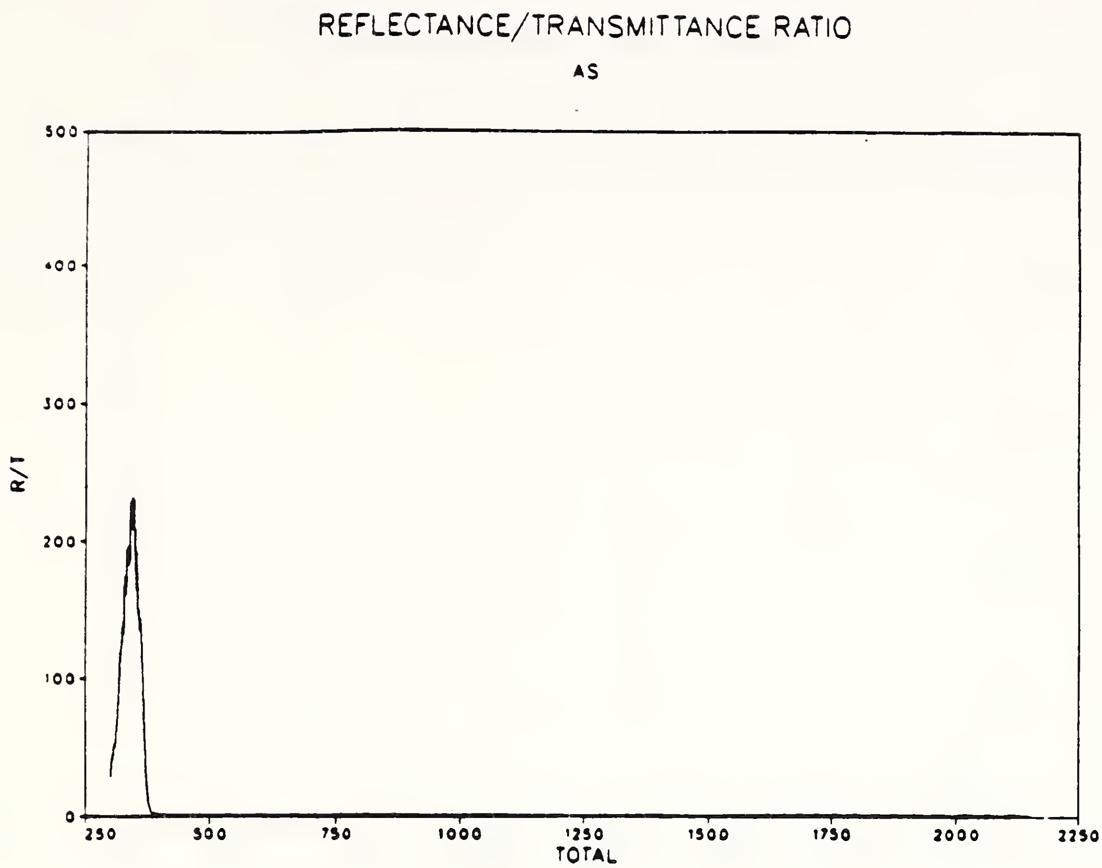


Figure 6.50 Sample AR, Total and visible ρ/τ versus wavelength



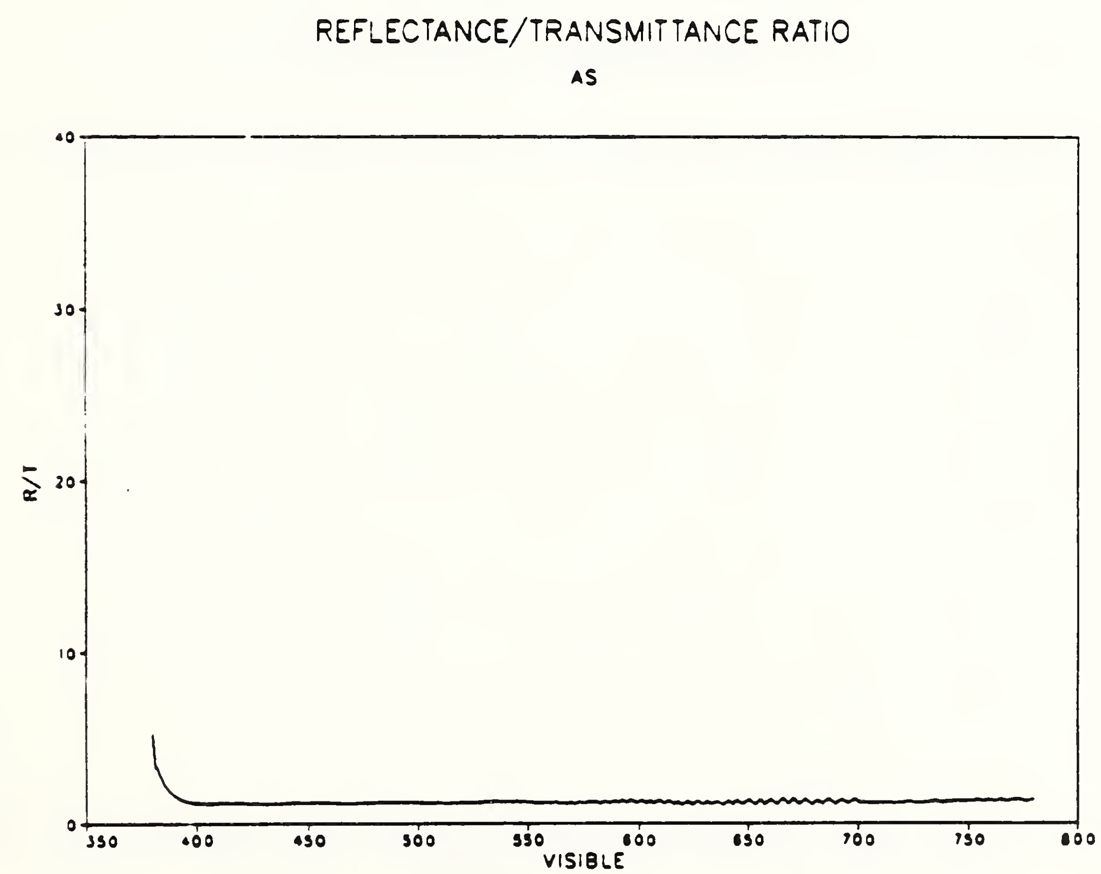


Figure 6.51 Sample AS, Total and visible ρ/τ versus wavelength

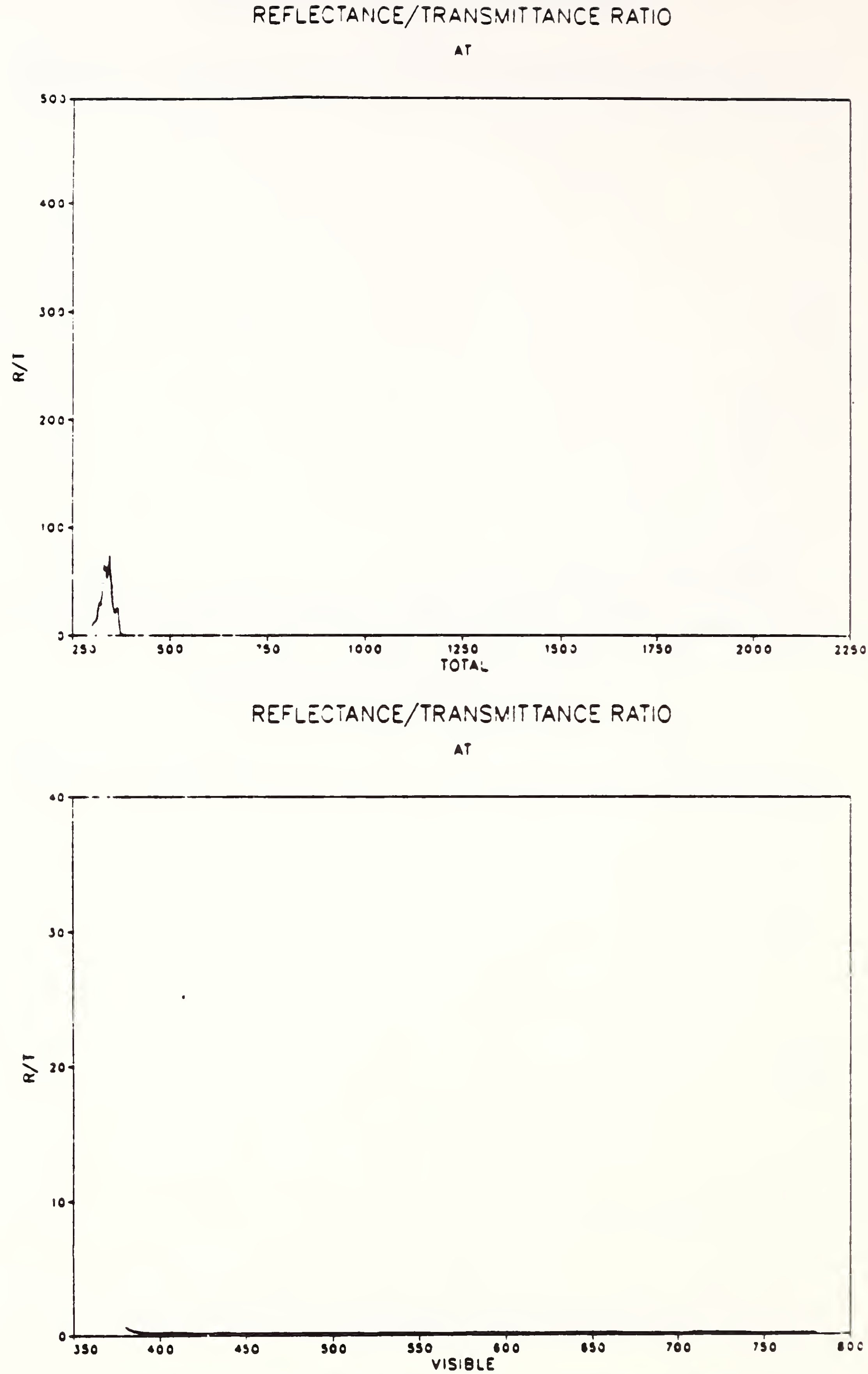


Figure 6.52 Sample AT, Total and visible ρ/τ versus wavelength

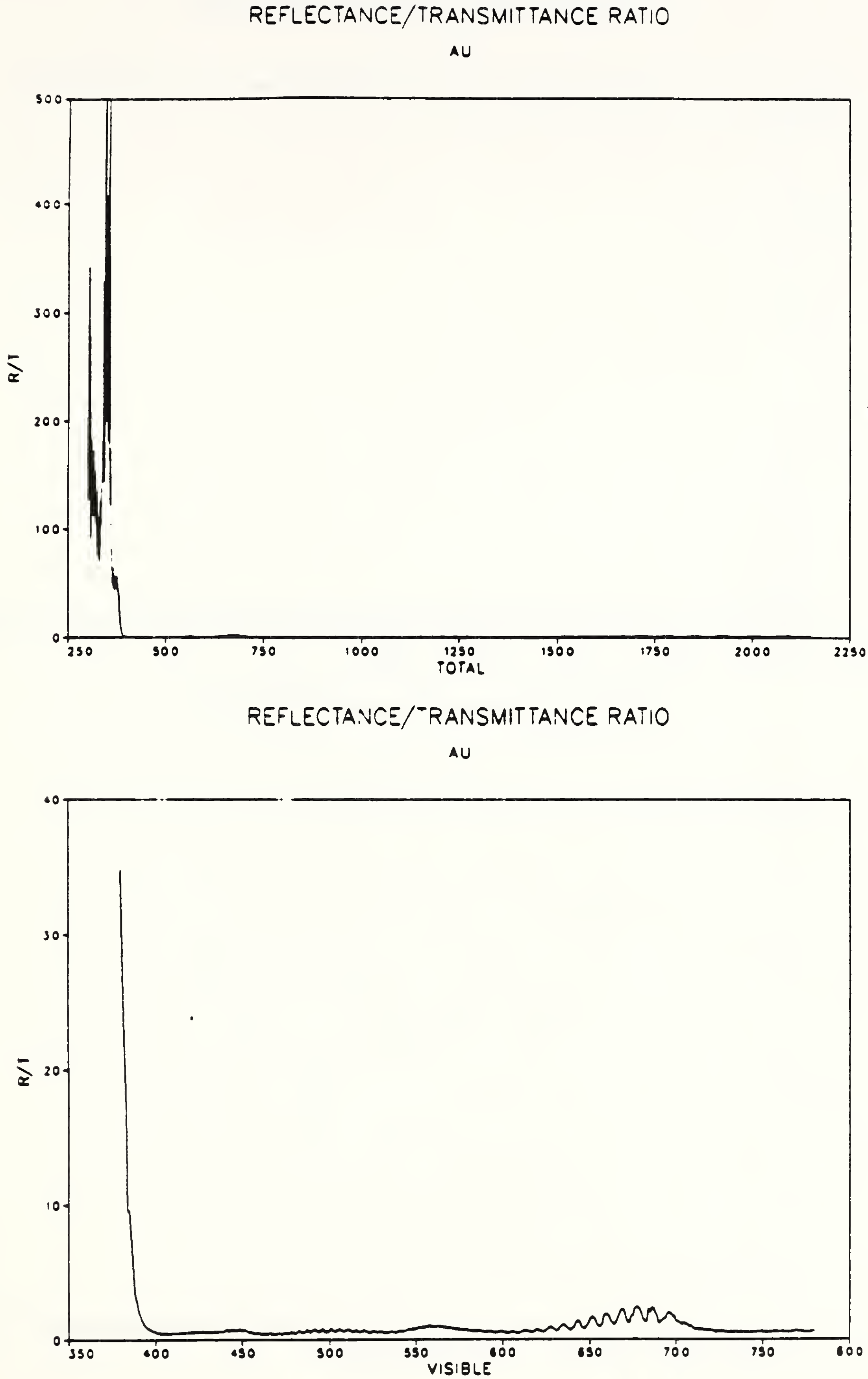
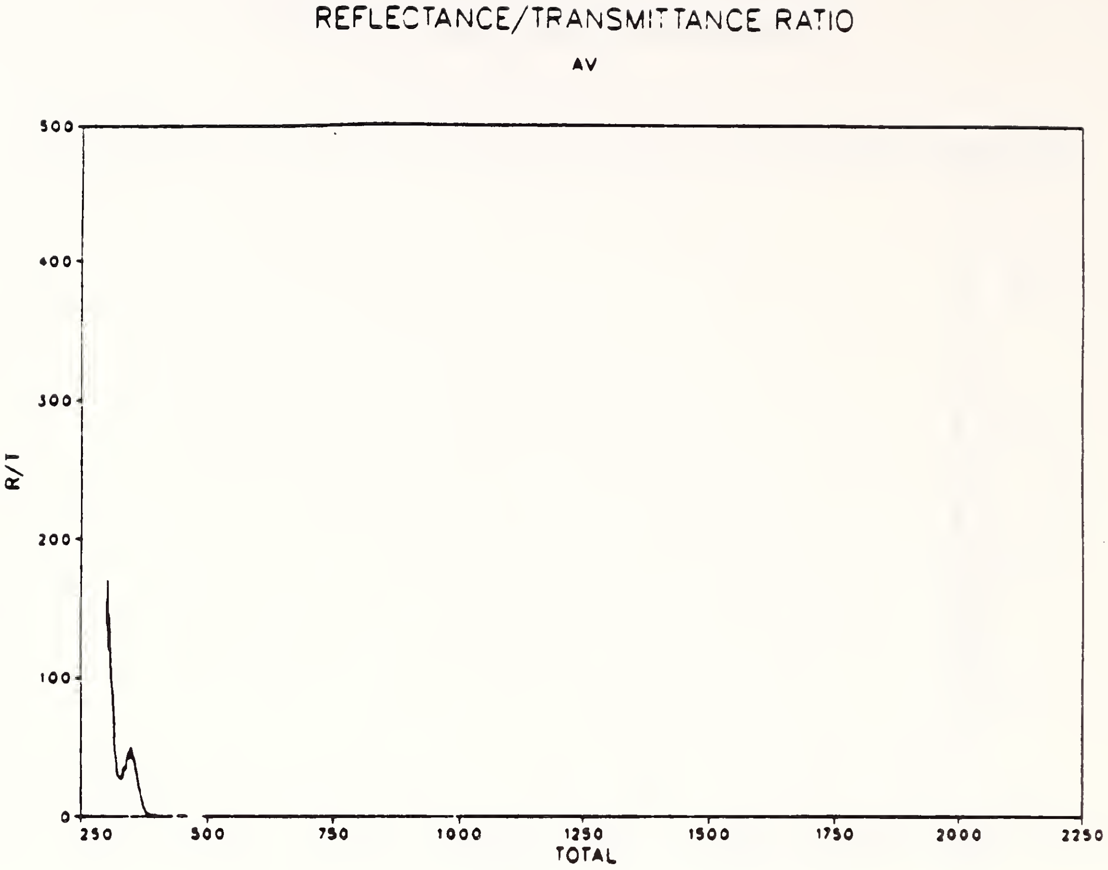


Figure 6.53 Sample AU, Total and visible ρ/τ versus wavelength



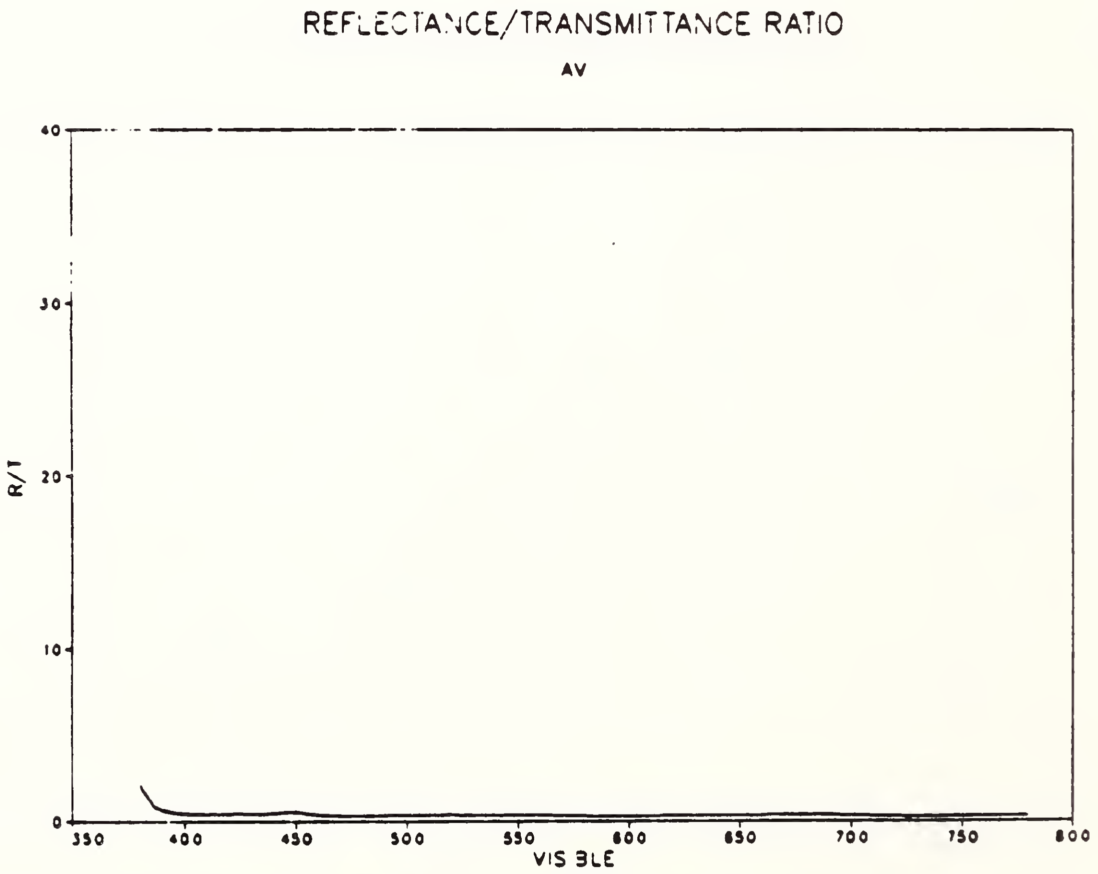
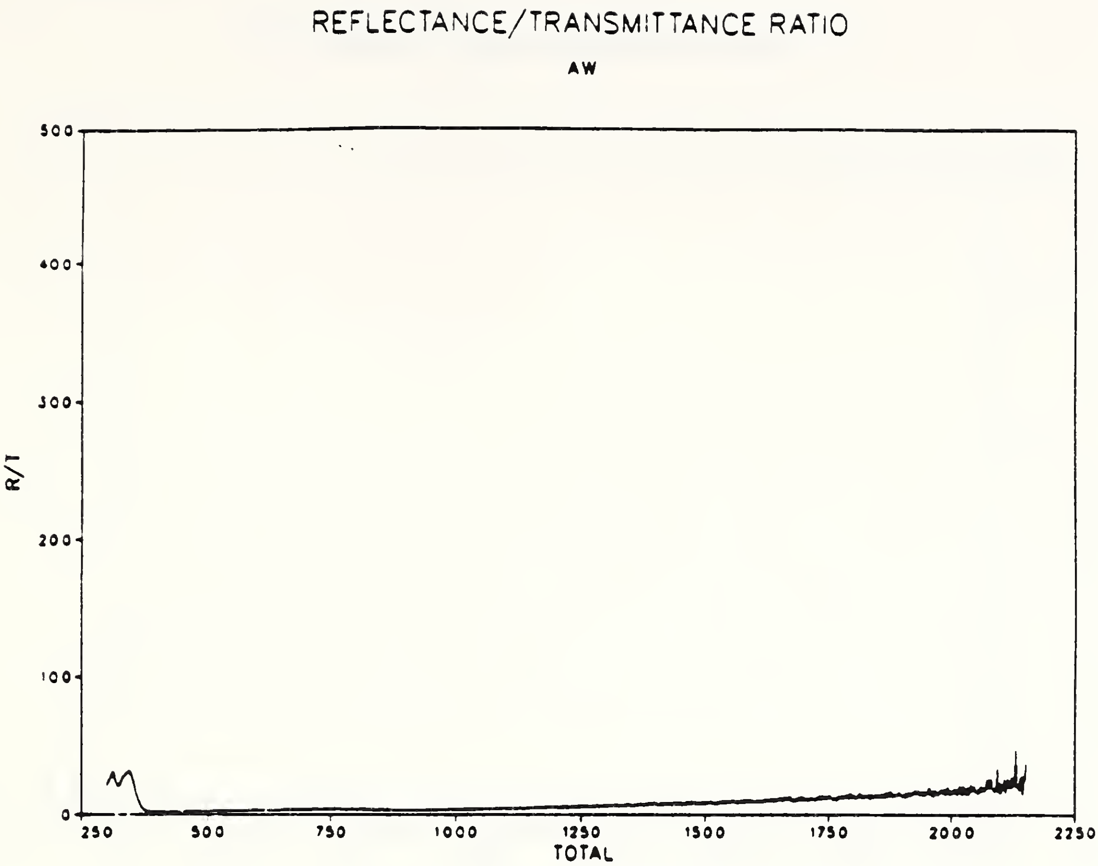


Figure 6.54 Sample AV, Total and visible ρ/τ versus wavelength



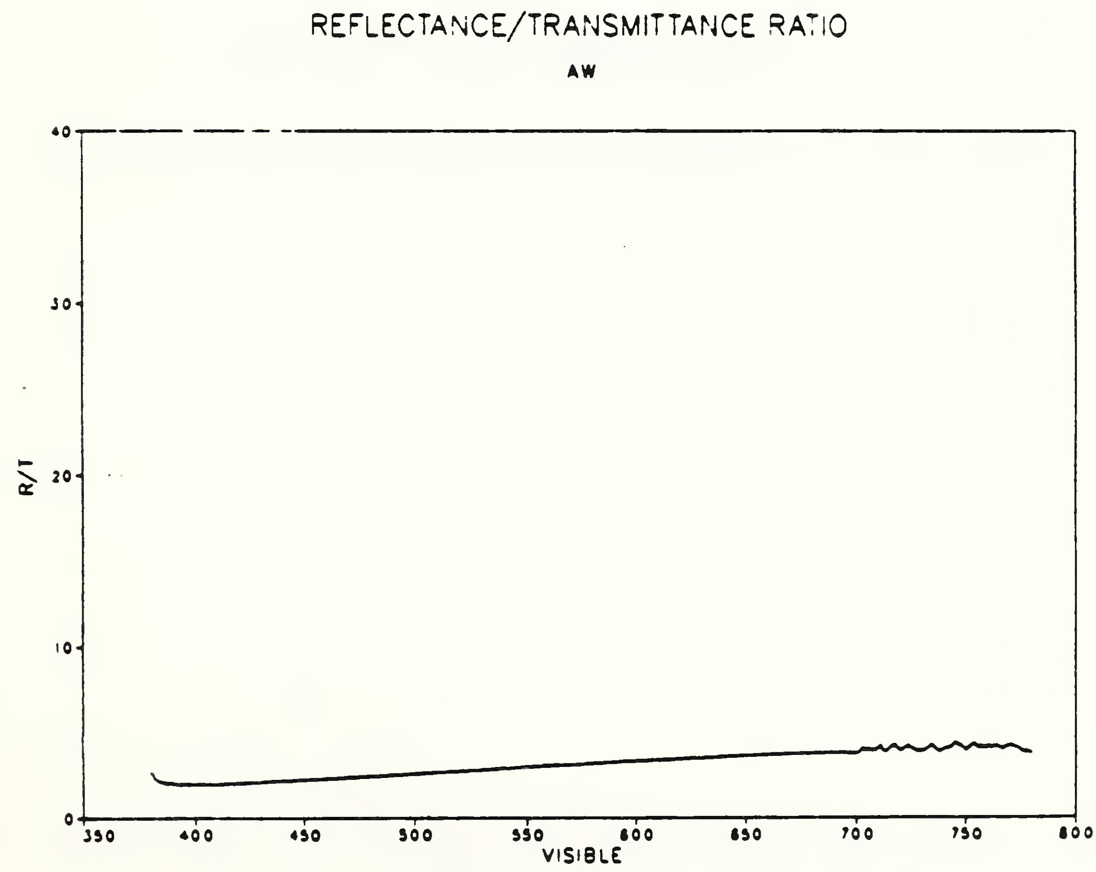
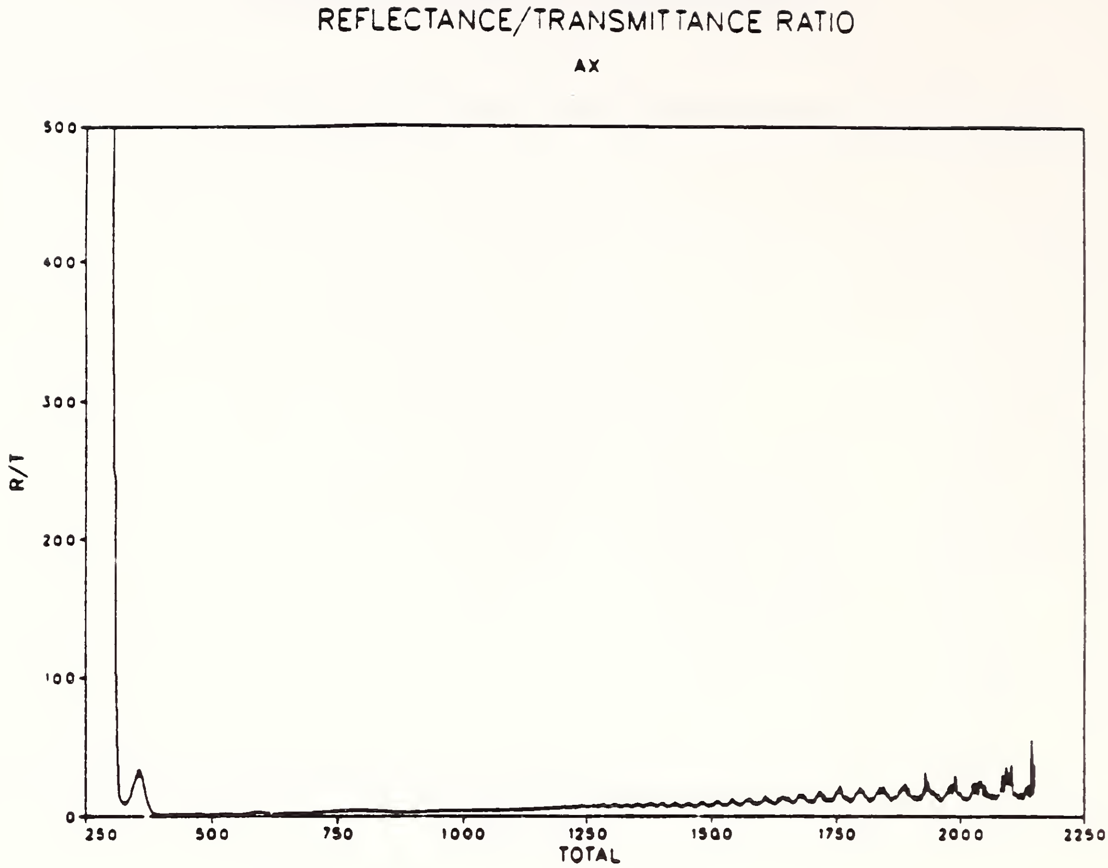


Figure 6.55 Sample AW, Total and visible ρ/τ versus wavelength



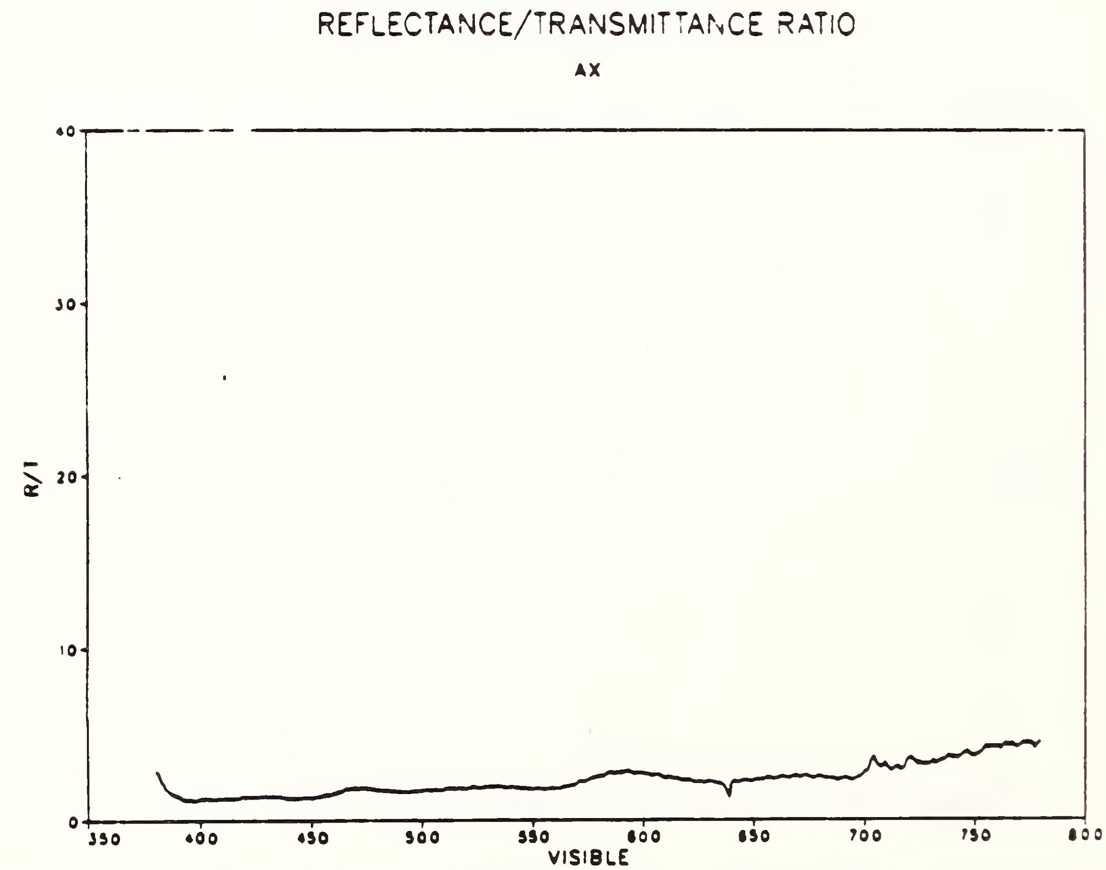


Figure 6.56 Sample AX, Total and visible ρ/τ versus wavelength

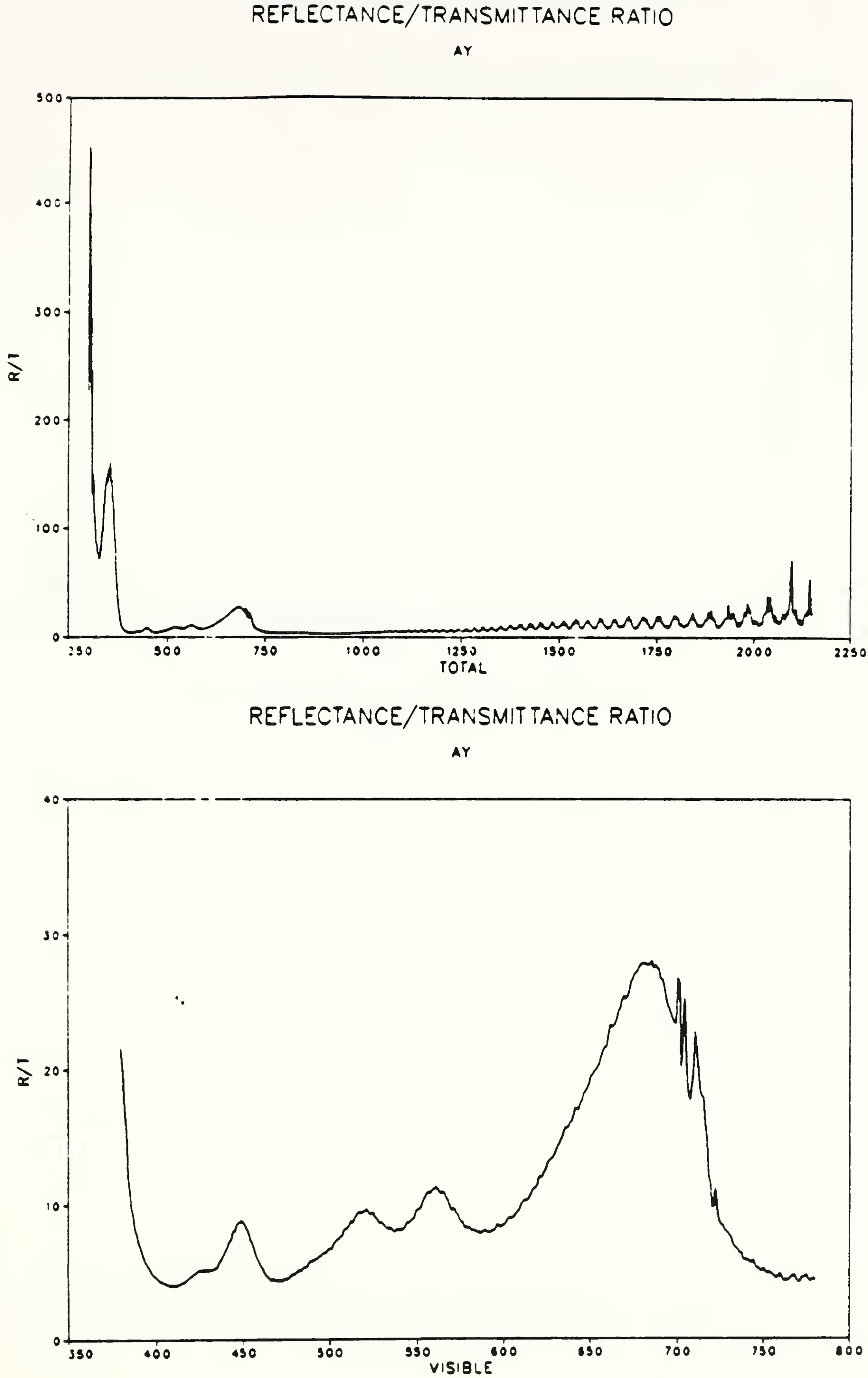
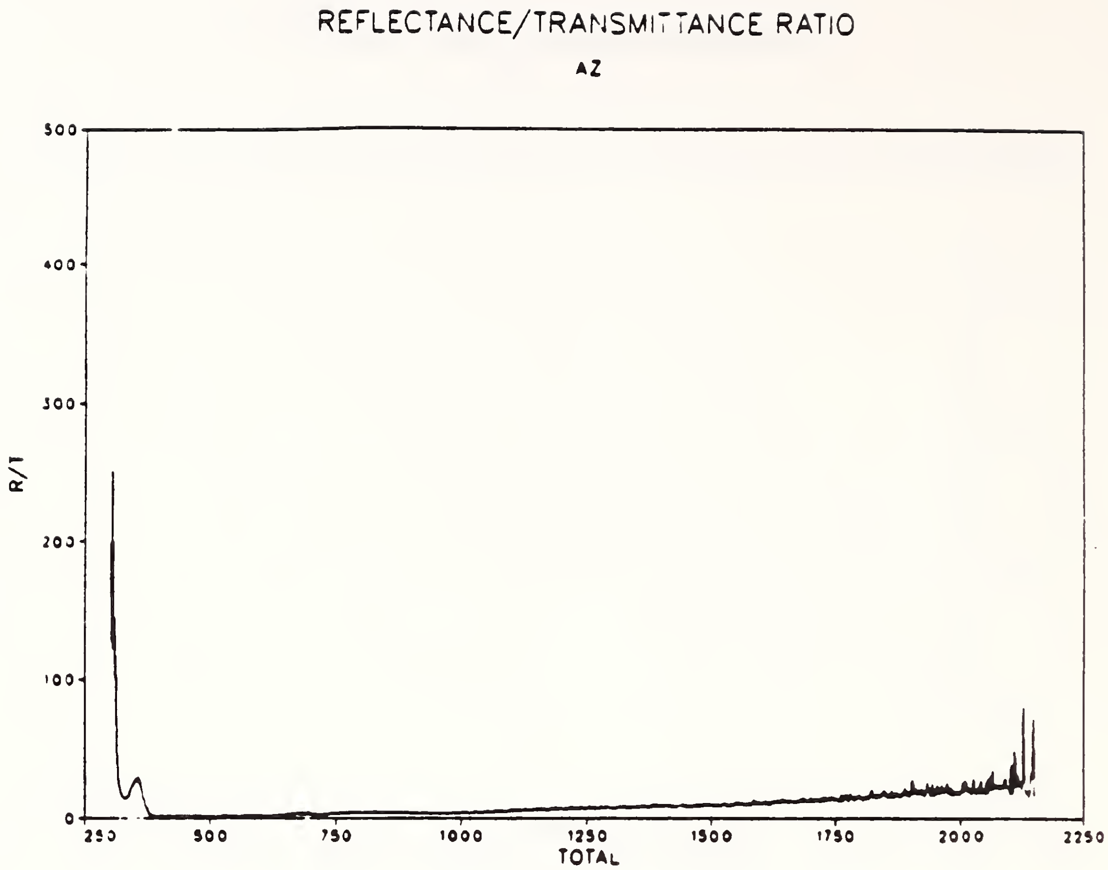


Figure 6.57 Sample AY, Total and visible ρ/τ versus wavelength



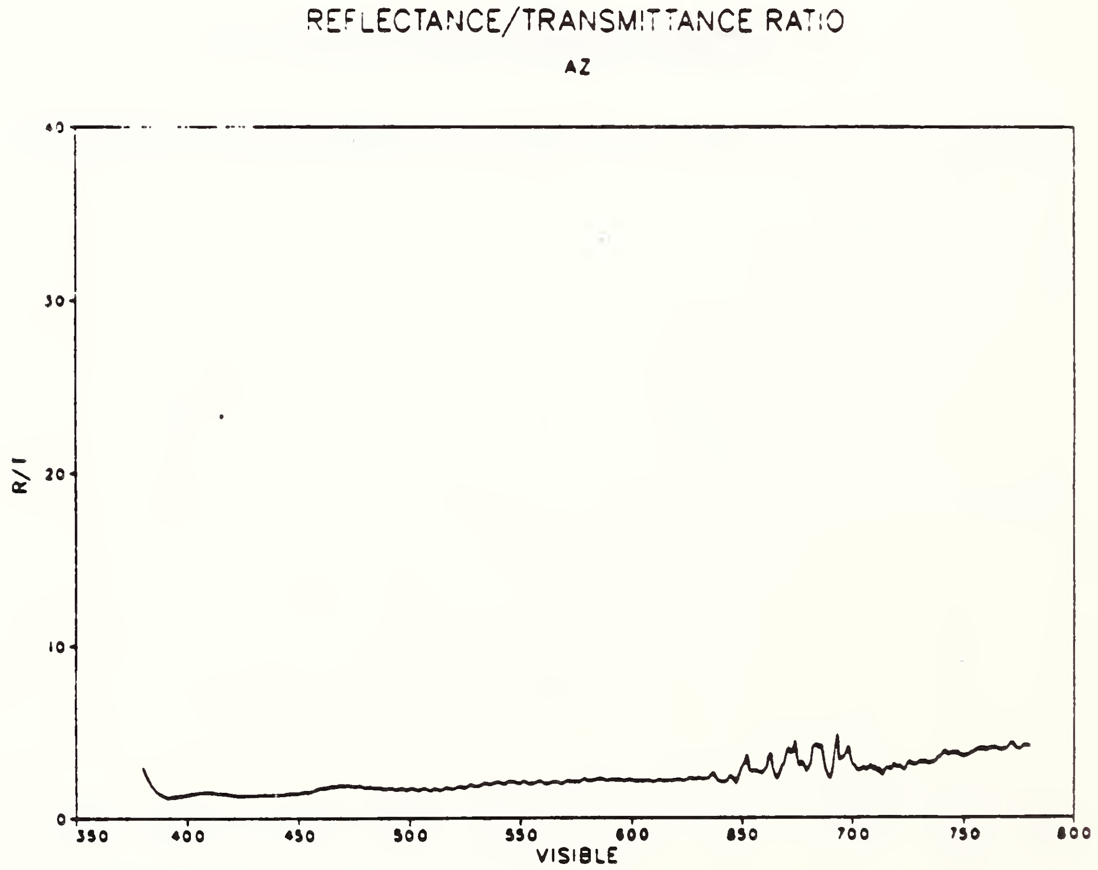


Figure 6.58 Sample AZ, Total and visible ρ/τ versus wavelength

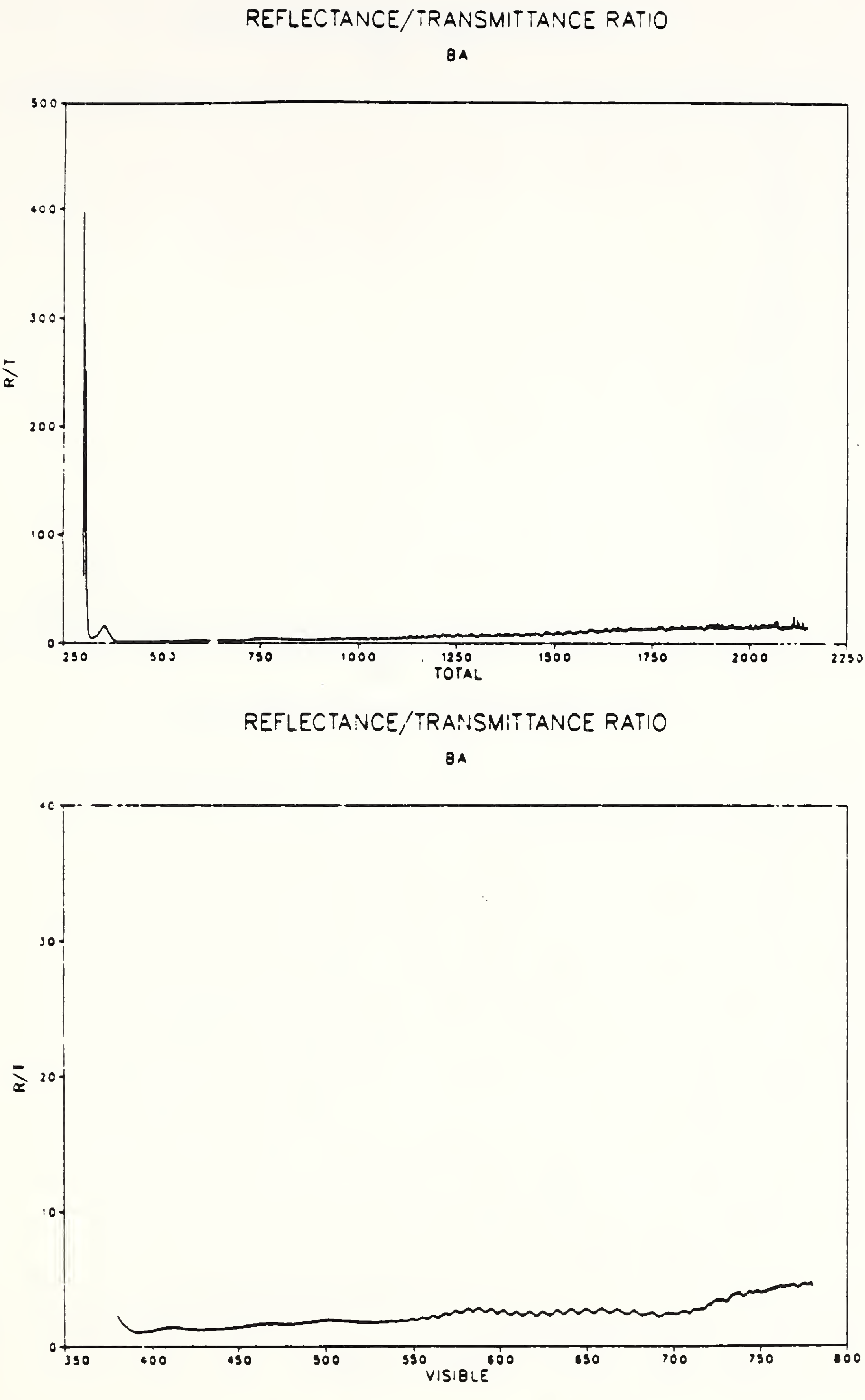


Figure 6.59 Sample BA, Total and visible ρ/τ versus wavelength

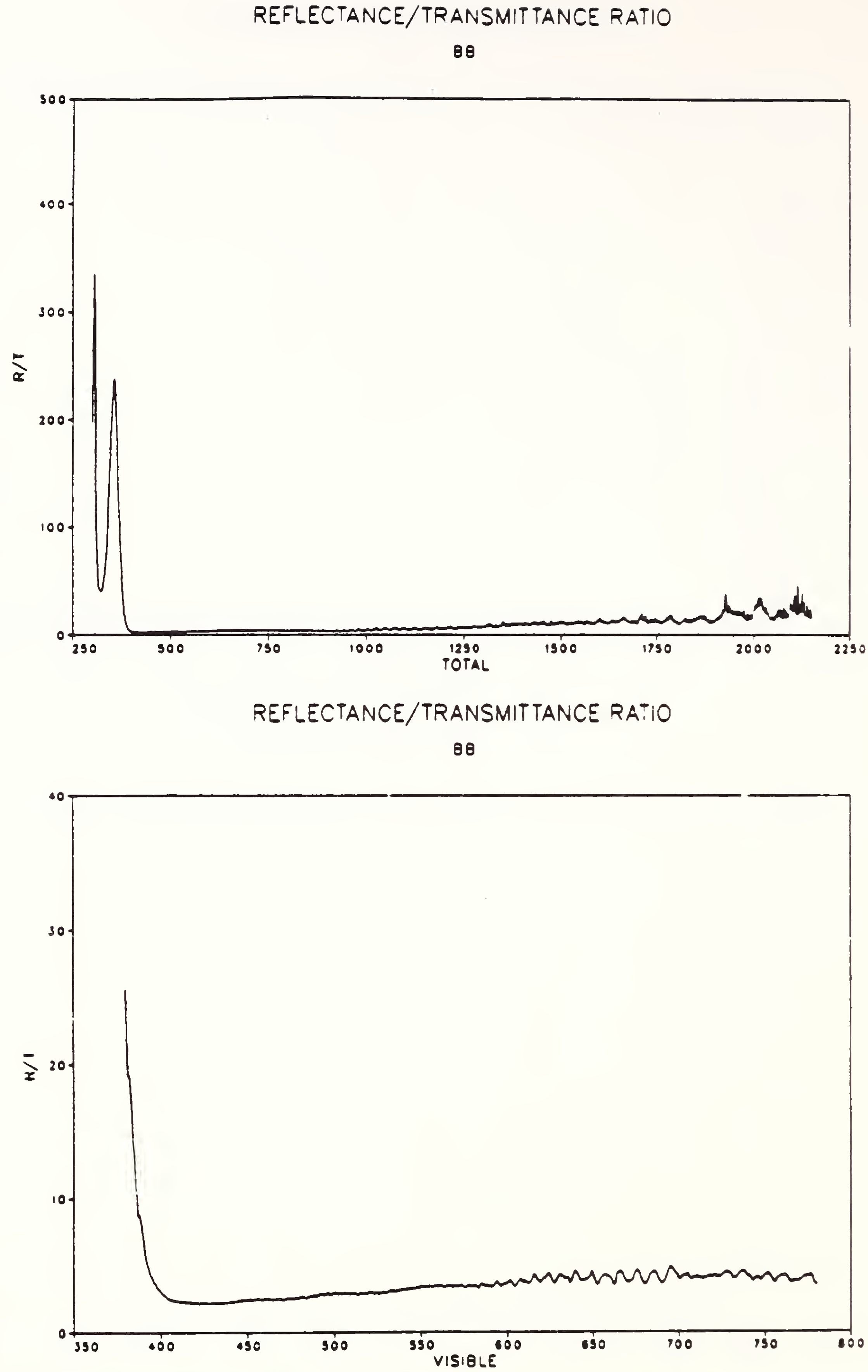


Figure 6.60 Sample BB, Total and visible ρ/τ versus wavelength

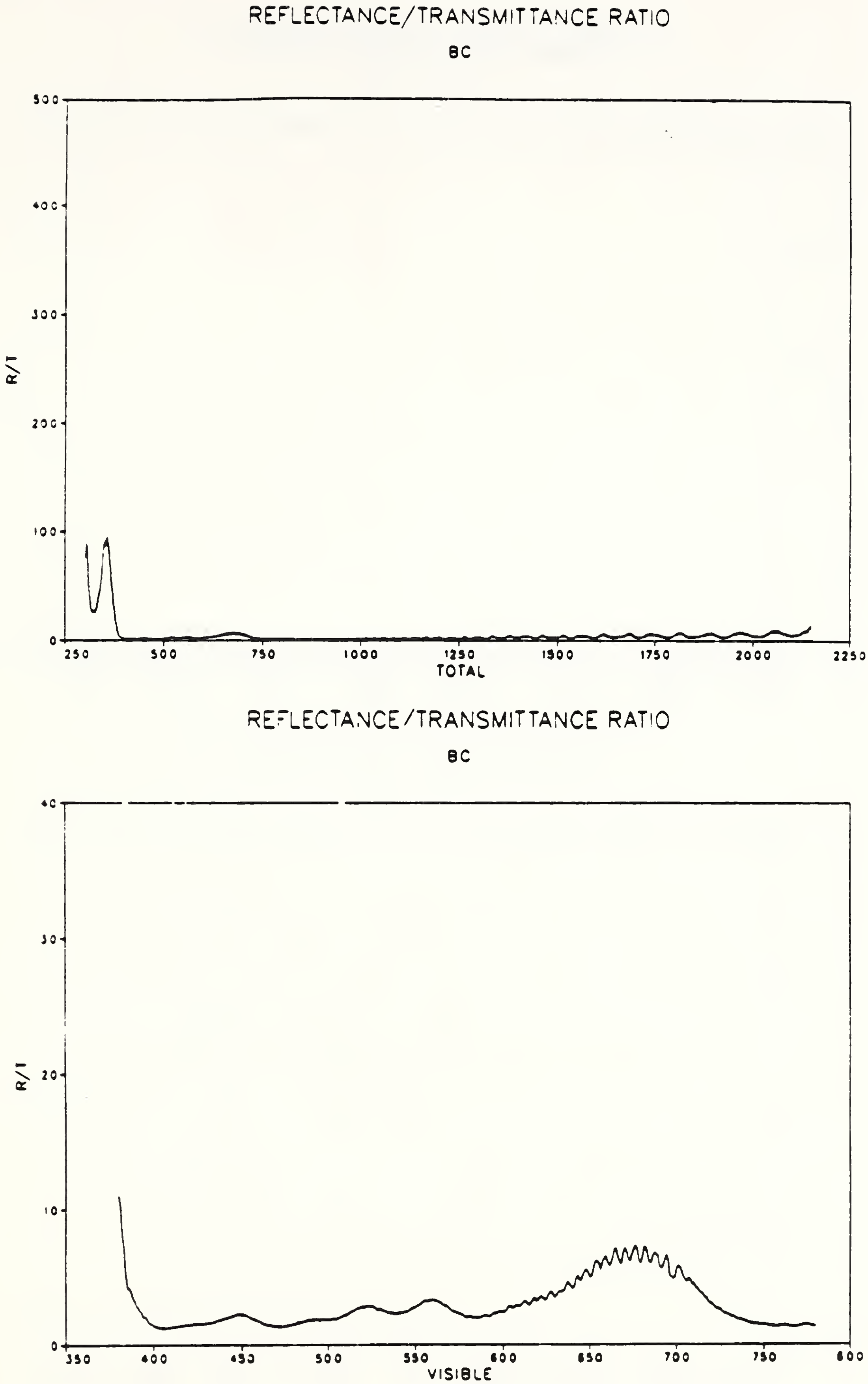


Figure 6.61 Sample BC, Total and visible ρ/τ versus wavelength

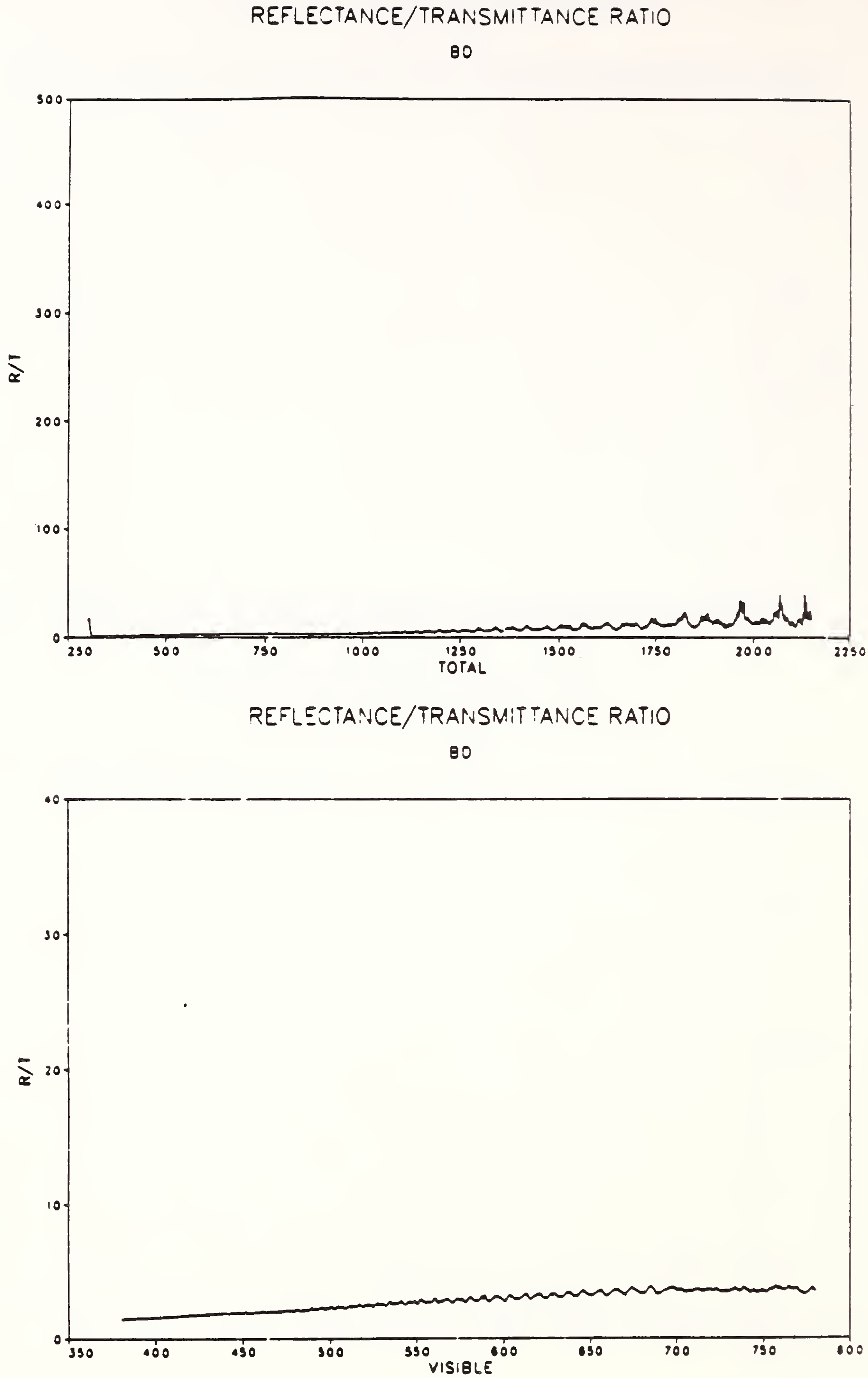
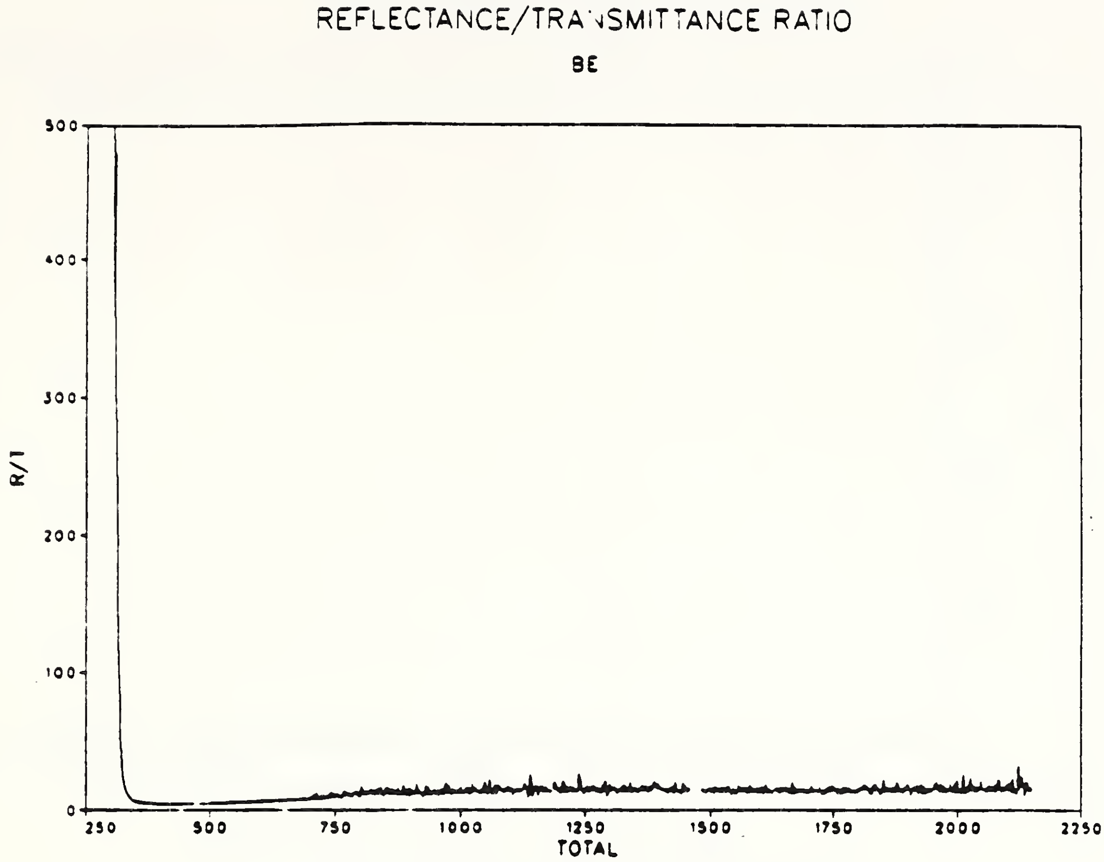


Figure 6.62 Sample BD, Total and visible ρ/τ versus wavelength



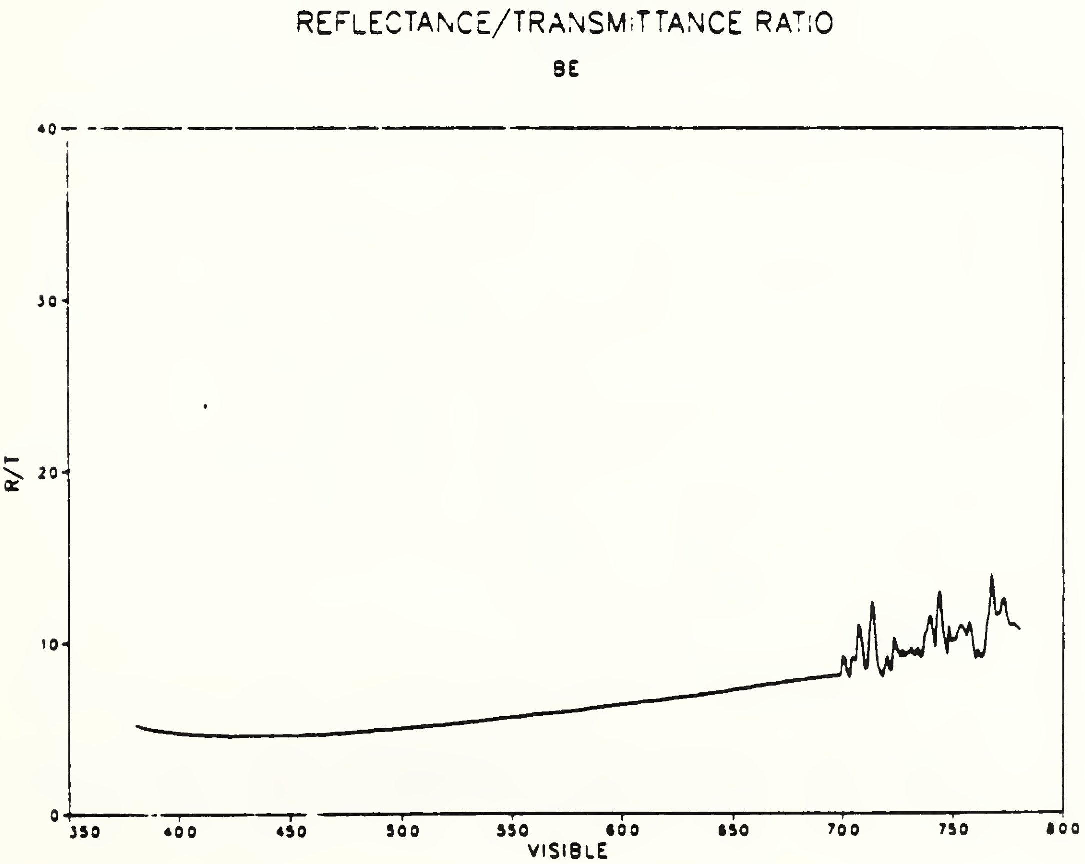


Figure 6.63 Sample BE, Total and visible ρ/τ versus wavelength

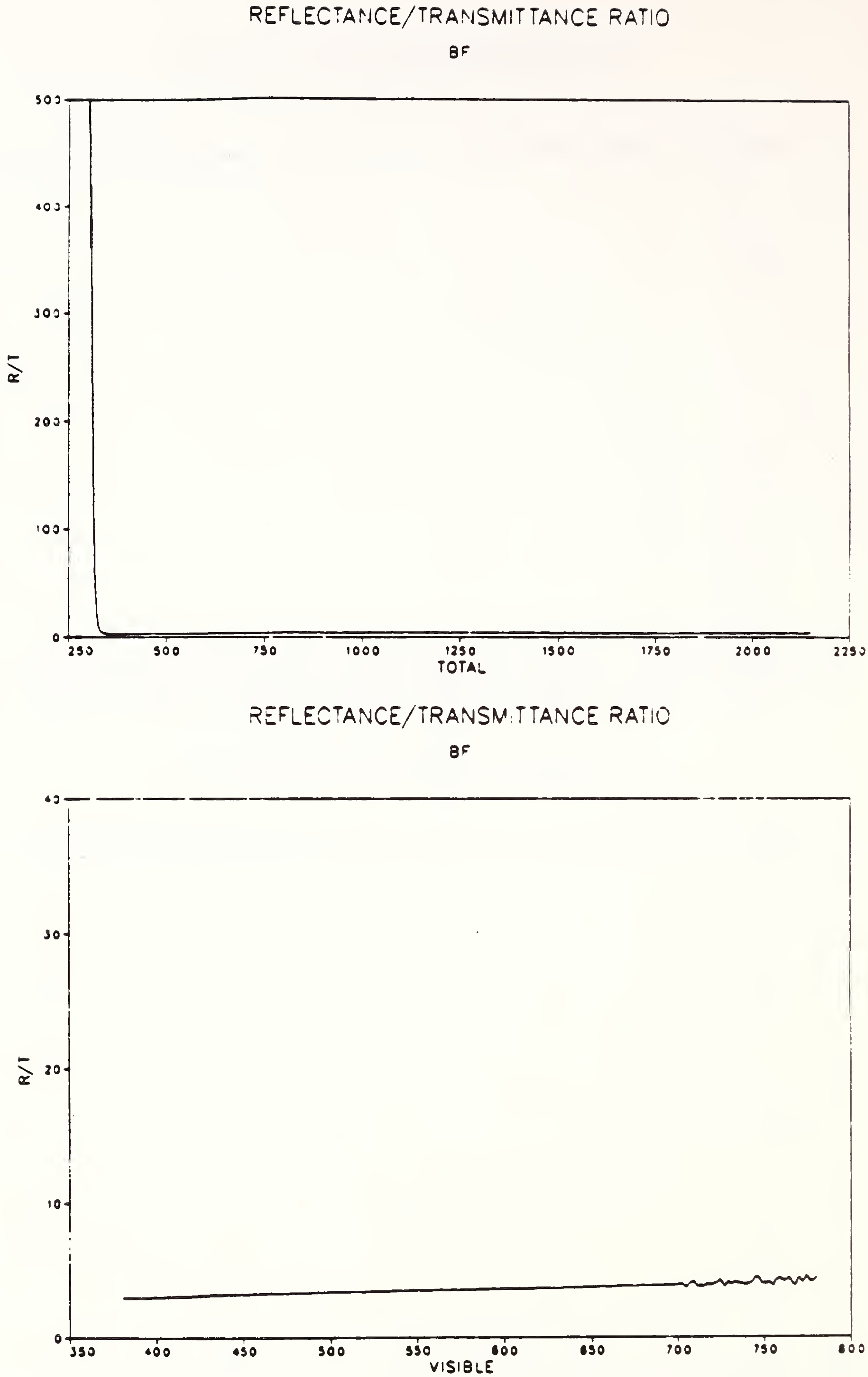


Figure 6.64 **Sample BF, Total and visible ρ/τ versus wavelength**

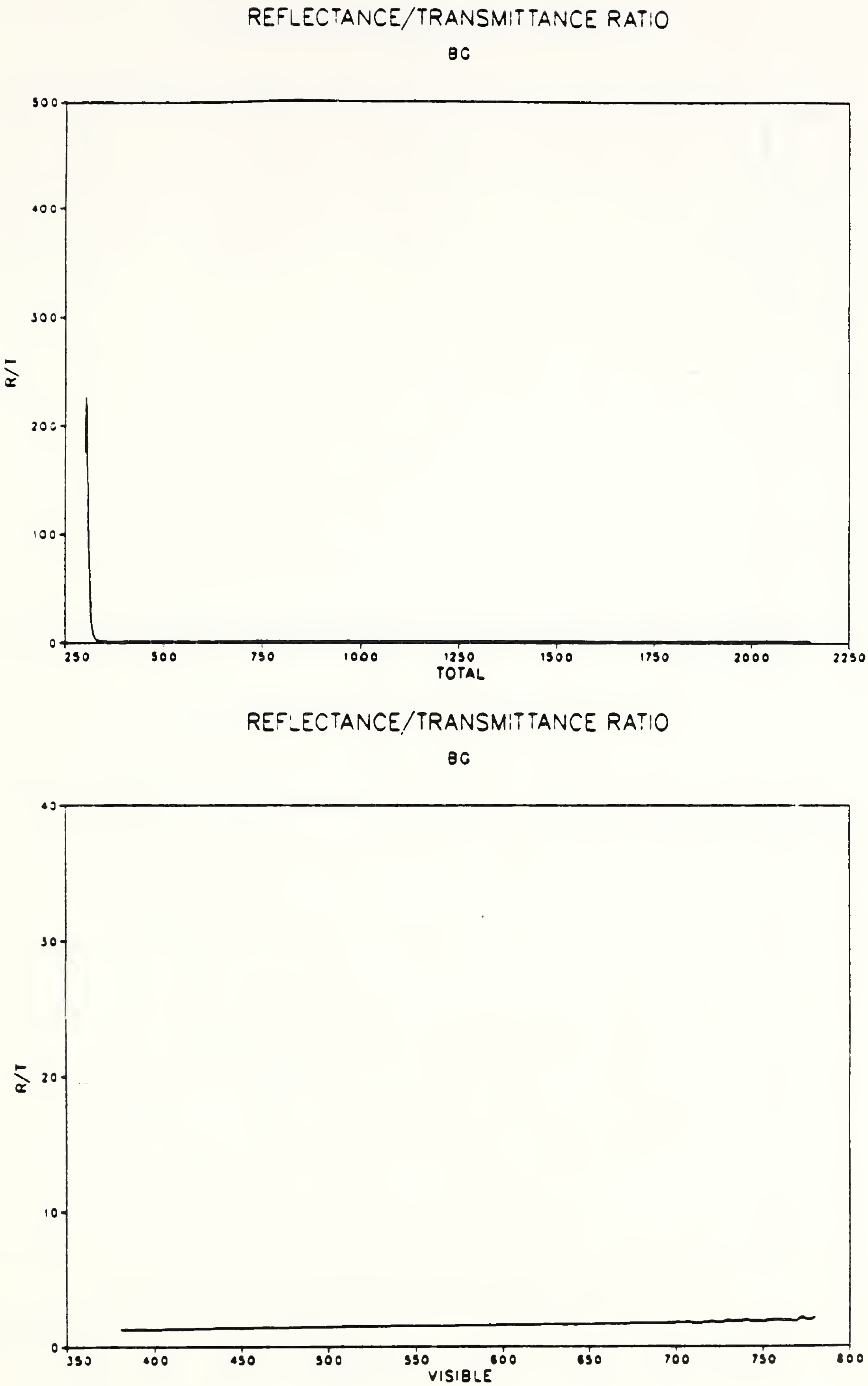
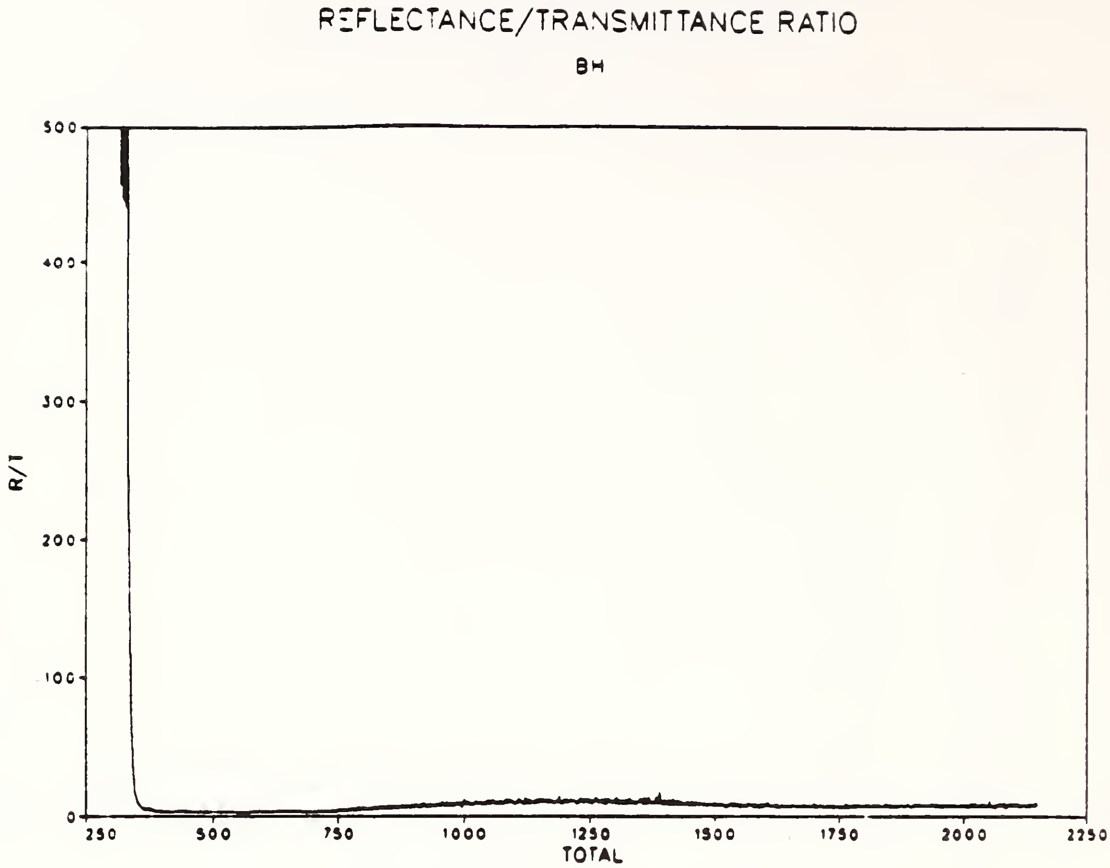


Figure 6.65 Sample BG, Total and visible ρ/τ versus wavelength



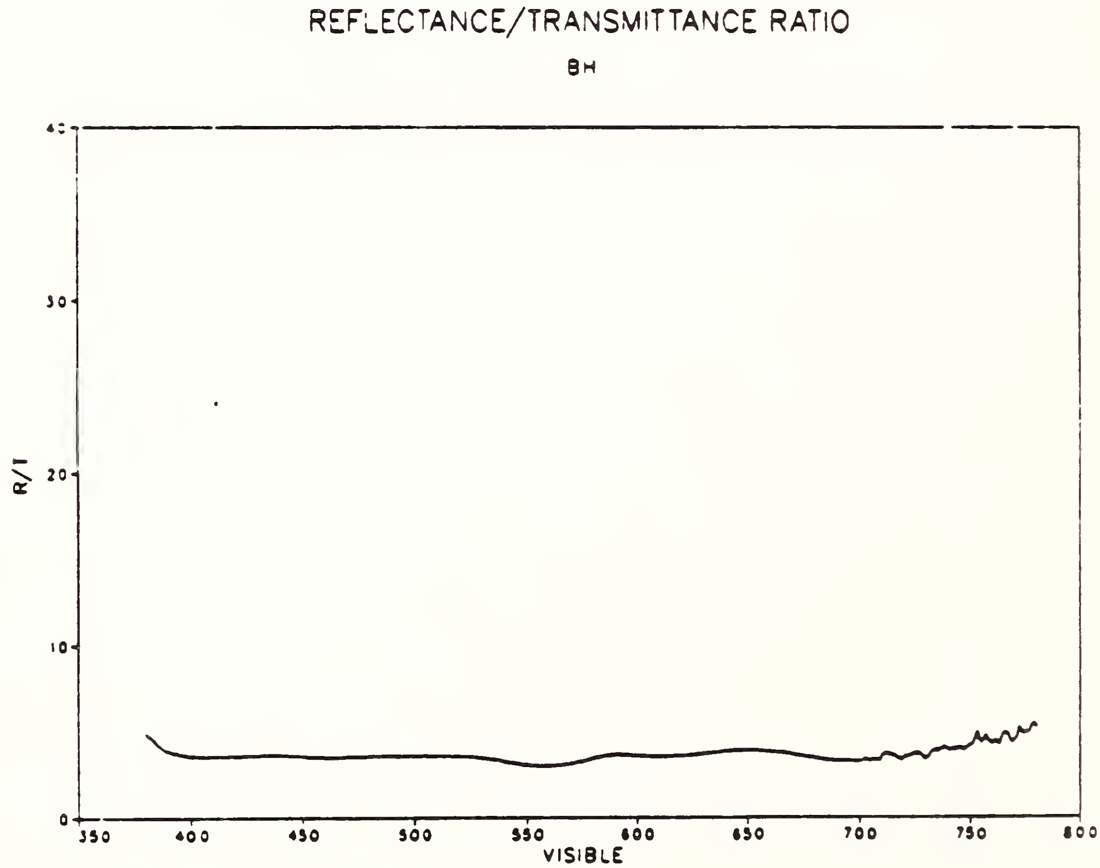
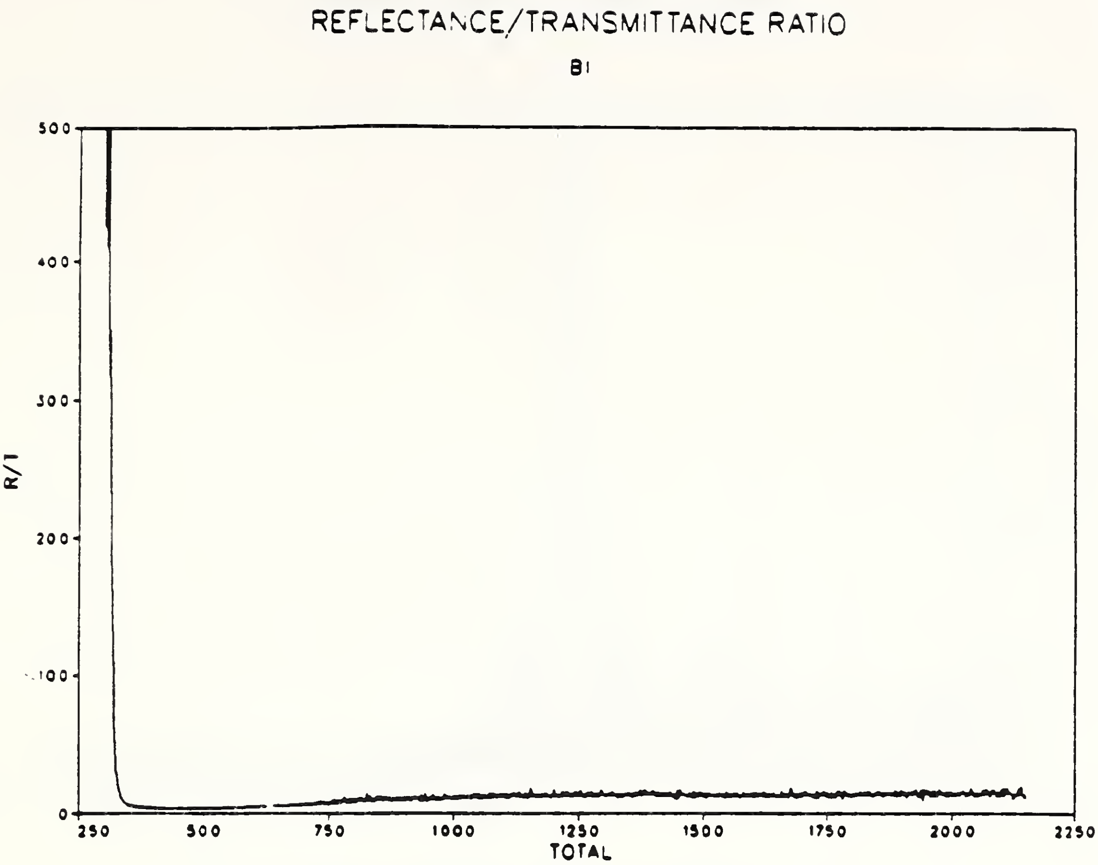


Figure 6.66 Sample BH, Total and visible ρ/τ versus wavelength



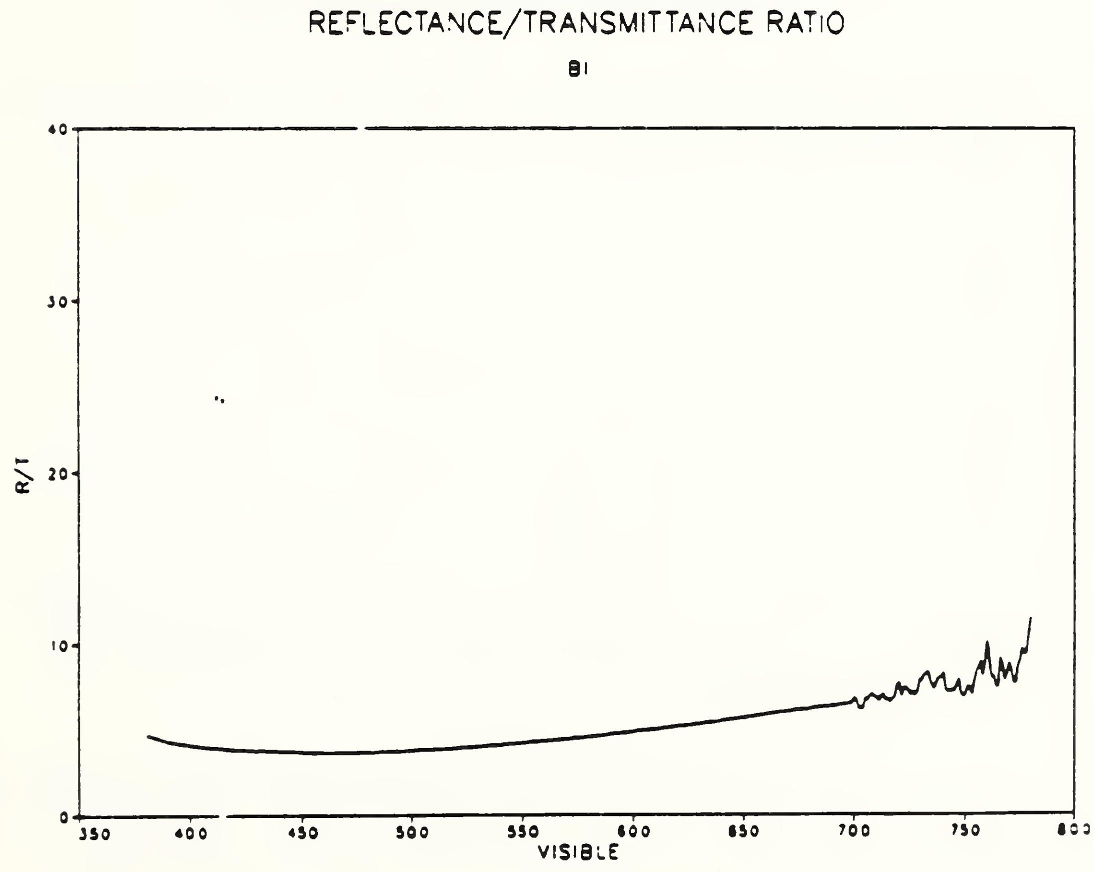


Figure 6.67 Sample BI, Total and visible ρ/τ versus wavelength

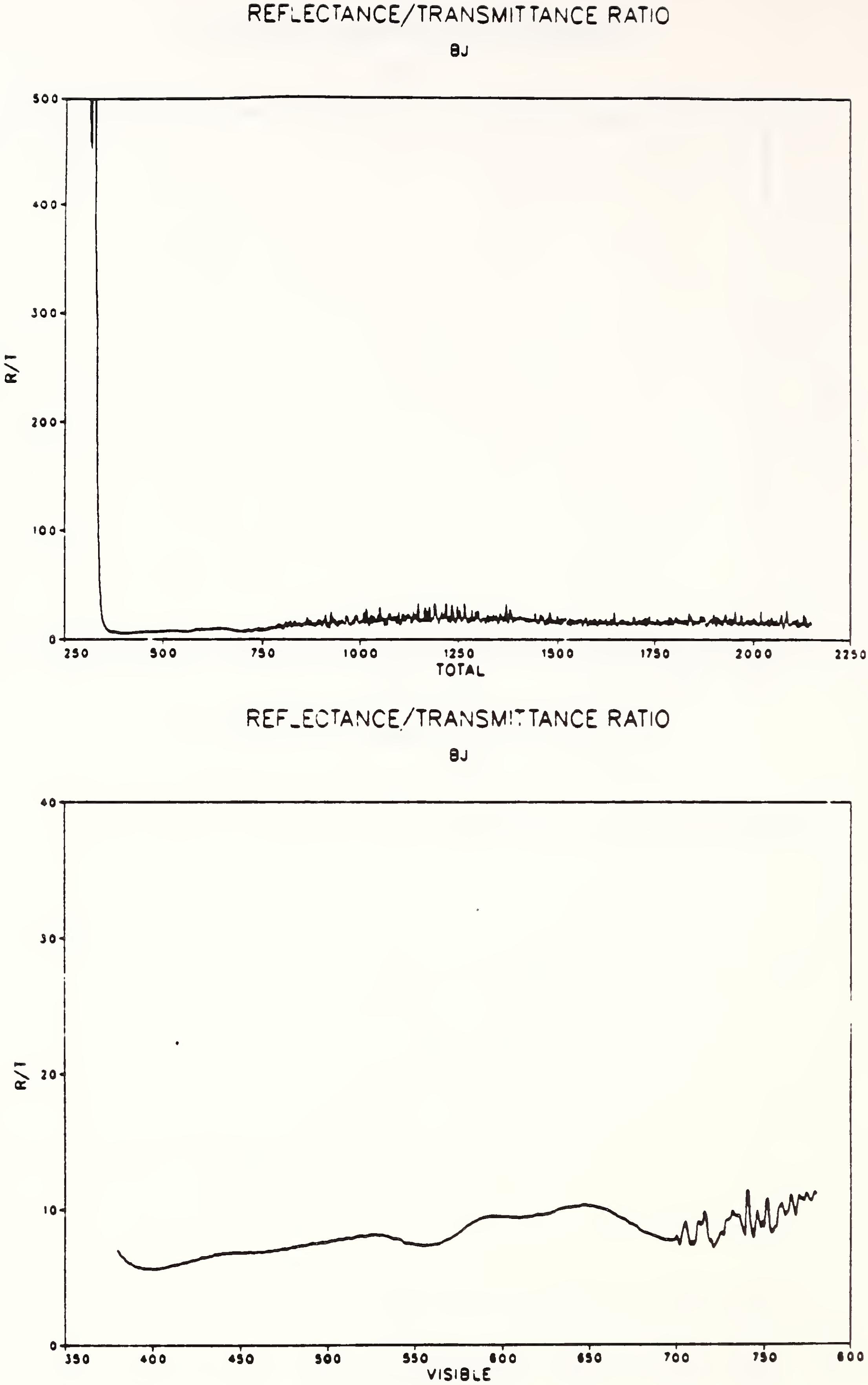
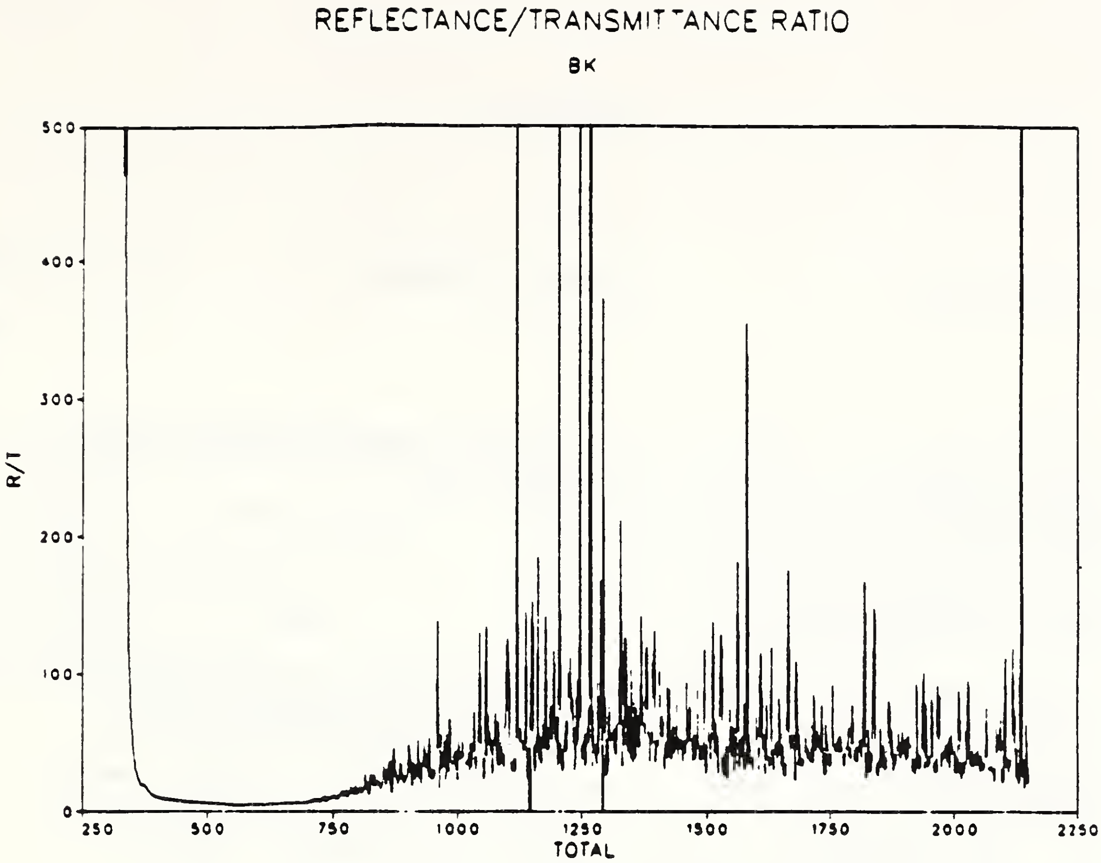


Figure 6.68 Sample BJ, Total and visible ρ/τ versus wavelength



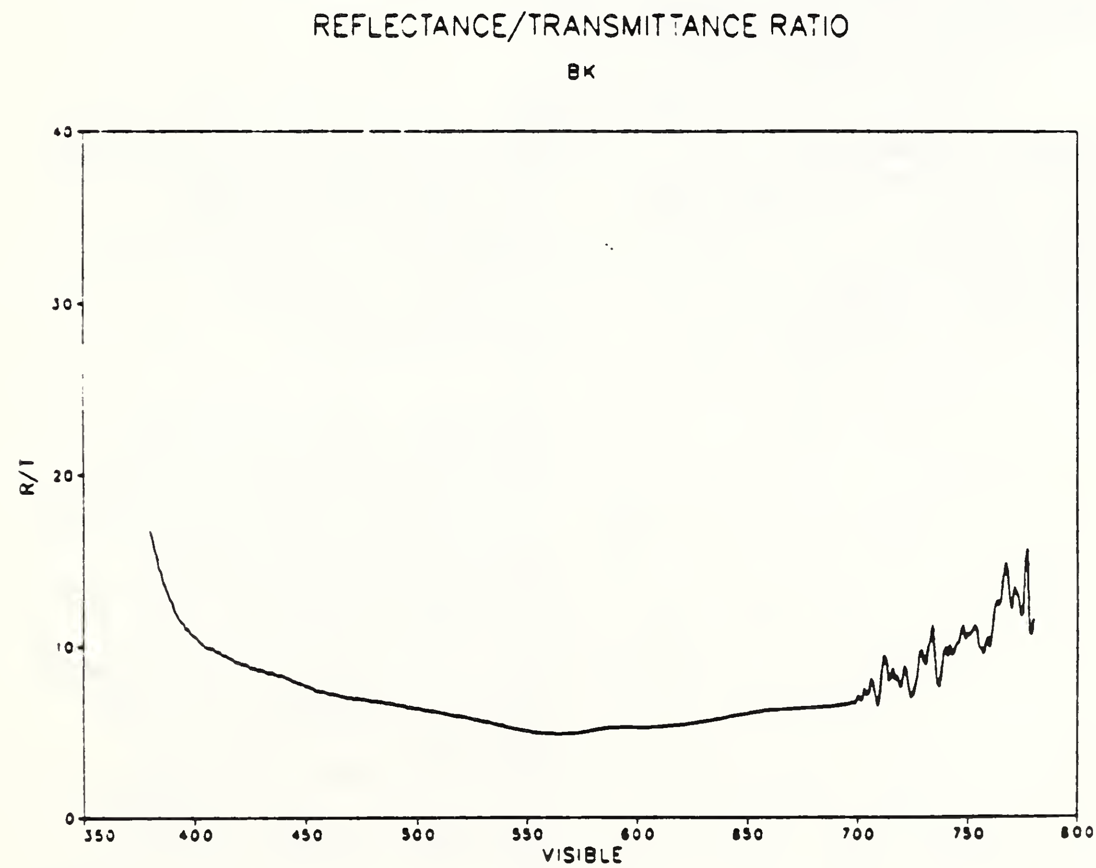


Figure 6.69 Sample BK, Total and visible ρ/τ versus wavelength

APPENDIX A

Corporation	Summary	Received Info Yes	No
Vacumet Corp. 20 Edison Dr. Wayne, NJ 07470 201-628-0400 Fax: 201-628-0491 Contact: Rob Walther	Is not involved in the window business.	x	
Hittman Materials & Medical Components, Inc. 9190 Red Branch Road Columbia, MD 21045-2051 301-730-7800 Fax: 801-730-7837 Contact: Patricia A. Miller Administrative Asst. Sales & Marketing	Manufacturer of miniaturized electronic component parts, such as ceramic-to-metal and glass-to-metal hermetic seals. Major product is feedthroughs for the pacemaker industry.	x	
Photon Technologies, Inc. 437-A Aldo Avenue Santa Clara, CA 95054-2302 408-727-0754 Fax: 408-727-0854 Contact: Michael R. Brown President	Small corporation specializing in optical thin film coatings and fabricated optical components (designed and produced in accordance with customer-furnished specifications). Coatings manufactured: Metallic, Dielectric and Polarizing Beam Splitters; Broad Band Anti-Reflective Coatings; Conductive Coatings; Sharp Cut-On and Cut-Off Filters; Infrared Filters; Hot and Cold Mirrors; Dichroic Filters; Ultra-Violet Filters; Aluminum-Enhanced Aluminum Coatings; Color Correcting Filters; Laser Coatings; Mirrors for Mask Alignment Systems; Lenses; Windows. Send drawing or specifications for sample coating with spectral scan.	x	

Corporation	Summary	Received Info Yes	Received Info No
Precision Engineered Glass Products A Division of Downey Glass Company 5631 Ferguson Drive Los Angeles, CA 90022 213-268-3661 Contact: Magdalena B. Ybarra Account Represent.	Cutting, grinding, polishing, shaping, drilling, notching, edge grinding and profiling, grooving, slotting, tube sawing, laminating, coating, thermal and chemical tempering, screen printing, etching, sandblasting and everything in between. Types of glass offered: clear sheet glass; clear float glass; tinted float glass; gauge glass, flashed opal glass; low-reflective meter glass; ground-surface glass; screen printed, sandblasted and acid-etched glass; water white glass; filter glass; welding glass; x-ray leaded glass; clear fused quartz; standard mirrors; front surface mirrors; heat absorbing filters; projection booth glass; light=diffusing plates; heat shielding glass; slide cover glass; coated glass; tubular gauge glass; visibility red line gauge glass; heavy-wall tubular gauge glass; polished pyrex 7740; rolled pyrex 7740; infra-red reflecting; pyrex 7740; amber pyroceram pyrex; furnace observation blue pyrex 7740/special coating; pyrex tubing and rod; vycor #7913 rolled and polished; Vycor #7913 tubing and rod cylinders and jars; MacBeth gauge glass; infra-red transmitting glass; micro sheet glass.	x	

Corporation	Summary	Received Info Yes	No
Dunmore Corporation Newtown Industrial Commons P.O. Box 1067, 207 Penns Trail Newtown, PA 18940 Office: 215-968-4774 Plant: 215-968-0442 Fax: 215-968-7471 Contact: D.A. Hallman Inside Sales Manager	Do not manufacture glass and window products for commercial building applications.	x	
Sun-Gard Energy Conservation Products Metallized Products 2544 Terminal Drive South St. Petersburg, FL 33712 813-327-2544 Fax: 813-327-7132 Contact: Kitty McCoy Sales - Service to order: 800-777-1770 Second letter received from: Joseph J. O'Brien President	Automotive, residential and commercial windows. Specialize in non-fading pigmented colors. Thermal windows. Samples of films included as well as test data and correspondence with various customers. Second letter received: Literature on Sun-Gard 365 enclosed (a summer/winter film). Conclusions and recommendations sheet from a DOC study, March 1983 on the most cost effective films (low emittance films). Studies showing the increased energy savings of summer/winter films in Miami, Tampa, and Tallahassee, Florida and a study done on double glazing in Las Vegas.	x	
Bausch & Lomb Vacuum Coating Division Optics Center 1400 N. Goodman St. Rochester, NY 14692-0450 716-338-6706 Fax: 716-338-6687 Contact: David C. Hoagland Marketing Admin.	Written materials sent seem to apply only to optical lenses and scientific instruments. Perhaps another division of Bausch & Lomb would have information more relevant to windows.	x	

Corporation	Summary	Received Info Yes	No
Bausch & Lomb, Inc. Vacuum Coating Division P.O. Box 450-TR Rochester, NY 14692-0450			

Corporation	Summary	Received Info Yes	No
BiltBest Windows 175 10th St., Ste. Genevieve, MO 63670 314-883-3571 Contact: Sandy Reed Marketing Ser.	ClerkSent product catalog containing information on what tests their commercial/resid-ental windows/patio doors will pass. Also has dimensions of windows available to be ordered. For further information contact the following distributor: Lowes of Frederick 5600 Urbana Pike Frederick, MD 21701 301-663-0700	x	
Norshield Norshield Security Systems, Inc. Suite 20 Executive Court 225 N. Memorial Drive Prattville, AL 36067 205-281-8440 Fax: 205-288-5485 Contact: Mark Oakes Marketing/Sales Mngr. 205-365-5713	Norshield is a manufacturer of physical barrier security products. A comprehensive security systems contractor, an electronic security systems subcontractor and a source for comprehensive security systems. Physical barrier products include: Doors/frames (pre-hung and completely factory finished); Windows (factory glazed and painted) Fixed and Teller; Modular Panels (opaque and transparent); Escape Hatches; Guard Towers; Guard Booths (modular and assembled); Gunports (hands free operation-slam lock feature); High Security Double Doors and Louvers for Generator Rooms; Blast resistant windows and doors. Their glass supplier is: Viracon, Inc. An Apogee Enterprise 800 Park Drive Owatonna, MN 55060 507-451-9555 800-533-2080 or	909 Aldridge Road Vacaville, CA 95688 707-446-4500 Enclosed is a specification guide from the glass supplier	x

Corporation	Summary	Received Info Yes	No
Plastic-View Inc. 15468 Cabrito Road P.O. Box 25 Van Nuys, CA 91409-0025 818-786-2801 800-468-6301 Fax: 818-786-1672 Contact: Sonny Voges President	Main products include film to glass and window shades. Includes specifications to contracts with DoT (Air traffic control) and DoC.	x	
(LLumar) (Solar Control Window Film) (Courtaulds Performance Films) Martin Energy Products Mid-Atlantic Service Center P.O. Box 5068 Martinsville, VA 24115 703-629-1711 800-621-6219 Fax: 703-629-3978 Contact: DeWitt Tharrington Manager Mid-Atlantic Region	Information sent includes: samples, product characteristics, brochures, copy of a current GSA contract with ordering and pricing information.	x	
Martin Processing Inc. Film Division P.O. Box 5068-T Martinsville, VA 24115			
Glass-TEK Industries, Inc. 16840-B Joleen Way Morgan Hill, CA 95037			
Optical Coating Lab., Inc. 2789 Northpoint Pkwy. Santa Rosa, CA 95407-7397 Contact: Clive Egerton Business Dev. Manager Cmercl Products Group 707-525-7435	**More info. to follow** from Flex Coatings Division on film products that filter heat/light as well as provide some level of privacy if there are differential lighting levels. Annual report enclosed. Information on multilayer antireflection coating (seems to be used on display monitors to cut down the glare mostly.)	x	

Corporation	Summary	Received Info Yes	Received Info No
Lamination Technology 12423-T Gladston Avenue Unit 27 Sylmar, CA 91342 Response came from: Security Glass Systems of California, Inc. 1032 Serpentine Lane #102 Pleasanton, CA 94566 Contact: William Knox 415-484-4730	Information on solar & solar security film products. 1. DTI (Depostion Technology Inc.) Solar Window Films. Window films available for energy savings, sun and glare control, exterior and interior design, personal safety, and security protection. Metallized sputtered film and conventional window film samples enclosed. (Some percentages listed). 2. ARMORCOAT - security and safety film is an optically clear thin, polyester film designed to be applied to theinterior surface of new and existing window and door glass.	x	
Applied Energy Technology, LTD Hwy. 965, South Swisher, IA 52338			
Rusco-Sage Industries, Inc. 3027 Larimer Street Denver, CO 80205			
IMCO Reinforced Plastics 858 N. Lenola Road Morrestown, NJ 08057			
Spectral Systems, Inc. 1767-T Front Street Yorktown Heights, NY 10598	Forwarding time expired from Yorktown Heights. Return to sender.		x
Omley Industries, Inc. Dept. B 63345 Nels Anderson Road Bend, OR 97701			

Corporation	Summary	Received Info Yes	No
Optical & Conductive Coatings 428 N. Buchanan Circle Suite 8 Pacheco, CA 94553			
Kaufman Glass Co. 1301-03 Northeast Blvd. Wilmington, DE 19899			
General Ruby & Sapphire Corp. P.O. Box 610 New Port Richey, FL 34656-0610			
Globe Amerada Glass Co. 2001-T Greenleaf Avenue Elk Grove Village, IL 60007			
Schott Glass Technologies, Inc. 989 York Avenue Duryea, PA 18642	Does not look like what we're looking for.		
returned envelope from: Schott Glass Technologies, Inc. 400 York Avenue Duryea, PA 18642 Contact: Robert W. Drouse Project Manager Laser Glass 717-457-7485	Projection booths, tables, viewing windows, glazing of display cases..., lenses, prisms, glass elements..., first and second surface mirrors, concave mirrors..., substrates for conductive and other coatings, photomasks, CRT and other faceplates,..., slides, bulbs, diffusers,.... Brochure enclosed.		

Corporation	Summary	Received Info Yes	No
Schott America Glass & Scientific Products, Inc. 3 Odell Plaza Yonkers, NY 10701 Contact: Hartmut R. Weimann Group Marketing Mngr. 914-968-8900	Brochures enclosed... Irox (solar reflective glass), non-reflective Amiran (clear view to outside at night, preventing inner light reflection), white flashed opal glass (100% privacy, 35% natural light penetration), fire resistant glass, UV barrier glass.	x	
Defender P.O. Box 3582-T Bridgeport, CT 06605			
Koolmaster Co., Inc. 300 Second Street LaSalle, IL 61301			
Kesko Products, Inc. 11885 C.R. 4 Middlebury, IN 46540			
AP Industries 635-T S. Lafayette Blvd. P.O. Box 4248 South Bend, IN 46634			
Lametco, Inc. 4623-T Greenwood Raod Shreeveport, LA 71109			
Weathervane Window, Inc. 5936-T Ford Court Brighton, MI 48116			
Thermoseal Glass Corporation 402 Water Street Gloucester, NJ 08030			
American Tempering, Inc. 2919 Samuel Drive Bensalem, CA 19020			

Corporation	Summary	Received Info Yes	No
The Naugatuck Glass Co. P.O. Box 71 Naugatuck, CT 06770			
Norment Industries, Inc. P.O. Box Drawer 6129 3224 Mobile Hwy. Montgomery, AL 36194			
Tyre Brothers Glass Co. 3008-T S. San Pedro Street Los Angeles, CA 90011			
Seaboard Industries, Inc. 597-T Monterey Pass Road P.O. Box 1140 Monterey Park, CA 91754			
Torstenson Glass Co. 3233 N. Sheffield Avenue Chicago, IL 60657			
Lawrence Plate & Window Glass Co. 417-T Canal Street P.O. Box 567 Lawrence, MA 01842			
North Shore Glass 539-T Flynn Road Duluth, MN 55804-3204			
Corning Glass Works Industrial Supplies Dept. MP21-1 Corning, NY 14831			
Precomp, Inc. 17 Barstow Road Suite 302A Great Neck, NY 11021			
Gillinder Brothers, Inc. Box 1007 Port Jervis, NY 12711			

Corporation	Summary	Received Info Yes	No
Dlubak Glass Co. 275-T Saxonburg Road Natrona Heights, PA 15065			
PPG Industries Glass Divisions 1-T PPG Place, 32 East Pittsburgh, PA 15272 for more info, Eastern Zone: 1436 Lancaster Avenue Suite 205 Berwyn, PA 19312 215-647-4300	Sent brochure which includes performance values on aesthetic effect, transmittance %, reflectance % (daylight and total solar, in and out), heat flow in winter and summer, and shading coefficient. Info on slope and strength.	x	
Enhanced Glass Corporation 1901-A W. Loop 340 Waco, TX 76711 received info from: Enhanced Glass Corporation 1701 West Loop 340 Waco, TX 76712 Contact: John A. Acker President 817-666-3536 cust. service: 800-882-7177	Enclosed information on clear solar control glazings, tinted solar control glazings, clear high transmittance high insulation glazings, heat mirror "total performance" benefits, heat mirror insulating glass system, specification and design guidelines.		
Wichita Glass & Mirro Co. P.O. Box 627 Wichita Falls, TX 76307			
Phifer Wire Products, Inc. P.O. Box 1700 Tuscaloosa, AL 35403-1700 Contact: Steve Wells Architectural Representative Sun Control Products 1-800-633-5955	Phifer Sun Control Products Manual.... Literature and samples of both exterior and interior shading products. The manual includes exterior and interior shading systems information provided by manufacturers who use Phifer's products in various application methods. Will receive more information as developed.	x	

Corporation	Summary	Received Info Yes	Received Info No
California Metal Enameling Co. 6904-T E. Slauson Avenue Los Angeles, CA 90040			
Metal Industries, Inc. P.O. Box 3044 Ontario, CA 91761	Return to sender, forwarding order expired.		x
JNT Company 700-T 47th Street Sacramento, CA 95819			
American Mfg. & Fabricating Inc. P.O. Box 1159-T Andover, NJ 07812 Returned with forwarding address: American Mfg. & Fabricating Inc. 573 Green Pond Raod Rockaway, NJ 07866	Letter returned with forwarding address. **Send letter to new address.**		
Belleville Wire Cloth Co., Inc. 137 Little Street Belleville, NJ 07109			
Solar Screen Company 53-11-T 105th Street Corona, NY 11368 718-592-8223 718-592-8222 Contact: Miles L. Joseph, President	Samples and literature about Solar-Screen Transparent Shades. Darker materials for one way vision during daylight. Transparent layer of aluminum to reflect solar energy. All products stop 98% of the near range of UV light (used in museums to control fade) Fabricate covers for fluorescent bulbs to control the UV light.	x	
Trem Inc. 240-T W. Britton Road Oklahoma City, OK 73114	Returned to sender, not deliverable		x

Corporation	Summary	Received Info Yes	No
Endura Products 9401-T Center Point Houston, TX 77054			
Argus Steel Products 1011 N. Lombardy Street P.O. Box 25133 Richmond, VA 23260			
Virginia Iron & Metal Co., Inc. P.O. Box 8229 Richmond, VA 23226	Returned to sender for "attempted not known"		x
Curbsun Systems, Inc. 555-T Hanlan Road Woodridge, Ontario, Canada L4L 4R8			
Coating Sciences, Inc. 48 E. Newberry Road Bloomfield, CT 06002			
Label Systems Corporation 57 Cherry Street Bridgeport, CT 06605			
Coating, Laminating & Converting P.O. Box 1362 Middleburg, FL 32068			
Sun Process Co., Inc. 485 Bonnie Lane Elk Grove Village, IL 60007			

Corporation	Summary	Received Info Yes	No
Midwest Coating, Inc. 1701 Rockland Road Lake Bluff, IL 60044 letter passed on to: Jessup Manufacturing Company 2815 W. Route 120 P.O. Box 366 McHenry, IL 60050 815-385-6650 Contact: Sharon Birk Sales	Nothing from Midwest Coating, Inc. at this time. Literature from Jessup Man. Co. on Glass Bandage #7100 which is a temporary protective warning cover for cracked or broken glass. (also "no-slip floor stickers") Samples enclosed.	x	
Bemis Associates, Inc. 294 Pleasant Street Watertown, MA 02172			
Argent Corporation 41131-T Vincenti Court Novi, MI 48051			
International Adhesive Coating Company 6 Industrial Drive P.O. Box 240 Windham, NH 03087			
Air-O-Plastik Corp. 150-T Fieldcrest Ave. Edison, NJ 08837			
Electro-Seal Corporation 55-T Wanaque Avenue Pompton Lakes, NJ 07442			
Kimberly-Clark, Brown Bridge 518 E Water Street Troy, OH 45373			
A-Beta Industries 1735-T S. Claudina Way Anaheim, CA 92805			

Corporation	Summary	Received Info Yes	No
Johnson Laminating & Packaging, Inc. 20631 Annalee Avenue Carson, CA 90746			

Corporation	Summary	Received Info Yes	No
3M/Energy Control Products Division 1601 S. Shamrock Monrovia, CA 91016 return address on envelope: 3M General Offices 3M Center St. Paul, Minnesota 55144-1000 Contact: Jeffrey F. Bradley Technical Service Supervisor 3M Energy Control Products 207-1W-08 3M Center return address on another letter:	Brochures and samples enclosed. Includes product performance and technical data.	x	
3M Construction Markets Depart. 3M Center Bldg. 223-4N-06 St. Paul, MN 55144-1000 Contact: Richard R. Dahlen Product Development Manager Construction Markets Dept. 612-733-1140 **formerly**: Energy Control 207-1W-08 3M Center St. Paul, MN 55144-1000 closest major distributor: Energy Products Distribution 320 Hillen Road Towson, MD 21204	Enclosed a general brochure which describes Scotchtint Window Films and lists the performance characteristics of various products on the back page. Enclosed sample cards of films: highly reflective - provide a degree of privacy but always on the side of the window where the illumination is lowest; a low visible light transmission film - provides a significant degree of privacy; a translucent film providing complete privacy while allowing some light transmission; and a relatively high visible transmission while providing a high level of solar energy control and insulating performance. This is a low-e film with an emittance of .25 and a shading coefficient of .43. It does have a relatively high visible reflectance of 40% on clear single glass, thus providing a degree of "daytime" privacy coupled with good outdoor visibility.	x	

Corporation	Summary	Received Info Yes	No
Southwall Technologies 1029-T Corporation Way Palo Alto, CA 94303 1-800-365-8794 415-962-9115 x261 Contact: Nancy S. Rhea Architectural Ser.	Literature describes the benefits that Heat Mirror brings to a building design: energy savings, increased comfort near windows, natural lighting, condensation control, and reduced fabric fading. Design freedom: the ability to use more glass, of any color, without the usual compromises. Products availablein all types of glazing applications: residential or commercial, vertical or sloped. Product comparisons and listing of glass manufacturers enclosed.	x	
Scharr Industries, Inc. 40 E. Newberry Road Bloomfield, CT 06002			
Applied Energy Technology, Ltd. Hwy 965 South Swisher, IA 52338			
Vacuum Depositing, Inc. 1294-T Old Fern Valley Road Louisville, KY 40219			
Thermoco, Inc. 7006 Blue Mountain Road Thurmont, MD 21788	no info sent directly from Thermoco as yet		x
received info from: General Solar Corporation 11625 Nebel Street Rockville, Md 20852 301-231-9500 fax 301-816-0816 contact: Tisha A. Fitzpatrick Sales Consultant or Astrid Hricak	Enclosed information: glass coatings and solar films manufactured by Thermoco, exterior sunscreens manufactured by VIMCO, and interior shades manufactured by VIMCO. Samples enclosed Thermal window insulationn	x	

Corporation	Summary	Received Info Yes	No
Madico, Inc. P.O. Box 4023 64 Industrial Pkwy. Woburn, MA 01888 Contact: Jay Frolick Product Manager 617-935-7850	Window films for security (against breakage and shattering) and solar energy control. Samples and information enclosed.	x	
Sun Control Products, Inc. 433 S. E. 4th Avenue Rochester, NY 55904			
Koolshade Corporation 717-B Fellowship Road Mount Laurel, NJ 08054-1003 (old address - do not use) New Address: 504 Douglas Drive Cherry Hill, NJ 08034-1342 1-609-667-7484 1-800-247-4233 Contact: David A. Milne President	Also president of JMS Manufacturer. See further on list. Call 1-800-247-4233 to get name of nearest dealer. KoolShade is sold as a complete installation which includes the KoolShade itself and a specially designed framing system. Shades that go on outside of window. Literature, specifications, technical data and a sample are enclosed.	x	
Solar Master Film Corp. 5718 Crescent Blvd. N P.O. Box 1307 Pennsauken, NJ 08109			
Chronar Corp. P.O. Box 177 Princeton, NJ 08540			

Corporation	Summary	Received Info Yes	No
Norton Performance Plastics 150 Dey Road Wayne, NJ 07470 Contact: Y. Michael Ni, Ph.D. Manager, Product & Business Development Film, Tape, & Laminates 201-696-4700	Manufacture and supply high performance fluoropolymer films including KORTON FEP, KORTON PFA, KORTON ETFE, KORTON PVDF, DORTON E-CTFE, CHEMFLUOR PTFE, KEMID ULTEM and LLUMAR and used in window applications. Excellent weather and/or radiation resistance. Available with 4 to 8 week lead time. Suggests LLUMAR from stipulations in our letter. To order products, contact customer service: Wayne, NJ 201-696-4700.	x	
Accurate Plastics, Inc. 16 Morris Place Yonkers, NY 10705			
Patco Corporation 211-T Weeden Street Pawtucket, RI 02862			
Stewart Company, Inc. 3646-T San Fernando Road Glendale, CA 91204			
Chartpak 1 River Road Leeds, MA 01053			
Solcoor, Inc. 2 Park Avenue New York, NY 10016			
National Glass Association 9748 East Artesia Blvd. Bellflower, CA 90706			
Southwall Technologies 1029 Corporation Way Palo Alto, CA 94303			

Corporation	Summary	Received Info Yes	Received Info No
Koolshade Corporation Box 207 Bridge Street Senoia, GA 30276			
3M Company Energy Control Gldg. 207-1 3M Center St. Paul, MN 55144			
Insulating Glass Co. 7115 West Lake Street Minneapolis, MN 55426			
Rolscreen Company 102 S. Main Street Pella, IA 50219 contact: Gary Mathes Architectural Services/ CAD System Supervisor 515-628-1000 nearest Pella Window Store: James A. Cassidy Co., Inc. Beltsville, MD 301-953-7700	Enclosed 2 catalogues (1 is missing). Performance data included. Windows, doors, sunrooms & skylights. Suggest slimshade and pleated shade products for our use.	x	

Corporation	Summary	Received Info Yes	No
Hendee Enterprises, Inc. (Don't know where they got our name.) P.O. Box 4289 Houston, TX 77210-4289 Contact: Santiago La Rotta Product Manager 713-796-2322 800-231-7275 or 9350 South Point Dr. Houston, TX 77054	(Don't know who forwarded our letter to them or which company they are affiliated with.) Deal with Fabric Shades: Enduro Shade, Multi-Lock Shade, Dura-Lene Shade, Dura-Lene Landscape Fabric, Enduro Enclosure Cloth. Enduro Shade - Ultimate high quality shade fabric for residential and commercial shading projects. Vinyl impregnated polyester yarn, woven and heat set for stability. Fire retardant. Has longest life of any shading product on the market. Ten year plus, life. Multi-Lock Shade - High-density knitted monofilament shade. Will not ravel when cut. Seven year plus, life. Dura-Lene Shade - Woven monofilament polypropylene yarn shade cloth. Not as stable as knitted shade cloth. Enduro Enclosure Cloth - A translucent laminate of nylon reinforced polyethylene, with UV inhibitors, admits light and retains heat. Comes in six fott widths. Easily cut and fastened. Just right for enclosing patios, sheltering and protecting plants and furniture. Samples enclosed.	x	

Corporation	Summary	Received Info Yes	No
Cardinal IG (Don't know where they got our name.) Product Development Laboratory 7115 West Lake Street Minneapolis, Minnesota 55426-4467 Contact: James E. Larsen Director Product Development 612-929-3134	(Don't know where they got our name from or which company passed our letter on to them.) Manufacturer of coated glass products and sealed insulating glass units. 1990 Sweet's Catalogue is enclosed outlining the basic performance parameters for all different coating types. Combinations of monolithic reflective, insulating reflective, insulating reflective incorporating LoE coatings with argon fill, and LoE coated glasses. Contact for samples.	x	
JMS Manufacturing, Inc. 504 Douglas Drive Cherry Hill, NJ 08034-1342 1-609-667-7916 1-800-247-4233 Contact: David A. Milne President	Also president of KoolShade Corporation - received information from them as well (same address). This company markets PARASOL (tm) Solar Screens. Sample, color brochure, and brief technical information is enclosed.	x	
Wasco Products, Inc. Residential Division P.O. Box 351 Sanford, Maine 04073 207-324-8060 Contact: Estelle M. Carroll Marketing Manager	Don't know where they got our name from or who forwarded our letter to them. Deal mainly with skylights and roof windows. Do have some information on glazing on these windows. Brochure enclosed as well as list of closest manufacturers.	x	

NIST-114A
(REV. 3-90)

U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

BIBLIOGRAPHIC DATA SHEET

1. PUBLICATION OR REPORT NUMBER
NISTIR 4711

2. PERFORMING ORGANIZATION REPORT NUMBER

3. PUBLICATION DATE
JANUARY 1992

4. TITLE AND SUBTITLE

Optical Performance of Commercial Windows

5. AUTHOR(S)

Stephen J. Treado and John W. Bean

6. PERFORMING ORGANIZATION (IF JOINT OR OTHER THAN NIST, SEE INSTRUCTIONS)

U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
GAITHERSBURG, MD 20899

7. CONTRACT/GRANT NUMBER

8. TYPE OF REPORT AND PERIOD COVERED

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (STREET, CITY, STATE, ZIP)

10. SUPPLEMENTARY NOTES

11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

The role of window system characteristics on privacy-related issues was examined. The optical characteristics of various window materials were measured and compared to determine the best candidates for enhancing building occupant privacy. Strategies for inducing privacy are discussed, along with related performance characteristics of window systems.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

absorptance; contrast; glazing; privacy; visibility; windows

13. AVAILABILITY

- [X] UNLIMITED
- [ ] FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NATIONAL TECHNICAL INFORMATION SERVICE (NTIS).
- [ ] ORDER FROM SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, DC 20402.
- [X] ORDER FROM NATIONAL TECHNICAL INFORMATION SERVICE (NTIS), SPRINGFIELD, VA 22161.

14. NUMBER OF PRINTED PAGES
178

15. PRICE
A09

ELECTRONIC FORM