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Broadband Integrated Transmittances (BITS)

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Broadband Integrated Transmittances (BITS) is an EOSAEL module that calculates transmittance for systems with broad spectral response. Path-integrated concentration data from COMBIC, other EOSAEL modules, or user models are used as input for BITS.

The primary function of BITS is to provide rigorous transmittance calculations for broadband systems, replacing the Beer-Lambert law used in most obscuration models. To use BITS, the system detector, filters, optics, and source spectral functions must be defined. The spectral transmittances of the atmosphere and mass extinction coefficient spectral data for the obscurant are also required. The output consists of transmittance as a function of concentration length for Beer's law and band-integrated computation methods.

The theory of the model, a description of the module organization, and an operations guide that provides input and output in EOSAEL format are provided in this user's guide. Example uses for BITS are also included.

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Contents

Figures

Figures (continued)

Appendix Figures

Appendix Figures (continued)

Tables

1. Introduction

The primary function of the EOSAEL module Broadband Integrated Transmittances (BITS) is to provide exact transmittance calculations for broadband systems operating in the ultraviolet through the far-infrared (IR) spectral regions by accounting for spectral dependence of the Beer-Lambert law across system bands. The module computes broadband integrated relative transmittances, accounting for detector, filters, system, atmosphere, source (target), and smoke and obscurant spectral characteristics. The spectral characteristics of these items are specified by the BITS user, who may either input spectral data or select certain data sets maintained by the module. The spectral transmittances of the atmosphere and mass extinction coefficient spectral data for the obscurant are also required.

The concentration-length (CL) data required for the transmittance calculations can be input directly through the card images or by CL files created to run models such as EOSAEL or COMBIC. For each CL, a wavelength-independent Beer-Lambert law transmittance, an ideal transmittance (using wavelength-independent system, atmosphere, and source, but a band-integrated extinction coefficient), and a broadband transmittance are computed.

The BITS module can be used as a stand-alone program or as an EOSAEL92 module. It is written with strict adherence to the FORTRAN 77 standards.

1.1 Availability

EOSAEL92 is available at no cost to the U.S. Department of Defense, specified Allied organizations, and their authorized contractors. U.S. Government agencies needing EOSAEL92 (EOSAEL92 is the most recent, 1992, release of EOSAEL) should send a letter of request, signed by a branch chief or division director, to the U.S. Army Research Laboratory (ARL)/Battlefield Environment Directorate. Contractors should have their Government contract monitor send the letter of request. Allied organizations must request EOSAEL92 through their national representative.

Intended uses should be included with requests. Indicate the type of 9-track tape your computer can read. EOSAEL can be supplied only as ASCII tapes or UNIX tar format tapes in either 1600 or 6250 bpi.

The EOSAEL92 point of contact is Dr. Alan Wetmore.

1.1.1 Mailing Address

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1.2 Documentation Conventions

Typefaces are used throughout this documentation to indicate different software entities. The following conventions apply:

1. MODULE names are in the universal font.

2. VARIABLE and SUBROUTINE names and SAMPLE INPUT are in the courier font.

2. Background

Most Army models that calculate transmittance do not account for detailed spectral characteristics of the radiation source, the receiver, or the intervening atmosphere. The BITS model was developed to provide modeled transmittance calculations, including the spectral signatures and responses of relevant elements. Spectral accounting is needed to accurately calculate the transmittance through smokes or obscurants that have mass extinction coefficients varying significantly with wavelength.

2.1 Conceptual Overview

Transmission of electromagnetic energy through the atmosphere has a major impact on modern military operations. The military is interested in more spectral regions for transmittances, including the ultraviolet through the millimeter wavelength bands. It is necesary to understand the nature of electromagnetic transmission in the spectral bands for the proper design of systems and tactics. Failure to understand the mechanisms of transmittance can result in inadequate system designs and unsuccessful field operations.

This section describes the calculation of BITS on a battlefield contaminated by natural and manmade smokes and obscurants. The model developed for these calculations is intended to aid in systems design and to provide insight on systems operations in the battlefield environment.

Modeling transmission of radiation through the atmosphere requires an elementary application of the theory of radiative transfer. A brief introduction to the radiative transfer equation is presented. Literature and textbooks on the subject of radiative transfer are abundant. An excellent treatment of the subject is presented in the classic volume *Radiative Transfer*. [1]

Modeling the transmittance perceived by a broadband system requires a knowledge of the spectral characteristics, the radiation source, the propagation media, and the receiving system components. The spectral characterizations treated in the BITS model include the source spectral energy distribution, the atmospheric attenuation, the filter and detector spectral responses, the system optics spectral responses, and the attenuation by the smoke or obscurant along the path of propagation.

To be consistent with other U.S. Army transmittance models, the BITS module calculates relative transmittances. The radiation signals received through clear air define the reference transmittance. To form relative transmittances, a ratio is calculated from radiation signals received as a function of time through smokes or obscurants to the clear-air reference signal. The calculation of relative transmittance is consistent with the recording of transmittance data in smoke or obscurant Army field testing programs.

2.2 Theoretical Basis of the BITS Model

The following sections give the theoretical basis and mathematical formulations used by the BITS model to perform broadband integrated transmittance calculations.

2.2.1 Radiative Transfer Theory

In this section, the radiative transfer equation is introduced, and conditions are established to reduce the general equation of transfer to the specific equation used by the BITS model.

2.2.1.1 *Equation of Transfer.*— A pencil beam of monochromatic radiation of specific intensity (or simply, intensity) I_λ, is shown traversing a medium (figure 1). After traversing a thickness *ds,* the intensity in the direction of its propagation is weakened by an amount dI_λ, expressed mathematically as follows:

$$dI_\lambda = -k_\lambda \rho I_\lambda \, ds \qquad (1)$$

where

k_λ = the mass extinction coefficient
ρ = the density of the material.

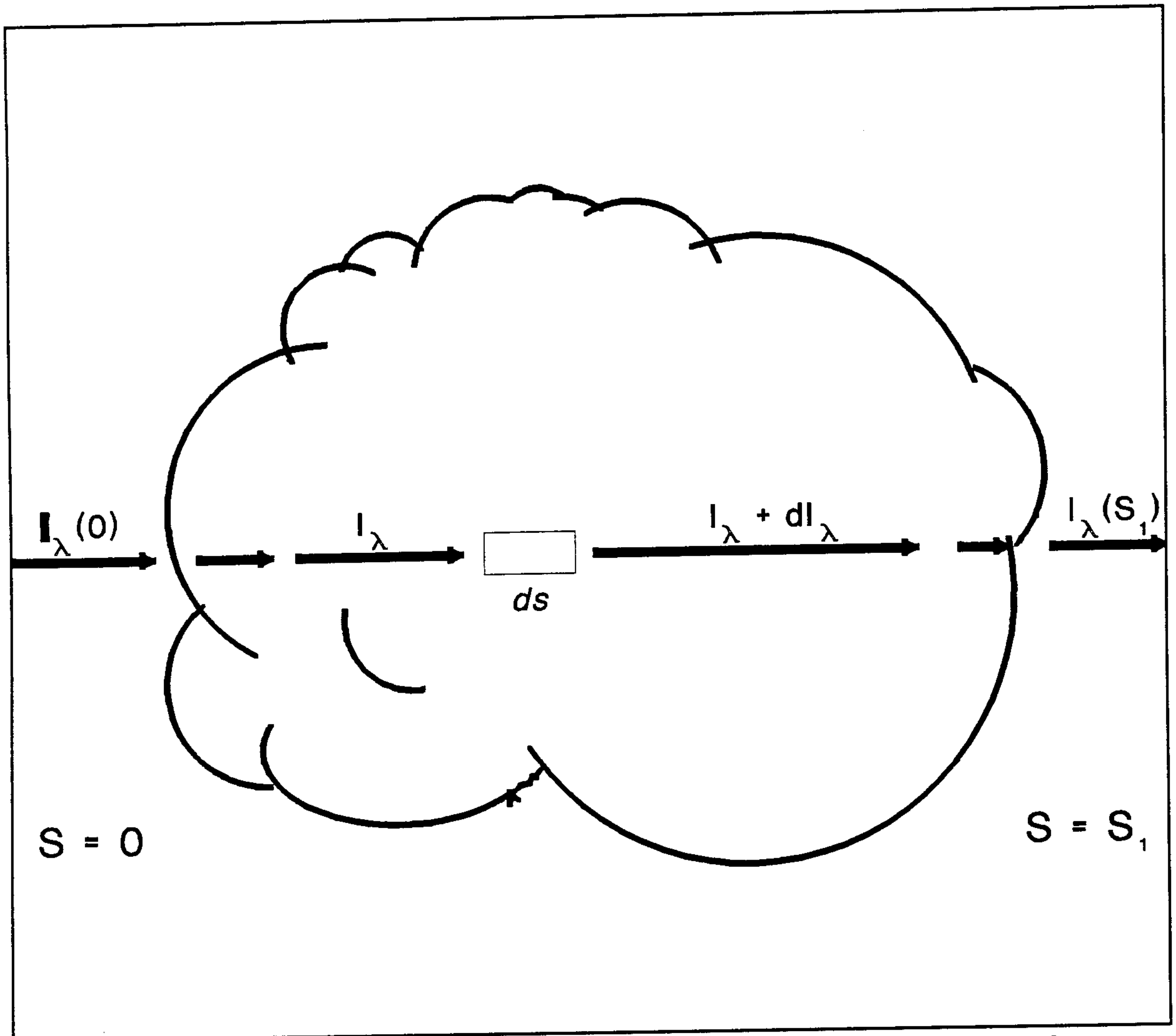

Figure 1. Reduction of specific intensity traversing an absorbing medium.

Because extinction of the radiation pencil can be the result of absorption and scattering by the medium, the mass extinction coefficient is the sum of the mass absorption and mass scattering coefficients, both of which are wavelength dependent.

The intensity of the radiation beam may be strengthened by emission of the material in the medium and/or multiple scattering of radiation from other directions into the path of propagation. The enhancement of intensity caused by emission and scattering is described as follows:

$$dI_\lambda = j_\lambda \rho ds \tag{2}$$

where

j_λ = the monochromatic source function coefficient.

Summing equations (1) and (2) accounts for the gains and losses in the radiant intensity:

$$dI_\lambda = -k_\lambda \rho I_\lambda ds + j_\lambda \rho ds. \tag{3}$$

The ratio of the source function coefficient to the mass extinction coefficient may be defined as the source function J_λ:

$$J_\lambda = \frac{j_\lambda}{k_\lambda}. \tag{4}$$

Equation (3) is rewritten as follows:

$$\frac{dI_\lambda}{k_\lambda \rho ds} = -I_\lambda + J_\lambda. \tag{5}$$

Equation (5) is recognized as the general form of the equation of transfer. When the equation is written in this manner, no coordinate system was imposed. Note the wavelength dependence of the equation.

2.2.1.2 *Beer's Law.*— For conditions in which emission and scattering are negligible, the source function becomes zero and the equation of transfer is written as follows:

$$\frac{dI_\lambda}{k_\lambda \ \rho ds} = -I_\lambda. \tag{6}$$

Letting the intensity at $s = 0$ be $I_\lambda(0)$, the emergent intensity at $s = s_1$ (see figure 1) is obtained by integrating equation (6):

$$I_\lambda(s_1) = I_\lambda(0) \exp\left(-\int_0^{s_1} k_\lambda \ \rho ds\right). \tag{7}$$

The integral appearing as the exponential argument in equation (7) is often referred to as the optical depth of the medium. For k_λ independent of path positions, the integral reduces to $-k_\lambda CL$ where

$$CL = \int_0^{s_1} \rho ds. \tag{8}$$

CL the path-integrated concentration is commonly calculated by Army smoke and obscuration models using simplified transport and diffusion algorithms. Rewriting equation (7) in terms of the mass extinction coefficient and CL yields the following expression:

$$I_\lambda(s_1) = I_\lambda(0) \exp\left(-k_\lambda \ CL\right). \tag{9}$$

Equation (9) is known as the Beer, Bouguer, or Lambert law and is referred to as Beer's law throughout. The use of Beer's law in broadband transmittance models can lead to misinterpretations of model results and erroneous conclusions by unwitting model users. These models ignore the wavelength dependence of equation (9) and the monochromatic wavelength dependence of Beer's law and use band-averaged mass extinction coefficients.

In the calculation of relative transmittance by these models, the attenuated intensity through smokes or obscurants is assumed to be referenced to the radiant intensity received at the sensor in clear air. Transmittance at a time t is defined as follows:

$$T_\lambda(t) = \frac{I_\lambda(t)}{I_\lambda(t_0)} = \exp\ (-k_\lambda\ CL) \tag{10}$$

where

$I_\lambda(t_0)$ = the radiant intensity at s_1 in the clear air
k_λ = the smoke and obscurant mass extinction coefficients
CL = the path-integrated concentrations.

It is important to note that this definition, also used in reporting transmittances recorded in smoke and obscurant field testing, is not an absolute transmittance.

2.2.1.3 *BITS.*— Most Army transmittance models assume that the wavelength dependence of mass extinction coefficient in Beer's law can be replaced by an average coefficient valid for a given spectral band. This assumption is based on the assertion that a single mean value mass extinction coefficient can be used for the spectral band of interest. For smokes or obscurants with mass extinction coefficient spectra that show little variation across the waveband, this assumption is reasonable. If the smoke or obscurant shows significant spectral variation of its mass extinction coefficient, the combined spectral characteristics of the system and atmosphere can result in actual transmittances quite different from those predicted by a wavelength-independent Beer's law.

BITS provides a transmittance model that accounts for the spectral characteristics of the system, atmosphere, and smoke or obscurant. The concept of relative transmittance is maintained throughout the development of the required mathematical algorithms. The contribution of the source function J_λ, along the path of propagation (see section 2.2.1.1) is assumed to be negligible. Effects such as beam geometry and field of view are not modeled, because only relative transmittance calculations are made.

Consider a source emitting or reflecting radiation, $S(\lambda)$. The source $S(\lambda)$ is equivalent to $I_\lambda(0)$ in equation (7). For any given wavelength, the radiation propagating along the line of sight is weakened by its interaction with the atmosphere. Allowing only for atmospheric transmittance, described by $A(\lambda)$, the monochromatic radiant energy received at R for wavelength λ is written as the product $S(\lambda)A(\lambda)$.

The receiver at R modifies the radiation before the incident power is converted into a signal by the receiver. The receiver can be an electronic instrument or the human eye. In general, the receiver consists of at least three major components that reduce the incoming signal: filters, optics, and detectors. For filter transmittance $F(\lambda)$, optics transmittance or spectral response $O(\lambda)$, and detector spectral response $D(\lambda)$, the resultant radiant intensity $S_R(\lambda)$ converted into a signal at R is expressed as follows:

$$S_R(\lambda) = S(\lambda)\ A(\lambda)\ F(\lambda)\ O(\lambda)\ D(\lambda). \tag{11}$$

The $S_R(\lambda)$ is equivalent to $I_\lambda(t_0)$ in equation (10) and represents the clear-air signal for monochromatic radiation. When radiation over an entire spectral band is considered, the total radiant intensity at R is given by the sum of all the monochromatic contributions, and is calculated by the following equation:

$$S_R(\Delta\ \lambda) = \int_0^\infty S(\lambda)\ A(\lambda)\ F(\lambda)\ O(\lambda)\ D(\lambda)\ d\lambda. \tag{12}$$

Equation (12) defines the clear-air signal used for reference in relative transmittances. The BITS model performs this integration for a specific waveband defined in terms of limits λ_1 and λ_2 (see section 4).

When a smoke or obscurant is introduced into the line of sight, an additional attenuation term must be included in equation (11). For the monochromatic signal at R, this term is given by Beer's law. The addition of this term to equation (11) results in the following expression for the radiant intensity at R with smoke:

$$S_{SR}(\lambda) = \exp(-k_\lambda CL)\, S(\lambda)\, A(\lambda)\, F(\lambda)\, O(\lambda)\, D(\lambda). \tag{13}$$

The term $S_{SR}(\lambda)$ is equivalent to $I_\lambda(t)$ in equation (10).

Integrating over all wavelengths yields the total signal at R:

$$S_{SR}(\Delta\lambda) = \int_0^\infty \exp(-k_\lambda CL)\, S(\lambda)\, A(\lambda)\, F(\lambda)\, O(\lambda)\, D(\lambda)\, d\lambda. \tag{14}$$

With equations (12) and (14), the broadband relative transmittance is defined as follows:

$$T_{\Delta\lambda} = \frac{\int_0^\infty \exp(-k_\lambda CL)\, S(\lambda)\, A(\lambda)\, F(\lambda)\, O(\lambda)\, D(\lambda)\, d\lambda}{\int_0^\infty S(\lambda)\, A(\lambda)\, F(\lambda)\, O(\lambda)\, D(\lambda)\, d\lambda} \tag{15}$$

where the numerator is the source signal at R attenuated by the smoke or obscurant, and the denominator is the clear-air signal at R.

The range in value for the relative transmittance defined by equation (15) is $0 < T_{\Delta\lambda} \leq 1.0$. In the case that no smoke is present along the path of propagation $CL = 0$, the exponential term becomes unity, and equation (15) reduces to a value of 1.0. For a very large *CL*, the exponential approaches zero and relative transmittance becomes vanishingly small.

In the case of a wavelength-independent mass extinction coefficient, the exponential term is moved outside of the integral, and equation (15) reduces to the Beer's law expression for the spectral band. In the past, most Army transmittance models have assumed that the exponential in equation (15) can be moved outside the integral by defining a wavelength-independent mass extinction coefficient that represents a mean value for the spectral band. For mass extinction coefficient functions that show little variation with wavelength, this assumption works reasonably well. Equation (15) shows that for mass extinction coefficients that vary significantly across the spectral band, this approach is not valid.

The BITS model uses equation (15) to calculate relative transmittances. This formulation does not account for factors such as nonlinear system effects or path radiance.

For conditions in which path radiance can be ignored or for analysis of transmissometer systems that chop their sources to remove path radiance contributions*, BITS is expected to be as accurate as the characterization of the spectral properties of the smoke or obscurant, atmosphere, and system. For conditions of significant path radiance, additional algorithms that consider the source function must be employed to determine an observed transmittance (signal) at the detector.

**To determine relative transmittance, a transmissometer must establish values for the 100 and 0 percent radiation levels that it will use in measuring the relative value. Even when the source is not radiating, path radiance in the line of sight falls on the detector, causing a nonzero radiation signal. To eliminate the path radiance from the calculation (making what the detector sees with the source off the zero level), the source is chopped, or blocked, at some frequency. This signal interruption is often accomplished by means of a rotating notched wheel placed in front of the source. The receiver electronics locks in to this frequency and removes the path radiance signal from the measurement.*

2.2.2 *Comparison of Beer's Law and Band-Integrated Transmittance Calculations*

This section presents a hypothetical example to illustrate the difference between Beer's law and band-integrated approaches. All system components, including the atmosphere, are taken as spectrally flat and normalized to unity in the 3- to 5-μm region. These values reduce the integrand in the numerator of equation (15) to just the exponential (obscurant) term and the integrand in the denominator to unity. Note that the value of the integral in the denominator of equation (15) is not unity.

The product of the system components outside of this spectral band is assumed to be zero, thereby allowing the limits of integration to be 3 to 5 μm. For the integrands to be zero, it is sufficient for only one system component of equation (15) to be zero outside of the 3- to 5-μm region.

The mass extinction coefficient for the hypothetical obscurant of this example, as shown in figure 2, is defined as a step function in the 3- to 5-μm band. To use Beer's law to calculate transmittance for this obscurant, a band-averaged mass extinction coefficient is required. The band average is easily computed for the step function and is found to be 0.625. The band-averaged value is shown as a horizontal line in figure 2.

Calculation of Beer's law transmittances is straightforward and is accomplished by applying equation (10). The mass extinction coefficient k_λ is replaced by the band-averaged value of 0.625. Table 1 presents a set of Beer's law transmittances as a function of CL.

The band-integrated transmittances must be calculated using equation (15). This calculation is accomplished numerically and easily for the example at hand.

For the denominator with the integrand equal to unity, the area described by the integral between the limits of 3 to 5 μm has a value of 2 (area = 1 * (5 - 3)).

The integrand curves for the numerator in equation (15) are described by the exponential term and, because of the form of the hypothetical mass extinction coefficient spectral dependence, are step functions. Numerator integrands, using the hypothetical mass extinction coefficient curve, have been computed for CL values of 0.25, 2.0, and 8.0. Figure 3 shows the integrands. For reference, integrand curves for the mean mass extinction coefficient 0.625 are also plotted in the figure.

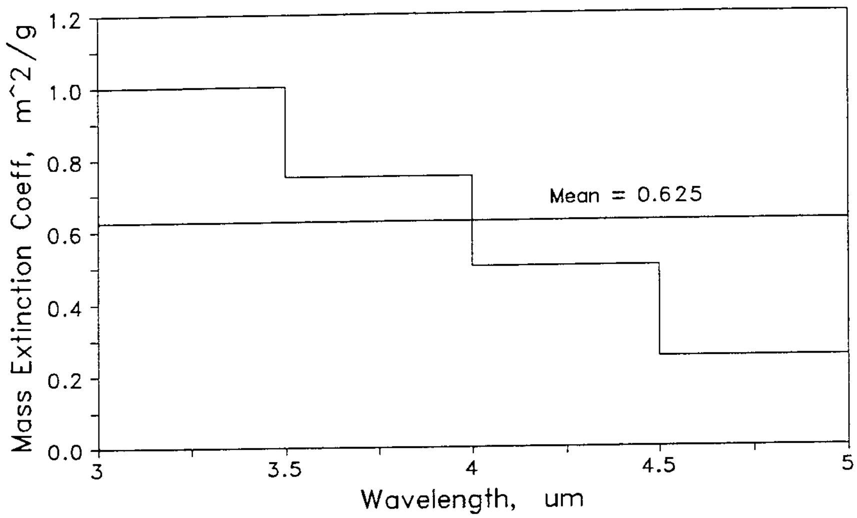

Figure 2. Hypothetical mass extinction coefficient for the 3- to 5-μm band. The mean value for the band is shown for reference.

Table 1. Beer's law transmittances $<k\lambda> = 0.625$

CL	Transmittance
0.0	1.000
0.25	0.855
0.50	0.732
1.0	0.535
2.0	0.287
4.0	0.082
8.0	0.007

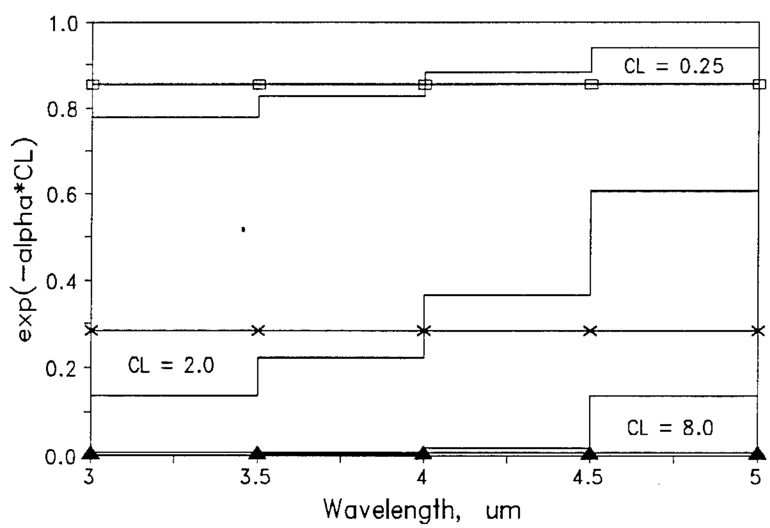

Figure 3. Integrand curves described by the numerator of equation (15) using the mass extinction coefficient step function shown in figure 2. Values are calculated for CL = 0.25, 2.0, and 8.0. The horizontal curves with symbols are the integrands for the mean mass extinction coefficient.

Transmittance, as defined by equation (15), is the ratio of the area computed in the numerator to the area computed in the denominator. If CL is 0.0, the integrand curve in the numerator is 1.0, just as in the denominator, and the area for both is equal to 2. The resulting ratio (relative transmittance) is 1.0. When CL is nonzero, the ratio is less than 1.0. Table 2 presents the areas under each of the integrands in figure 3 and the resulting transmittances computed from the ratios.

Table 2. Areas under integrand curves

Waveband	CL 0.25		CL 2.0		CL 8.0	
	step[1]	mean[2]	step	mean	step	mean
3-3.5	0.389	0.428	0.068	0.143	0.000	0.003
3.5-4.0	0.415	0.428	0.112	0.143	0.001	0.003
4.0-4.5	0.441	0.428	0.184	0.143	0.009	0.003
4.5-5.0	0.470	0.428	0.303	0.143	0.068	0.003
area sum:	1.715	1.711	0.666	0.573	0.078	0.013
ratio: (transmittance)	0.857	0.855	0.333	0.287	0.039	0.007

[1]*step = areas under wavelength-dependent mass exinction coefficient curves*
[2]*mean = areas under band-averaged mass extinction coefficient curves*

Table 2 shows that, for a given CL, the areas under the wavelength-dependent mass extinction coefficient integrand and the mean mass extinction coefficient integrand differ. If the mass extinction coefficient has significant spectral variability in the waveband of interest, the use of a band-averaged coefficient does not produce the correct transmittance, regardless of the spectral characteristics of the atmosphere and/or system.

As a consistency check, it is worthwhile comparing the transmittances calculated numerically in table 2 for the band-averaged coefficient with the transmittances calculated using Beer's law in table 1. These values are identical because equation (15) reduces to Beer's law for wavelength-independent mass extinction coefficients.

Figure 4 compares the transmittances calculated by the Beer's law approach and the band-integrated approach for the hypothetical obscurant. As with some real obscurants, significant differences between the Beer's law and band integrated transmittances begin to occur for transmittances less than 10 percent.

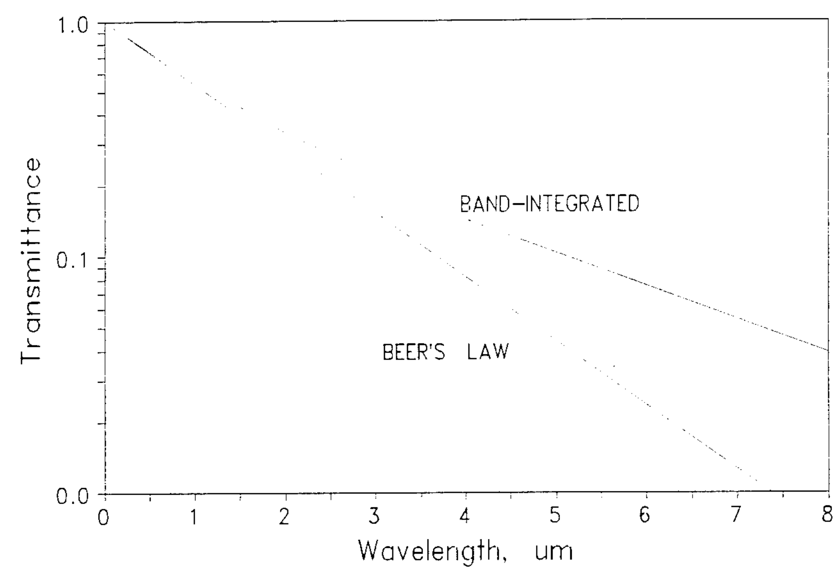

Figure 4. Comparison of Beer's law and band-integrated transmittances calculated for the example hypothetical obscurant.

2.3 Software Overview

A brief description of the BITS module program is given in the following sections.

2.3.1 BITS Module Structure

The BITS module consists of a main subroutine that calls other subroutines. In addition, the software has 16 subroutines and 4 function routines. Figure 5 displays the relationship of the BITS routines to one another.

The BITS module is written according to EOSAEL specifications and uses card images for data input, which is consistent with earlier modules. The first four columns of every input card image are reserved for a four-letter card identifier; columns five through eight are available for user labels or identifiers. All cards have the standard format (A4,6x,7(F10.3)). The format for the data cards was modified to allow more data points per card than allowed by the standard format.

In keeping with EOSAEL philosophy, the data card image input is nearly order independent. However, these card sequences are order dependent because of the nature of data input for system characterizations.

Section 4 gives the card images. Section 5 gives the descriptions and inputs and outputs for three sample runs.

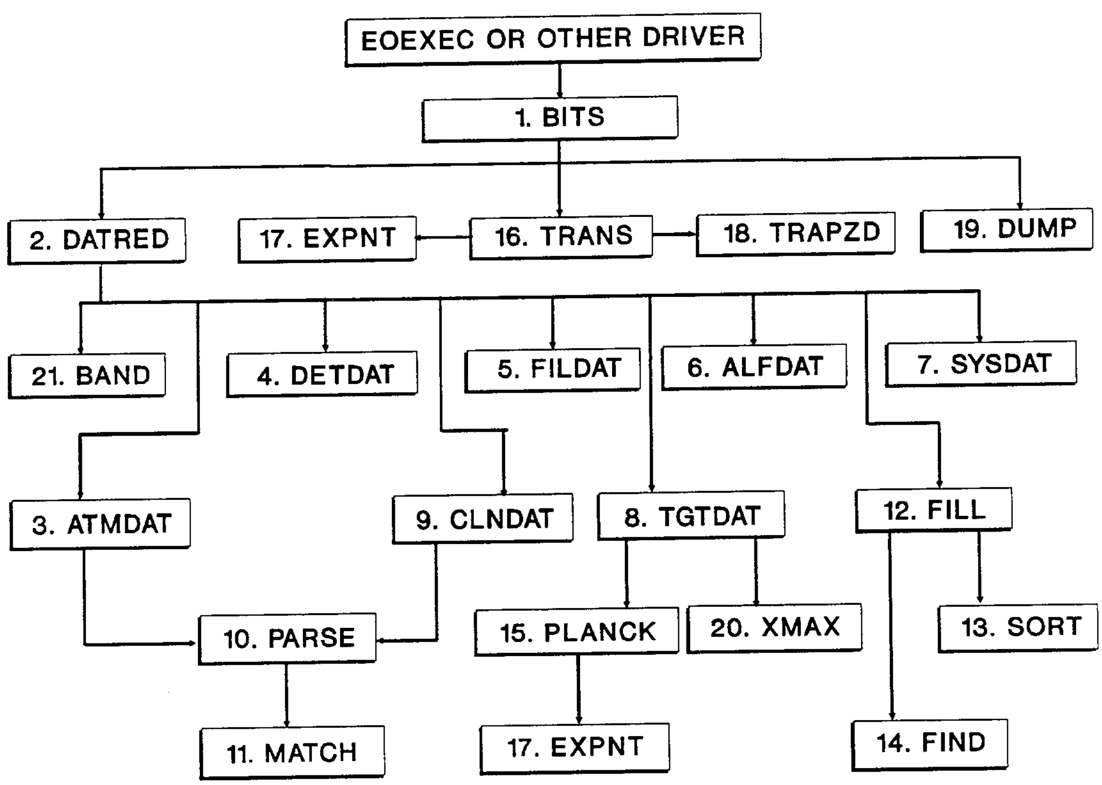

Figure 5. BITS module structure. This diagram is not a flowchart, but a hierarchy of calls showing subroutine relationships.

2.3.2 *Subroutine Descriptions*

This section presents brief descriptions of BITS subroutines and function routines to provide a general knowledge of the individual component roles. The paragraph numbers assigned to each routine description correspond to the number displayed with the routine name given in figure 5.

1. Subroutine BITS directs subroutine calls for input (DATRED), processing (TRANS), and output (DUMP) whether the BITS model is used as an EOSAEL module or as a stand-alone program. This subroutine monitors the logical error flags and passes them on to the driver after alerting the user when an error is detected.

2. Subroutine DATRED returns a set of arrays describing the spectral responses of the detector, filter, instrument, atmosphere, target, and obscurant as functions of wavelength. These data are entered as transmittance-wavelength pairs or spectral response-wavelength pairs. DATRED reads the input cards and provides basic error-trapping logic.

Data for system characterization need not be input with the same wavelength resolution. In fact, the wavelength resolution need not be constant for a given input data set. These arrays are all adjusted to the user-specified wavelength resolution through linear interpolation (subroutine FILL) after the data are read into the module.

In addition to establishing uniform wavelength resolution, the module logic is set up to sort these input data pairs to ensure that data points are sequential in wavelength. This feature is particularly advantageous to the user who enters data through the card images. Should the user decide after entering a significant number of transmittance-wavelength data pairs that additional resolution is required for more accurate interpolation, or that some data pairs have been unintentionally omitted, additional data pairs can be appended to the end of the data input set.

The source of the input data is determined by options designated in the card input. Based on the options selected, data are acquired from one of three sources: the input card deck, archived data stored in the BITS code, or external data files. The last option, external data files, is only available for atmospheric transmittance and CL data.

3. Subroutine ATMDAT returns an array filled with atmospheric transmittance values, argument A( ) in equation (15), as a function of wavelength. Depending on the option selected by the user, the atmospheric data are read into the array from the data cards, from an EOSAEL LOWTRN module output file or a user-supplied input file.

4. Subroutine DETDAT returns an array, argument D( ) in equation (15), filled with detector response-wavelength data pairs. Depending on the option selected by the user, data for the detector are input via the card images or from a BITS archive for standard detectors.

5. Subroutine FILDAT fills the filter transmittance-wavelength data pair array, argument F( ) in equation (15). Although there are no BITS archived filter response functions, the capability to employ such functions at a future date is built into the code logic.

6. Subroutine ALFDAT fills a mass extinction coefficient versus wavelength array, argument k in equation (15). Mass extinction coefficient spectra for white phosphorus (WP), fog oil, and diesel oil are archived in BITS. The user may also choose to enter mass extinction coefficient data.

7. Subroutine SYSDAT allows the user to incorporate additional system/instrumental spectral characterizations, such as instrument optics, into the calculations. Should multiple characterizations be required, such as accounting for two mirror surfaces, the user must compute the combined spectral response of these components and input the result as a function of wavelength. This is argument O( ) in equation (15).

Spectral responses for silver, aluminum, and gold surfaces from 0.2 to 10.0 μm are included as user options in the BITS data archive.

8. Subroutine TGTDAT fills the target spectral signature array, argument S( ) in equation (15). Target signatures as a function of wavelength may be input via card images. The target signature with the blackbody option may be selected by specifying the target temperature. A quartz lamp operating at 3000 K is also available as a user option.

9. Subroutine CLNDAT fills the CL array, argument CL in equation (15), with CLs and a user-selected index, such as "time" or "line-of-sight identifier." These data may be input through a COMBIC output file, card images, or a user-supplied data file. CL data must be supplied for BITS to execute.

10. Subroutine PARSE parses a character string into individual tokens and returns the starting and ending array indices of the requested token. This subroutine is used by ATMDAT and CLNDAT subroutines when EOSAEL files from LOWTRN and COMBIC are specified as BITS input. Subroutine PARSE calls function routine MATCH.

11. Function routine MATCH determines if a character matches a character in a string. The function routine is used by subroutine PARSE to determine if a column-delimiting character has been read. The routine returns a "1" if a match is found and a "0" if no match is found. PARSE and MATCH locate the start of required data in EOSAEL files that have an unknown number of information lines at the beginning of the file.

12. Subroutine FILL interpolates the input system spectral response arrays to the wavelength resolution specified by the user. The subroutine calls subroutine SORT to ensure that the arrays are in ascending order by wavelength. Following the SORT calls, subroutine FILL calls subroutine FIND to aid in the interpolation of the data arrays.

13. Subroutine SORT sorts the system characterization arrays in ascending order by wavelength. It returns a sorted array. The subroutine allows the user to append input data sets with additional transmittance-wavelength pairs or response-wavelength pairs without reordering the input files or card images.

14. Subroutine FIND is used in the interpolation scheme of subroutine FILL to locate input data points adjacent to the desired wavelength point. It returns the index J and J+1 of the points in the array, which are needed to interpolate to the desired point.

15. Function PLANCK computes Planck blackbody radiation in units of W m^{-2} μm^{-1} sr^{-1}. The values are computed as a function of wavelength based on the user-defined temperature.

16. Subroutine TRANS computes transmittance in three ways. The main purpose of the BITS module is to compute the waveband-integrated transmittance for a given CL through numerical integration of equations (12) and (14) described in section 2.2.1.3.

For comparison, TRANS calculates the transmittances using the band-averaged mass extinction coefficient and transmittance with the band-integrated extinction coefficient for an ideal system. The ideal system is defined such that target, atmosphere, detector, filter, and all other system optics are spectrally invariant in the waveband and are set to unity. Only the smoke/obscurant is assumed to have spectral variation through the waveband. (For band-averaged extinction coefficients, the system components drop out of the calculation; see equation (15), section 2.2.1.3.)

This subroutine loops over all CL values requested by the user.

17. Function EXPNT returns the value of the FORTRAN DEXP function, but with overflow and underflow protection. If an overflow or underflow is detected, the user is given a warning message and the return value is set to a minimum or maximum value. The minimum and maximum arguments allowed in the function routine are -170 and +170, respectively. For arguments exceeding these limits, the function returns 0.0 (minimum) and 10^{38} (maximum).

18. Function TRAPZD performs numerical integration using a trapezoid integration algorithm. It is called by subroutine TRANS.

19. Subroutine DUMP writes out the results of the transmittance calculations as well as the interpolated system spectral response arrays. These data may be plotted with the plot packages available to the user.

20. Function XMAX returns the maximum value in an array. It is used by the subroutine TGTDAT to normalize the target spectral signatures.

21. Subroutine BAND performs error trapping on the waveband parameters established by the user. It also returns an array of wavelengths based on the wavelength resolution and the waveband definition specified by the user. The interpolation of the system characterization arrays is based on the wavelength array created in subroutine BAND.

2.4 Error Checking

The BITS module performs two types of error checking during execution. First, inputs are checked for validity. Options specified on various option cards are checked to see if the values are within the allowed range. For example, the IOPTN parameter can only take the values of 0.0 or 1.0. Any other value for this parameter results in an error message and program termination. Second, divide-by-zero error conditions are prevented by BITS. See section 3.4.1 for error and other messages issued by BITS.

3. Caveats

This section includes descriptions of module limitations and assumptions, as well as a listing of error messages and methods for determining whether the module ran successfully.

3.1 Grade of Software

The BITS module software is research grade, according to the definitions established in the EOSAEL92 Executive Summary, Volume 1, and the EOSAEL Executive User's Guide, Volume 2. Research-grade software describes phenomena based on a physical or meteorological theory limited to evaluations in the field or laboratory.

3.2 Module Limitations

Certain limits concerning modeled instrumentation operations are implicit in the BITS module. Be aware of these limitations when employing BITS, to avoid module misuse or misinterpretation of module results.

A major assumption made by the BITS module is that the instruments modeled are linear in operation. BITS does not model instrument electronics. Therefore, the effects of nonlinear electronics, such as amplifiers, cannot be studied using the module as it exists. In addition, detector power-to-voltage characterizations are not included in the current BITS module algorithms. The assumption is that the incident power on the detector is such that the detector is operating on the linear portion of the power-to-voltage curve.

The effects of path radiance, including spontaneous, thermal, or stimulated emission and multiply scattered radiation, are not modeled by the current version of BITS. For systems, such as transmissometers, that chop their sources, path radiance is removed before a transmittance is computed. If the path radiance does not force the detector to operate on the nonlinear portion of the power-to-voltage curve, the BITS calculations of observed relative transmittance are valid.

For systems, such as imagers, that do not chop sources (targets), the effects of path radiance may become important. When modeling such systems, keep in mind that transmittance alone generally does not predict system performance.

The effects of system field of view or source geometries are not modeled by BITS. Field of view could play an important role in determining whether the system is operating linearly, particularly if the background is a strong source of radiation and the field of view is large. Source geometries, such as intensity distribution of the source beam, could effect the overall system output. If either field of view or source geometry is important to an analysis, BITS should be employed with caution.

Finally, BITS does not model atmospheric turbulence. The signal from the source is assumed to be invariant over the time of observation for a given CL. If an analysis of system performance in conditions producing a fluctuating signal over an observation time period is required, the current version of BITS is inadequate.

3.3 User Cautions

The BITS module requires that care and understanding be exercised in choosing certain types of parameters. Particularly notable in this regard are the waveband limits and waveband resolution specified in the BAND card (see section 4). The following paragraphs discuss some of the considerations to keep in mind when specifying these parameters.

3.3.1 Waveband Limits

Caution must be exercised in coordinating the waveband specified integration with wavebands covered by the system spectral response data sets. On the BAND card, the limits λ_1 and λ_2 are specified for the waveband over which BITS is to perform the band-integrated calculations. If any spectral response data sets, specified by the user as data pairs or called up from an archived BITS data file, are undefined within limits specified on the BAND card, BITS issues an error message and aborts. BITS does not perform extrapolation to expand system response data to cover the specified waveband, because such extrapolations could lead to erroneous representations of system characteristics. To avoid these error messages when using system spectral response data that do not cover the entire waveband, data points may be added at the endpoints of the specified waveband if there is justification for such values.

The converse problem arises if all system response curves include data points outside the specified wavelength limits. (If any one of the responses is zero outside the limits this problem does not arise.) If there is significant system response outside the waveband limits (whether or not these data points are given to BITS), the module performs the calculations without error messages. However, be aware that such calculations may not correctly represent the actual performance of the system. The user must decide if system sensitivity outside of the waveband integration limits is significant or if it can safely be ignored.

3.3.2 Waveband Resolution

The mathematical accuracy of the band-integrated transmittance calculations depends on the spectral resolution of the system components defined by the user. The resolution specified on the BAND card should match the lowest component resolution. If the specified resolution is lower than the lowest component resolution, the calculations do not take full advantage of the data available. If the resolution is higher than the lowest component resolution, no advantage is gained, because BITS must interpolate to the resolution specified using the data available.

3.4 Error Detection

During the execution of the BITS module, BITS may issue various messages. These messages fall into three categories: error messages, warning messages, and other messages. Error messages are always accompanied by termination of the module. Warnings and other messages are not accompanied by termination. Sections 3.4.1 and 3.4.2 list the BITS messages and their meanings.

Error messages are always written to a file named BITERR on unit 7. This file is always created, even if no errors occur. All BITS messages, including error messages, are also written to the normal BITS output file (on unit 6). If an error has occurred during the execution of BITS, the normal output file contains the error messages as well as any results BITS was able to complete before the error occurred. Warnings and other messages only appear in the normal BITS output file and not in BITERR.

If no error occurs while running BITS, the BITERR file is created but remains empty. If a file called BITERR exists before BITS is run, its contents are erased and replaced with error messages (if any) from the current BITS run. To maintain copies of the error message files, change the current BITERR filename before each new BITS run.

3.4.1 *Error Messages*

The error messages that BITS produces are intended to be a diagnostic to determine where an error occurred and how to prevent its recurrence. The following is a list of the error messages BITS can produce, along with explanations of each.

BITS MODULE: ERROR! CARD DECK ON UNIT IOIN HAS NOT BEEN CONNECTED

This error message appears when the input unit for reading the input card deck has not been opened. In BITS, as with other EOSAEL modules, the primary input unit is FORTRAN unit 5. Unit 5 is assigned to the variable IOIN. The BITS or EOEXEC driver should open and verify unit 5 before BITS is invoked. On UNIX and some other systems, FORTRAN unit 5 is equivalent to stdin and is pre-opened by the operating system. If this error occurs, check to see that FORTRAN unit 5 was not inadvertently closed or reassigned before the BITS module was called.

BITS MODULE: ERROR! ERROR IN TRYING TO OPEN UNIT IOOUT WHICH WAS NOT PREVIOUSLY CONNECTED

This error message appears when the output unit for writing the BITS results was not opened and BITS cannot open the file itself. When BITS finds that output unit 6 (stored in variable IOOUT) was not opened, BITS tries to open it with the filename BITOUT. If BITS cannot open this file for some reason, the above error message results and the module aborts. As with the input file, the BITS or EOEXEC driver should open unit 6 before BITS is invoked. On UNIX and some other systems, FORTRAN unit 6 is equivalent to stdout and is pre-opened by the operating system. If this error occurs, check to see that FORTRAN unit 6 was not inadvertently closed or reassigned before the BITS module was called. If BITS cannot take corrective action by opening unit 6 itself, it may be that another file already exists with the filename BITOUT.

BITS MODULE: ERROR! INVALID OPTION CARD: [card name]

The name of the card in which the error was detected is inserted for [card name].

This error message appears when one of the cards on which options are specified is invalid. Usually this type of error occurs when the card name is misspelled. It also may mean that the user included data cards in the input file without the corresponding options card, for example, including a series of EXTR cards without first placing an ALFA card. Because the card name is listed in the message, determining the cause of the error should not be a problem.

BITS MODULE: ERROR! INVALID EXTR CARD OR MISSING EXTQ CARD

BITS MODULE: ERROR! INVALID ATMR CARD OR MISSING ATMQ CARD

BITS MODULE: ERROR! INVALID TGTR CARD OR MISSING TGTQ CARD

BITS MODULE: ERROR! INVALID DETR CARD OR MISSING DETQ CARD

BITS MODULE: ERROR! INVALID FILR CARD OR MISSING FILQ CARD

BITS MODULE: ERROR! INVALID SYSR CARD OR MISSING SYSQ CARD

BITS MODULE: ERROR! INVALID CLNR CARD OR MISSING CLNQ CARD

One of these error messages appears when an expected data card (EXTR, ATMR, etc.) is invalid or when one of the quit cards (EXTQ, ATMQ, etc.) is missing. This type of error usually results from a misspelling or an oversight and can be easily remedied.

BITS MODULE: ERROR! INVALID UNITS OPTION (IUNIT): [value]

The value read in from the input card deck is inserted for [value].

The error message appears when the IUNIT option on one of the option cards is invalid. This error occurs when a value other than 0.0 or 1.0 is chosen.

BITS MODULE: ERROR! ILLEGAL OPTION (IOPTN) IN ATMO CARD: [value]

BITS MODULE: ERROR! ILLEGAL OPTION (IOPTN) IN DETC CARD: [value]

BITS MODULE: ERROR! ILLEGAL OPTION (IOPTN) IN ALFA CARD: [value]

BITS MODULE: ERROR! ILLEGAL OPTION (IOPTN) IN TRGT CARD: [value]

BITS MODULE: ERROR! ILLEGAL OPTION (IOPTN) IN CONL CARD: [value]

BITS MODULE: ERROR! ILLEGAL OPTION (IOPTN) IN SYSM CARD: [value]

BITS MODULE: ERROR! ILLEGAL OPTION (IOPTN) IN FILT CARD: [value]

The value read in from the input card deck is inserted for [value].

One of these error messages appears when the IOPTN parameter on one of the option cards is invalid. Review the documentation to see which values of IOPTN are valid for a particular option card.

BITS MODULE: ERROR! INCOMPLETE CARD DECK

This error message means that some necessary cards were not specified. The user should review the input deck to determine which of the required cards is missing. The input specifications in section 4.2 list the required and optional cards.

BITS MODULE: ERROR! MISSING DONE OR GO CARD

This error message is self-explanatory. A DONE or GO card must terminate each set of input cards.

BITS MODULE: ERROR! ERROR ON READ! CHECK CARD DECK FOR INVALID CHARACTERS

This error message means that a non-numeric character was found in one of the numeric fields of one of the cards, usually because of a typing error.

BITS MODULE: ERROR! CANNOT OPEN USER OR LOWTRN DATA FILE: [filename]

The filename specified in the input card deck is inserted for [filename].

This error message means that the IOSTAT parameter of the FORTRAN OPEN statement flagged an error when trying to open the file. This is an error flagged by the operating system and probably means that the file specified does not exist. When specifying a filename in the input card deck, the full path name should be given if the file is not in the current directory. Also, filenames and path names should conform to the rules of the operating system.

BITS MODULE: ERROR! CANNOT OPEN USER OR COMBIC DATA FILE: [filename]

The filename specified in the input card deck is inserted for [filename].

This error message means that the IOSTAT parameter of the FORTRAN OPEN statement flagged an error when trying to open the file. This is an error flagged by the operating system and probably means that the file specified does not exist. When specifying a filename in the input card deck, the full path name should be given if the file is not in the current directory. Also, filenames and path names should conform to the rules of the operating system.

BITS MODULE: ERROR! CANNOT LOCATE TRANSMITTANCE DATA IN LOWTRN FILE: [filename]

The filename specified in the input card deck is inserted for [filename].

When transmittance data are to be read in from a LOWTRN file, BITS locates the data by searching the file for the header "CM-1 MICRONS TRANS." If the header cannot be located, it may be missing from the file. The current version of the LOWTRN module may have a different way of formatting its output from that expected by BITS. BITS relies on the consistency of the LOWTRN output in this regard. The best remedy may be to tell BITS that the transmittance data is coming from the user's data file and specify the number of headers to skip and the relevant column numbers.

BITS MODULE: ERROR! CANNOT LOCATE CL DATA IN COMBIC FILE: [filename]

The filename specified in the input card deck is inserted for [filename].

When CL data are to be read in from a COMBIC file, BITS locates the data by searching the file for the header "(G/M**2)". If the header cannot be located, it may be missing from the file, or the current version of the COMBIC module has a different way of formatting its output from that expected by BITS. BITS relies on the consistency of the COMBIC output in this regard. The best remedy may be to tell BITS that the CL data is coming from the user's data file and specify the number of headers to skip and the relevant column numbers.

BITS MODULE: ERROR! INVALID COLUMN SPECIFICATION IN ATMO CARD

This error message appears when a column number of less than or equal to zero has been specified for a transmittance data file. The first column of a data file is column 1.

BITS MODULE: ERROR! INVALID COLUMN SPECIFICATION IN CONL CARD

This error message appears when a column number of less than or equal to zero has been specified for a CL data file. The first column of a data file is column 1.

BITS MODULE: ERROR! CANNOT OPEN [filename] SINCE LOUNIT IS ALREADY ASSIGNED

BITS uses unit 12 (LOUNIT) for the LOWTRN file or the user's transmittance data file. This error message means that unit 12 cannot be opened for this purpose because it has been previously opened. If this error occurs, check to see that FORTRAN unit 12 was not inadvertently reassigned before the BITS module was called.

BITS MODULE: ERROR! CANNOT OPEN [filename] SINCE NCLIMT IS ALREADY ASSIGNED

BITS uses unit 8 (NCLIMT) for the COMBIC file or the user's CL data file. This error means that unit 8 cannot be opened for this purpose because it was previously opened. If this error occurs, check to see that FORTRAN unit 8 was not inadvertently reassigned before the BITS module was called.

BITS MODULE: ERROR! BB TEMP IS < = ABSOLUTE ZERO, CHECK SPECIFICATION IN TRGT CARD

This error message is self-explanatory and appears when a blackbody temperature less than or equal to -273.16 °C is specified. The BTMP option on the TRGT card requires a temperature in degrees Celsius.

BITS MODULE: ERROR! MAXIMUM TARGET SIGNAL < = 0.0

This error message appears when the largest relative target signal within the waveband specified is less than or equal to zero. This error indicates a problem in the module code.

BITS MODULE: ERROR! USER-DEFINED WAVEBAND DOES NOT MATCH WITH EXTINCTION RESPONSE DATA

BITS MODULE: ERROR! USER-DEFINED WAVEBAND DOES NOT MATCH WITH ATMOSPHERE RESPONSE DATA

BITS MODULE: ERROR! USER-DEFINED WAVEBAND DOES NOT MATCH WITH TARGET RESPONSE DATA

BITS MODULE: ERROR! USER-DEFINED WAVEBAND DOES NOT MATCH WITH DETECTOR RESPONSE DATA

BITS MODULE: ERROR! USER-DEFINED WAVEBAND DOES NOT MATCH WITH FILTER RESPONSE DATA

BITS MODULE: ERROR! USER-DEFINED WAVEBAND DOES NOT MATCH WITH SYSTEM RESPONSE DATA

One of these error messages appears when one of the components does not entirely cover the wavelength interval defined in the BAND card. (System response for all wavelengths within the band must be specified even if the response is zero--see section 3.3.) BITS does not extrapolate response functions to cover the waveband (see section 3.3.1). When this error occurs, the specification for the band interval should be changed, or wavelengths to the response function of the component in question should be added.

BITS MODULE: ERROR! THE EXTINCTION HAS ONE OR ZERO VALID DATA POINTS SPECIFIED

BITS MODULE: ERROR! THE ATMOSPHERE HAS ONE OR ZERO VALID DATA POINTS SPECIFIED

BITS MODULE: ERROR! THE TARGET HAS ONE OR ZERO VALID DATA POINTS SPECIFIED

BITS MODULE: ERROR! THE DETECTOR HAS ONE OR ZERO VALID DATA POINTS SPECIFIED

BITS MODULE: ERROR! THE FILTER HAS ONE OR ZERO VALID DATA POINTS SPECIFIED

BITS MODULE: ERROR! THE SYSTEM HAS ONE OR ZERO VALID DATA POINTS SPECIFIED

One of these error messages appears when BITS finds only one or zero valid data points for the response function of a given component. When BITS finds duplicate wavelengths in the input for a given component, the second wavelength and its response value are ignored. When BITS finds a component response value less than 0.0 or greater than 1.0, that value is ignored (except for the target component). One of these error messages results if the number of response values remaining is one or zero. Specify all response functions (except for target) as normalized values between 0.0 and 1.0. The response values for the target are normalized in the code. If this error results for the target component, it probably means that almost all the wavelengths were the same and, therefore, were ignored.

BITS MODULE: ERROR! CLEAR-AIR TRANSMITTANCE <= 0.0. CHECK FOR A NULL TRANSMITTANCE ACROSS WAVEBAND

This error message appears if one of the components was specified as completely opaque across the waveband (the response values are all 0.0). Review the input card deck to determine if any components were specified with all 0.0 response values within the waveband.

BITS MODULE: ERROR! WAVEBAND CONTAINS TOO MANY INCREMENTS

The maximum number of increments allowed for a waveband is 401. Adjust either the waveband limits or increment so that no more than 401 increments result.

BITS MODULE: ERROR! WAVELENGTH RESOLUTION (DELWV) TOO SMALL OR NOT SPECIFIED

This error message appears when the wavelength increment DELWV is very near zero or has not been specified on the BAND card.

BITS MODULE: ERROR DETECTED IN SUBROUTINE DATRED

BITS MODULE: ERROR DETECTED IN SUBROUTINE TRANS

BITS MODULE: ERROR DETECTED IN SUBROUTINE DUMP

BITS MODULE: ERROR DETECTED IN SUBROUTINE ALFDAT

BITS MODULE: ERROR DETECTED IN SUBROUTINE ATMDAT

BITS MODULE: ERROR DETECTED IN SUBROUTINE TGTDAT

BITS MODULE: ERROR DETECTED IN SUBROUTINE DETDAT

BITS MODULE: ERROR DETECTED IN SUBROUTINE FILDAT

BITS MODULE: ERROR DETECTED IN SUBROUTINE SYSDAT

BITS MODULE: ERROR DETECTED IN SUBROUTINE CLNDAT

BITS MODULE: ERROR DETECTED IN SUBROUTINE FILL

These error messages inform the user where in the code an error was detected and are always accompanied by a diagnostic error message. A number of these error messages usually result when an error is detected. These messages reveal how a particular error propagated through the code.

BITS MODULE ABORTED.

This message accompanies any of the error messages. All error messages are followed by program termination.

3.4.2 *Warnings and Other Messages*

BITS alerts the user to certain possible problems when the module is run. Unlike the problems that cause error messages, however, these problems do not result in program termination.

BITS MODULE: MESSAGE: UNIT IOOUT NOT PREVIOUSLY CONNECTED. OUTPUT DIRECTED TO FILE: BITOUT

This message alerts the users that output unit 6 was not pre-opened by the driver or operating system. In this event, BITS opens unit 6 itself and the output file is named BITOUT.

BITS MODULE: WARNING: NAME CARD OUT OF SEQUENCE

This message appears when a NAME card was encountered at a place other than the top of the card deck. The NAME card should be the first card and should only appear once per input set.

BITS MODULE: WARNING: THE EXTINCTION HAS BEEN SPECIFIED WITH [number] BAD DATA VALUES

BITS MODULE: WARNING: THE ATMOSPHERE HAS BEEN SPECIFIED WITH [number] BAD DATA VALUES

BITS MODULE: WARNING: THE TARGET HAS BEEN SPECIFIED WITH [number] BAD DATA VALUES

BITS MODULE: WARNING: THE DETECTOR HAS BEEN SPECIFIED WITH [number] BAD DATA VALUES

BITS MODULE: WARNING: THE FILTER HAS BEEN SPECIFIED WITH [number] BAD DATA VALUES

BITS MODULE: WARNING: THE SYSTEM HAS BEEN SPECIFIED WITH [number] BAD DATA VALUES

The number of bad data points are inserted for [number].

Bad data points are ignored by BITS. These messages alert the user as to how many data points were ignored. A response value is ignored if it is less than 0.0 or greater than 1.0 (except for the target) or if its wavelength was already specified for that component.

BITS MODULE: MESSAGE: OVERFLOW DETECTED IN DEXP FUNCTION

This message alerts the user that BITS has predetected an overflow condition. It was determined that the argument of the FORTRAN exponential function

DEXP may cause an overflow condition. BITS circumvents the DEXP function and substitutes a large float value for the function. An exponent of +170.0 or greater causes BITS to substitute the value of +1.0D38.

BITS MODULE: MESSAGE: UNDERFLOW DETECTED IN DEXP FUNCTION

This message alerts the user that BITS has predetected an underflow condition. It was determined that the argument of the FORTRAN exponential function DEXP may cause an underflow condition. BITS circumvents the DEXP function and substitutes a value of zero for the function. This condition arises when the exponent is -170.0 or less.

BITS MODULE: WARNING! WAVELENGTH LIMITS IN WRONG ORDER. WAVEBAND LIMITS ASSUMED: [lower limit] TO [upper limit] MICRONS

This message alerts the user that the waveband limits specified in the BAND card were not in the correct order. BITS assumes that the user has simply specified the waveband limits in the wrong order and continues executing the code.

MODULE CYCLE [cycle number]

This message is printed once for each GO card contained in the input card deck. A GO card causes the BITS module to be rerun. The cycle number is inserted for [cycle number] beginning with cycle 2. This message is not printed when the module is run only once.

END MODULE BITS

This message signifies the natural termination of the BITS module and all its recycling runs.

3.5 Verification Tests

The code in the BITS module was validated in several ways. Numerous runs were made to test the algorithm in several limiting cases. In one limiting case the mass extinction coefficient is constant across the waveband. In this case, the Beer's law transmittances, ideal transmittances, and band-integrated transmittances should be equal (see section 2 for definition of these transmittances). The output from the first cycle of example 3 in section 5 shows that the outputs were as expected for this case. Other limiting cases were also tested.

The BITS code was tested for successful error trapping. Many runs were made with input card decks containing invalid options specified, invalid characters, and invalid card identifiers. Runs were made to invoke all error messages, warning messages, and other messages that BITS can issue. In all cases, the code was verified to perform as expected.

Model predictions from BITS were compared to field test measurements. In one test, four BITS runs were made and the results compared to trial 131 (phosphorus) of the Characterization, Evaluation, and Comparison of Army Transmissometer Systems (CECATS) field test. During this trial, transmittances through phosphorous smoke were measured by ARL's research visible and IR transmissometer (REVIRT) and simultaneous multispectral absolute radiometer transmissometer (SMART) systems.

Four BITS runs were made to model SMART and REVIRT in the far- (5 through 15 μm) and mid-IR (2 through 6 μm) regions. The atmospheric transmittances specified for each run were obtained from LOWTRAN6 runs. These LOWTRAN6 runs were made beforehand using meteorological conditions measured during the CECATS trial. The mass extinction data used in all four runs for the phosphorous smoke came from a Chemical Systems Laboratory (CSL) report. [2] For SMART, the source was specified as a blackbody with a temperature of 1200.0 °C; for REVIRT the source was a blackbody at a temperature of 1000.0 °C.

Because REVIRT does not use a filter in the mid or far IR, a flat filter response was used as input for this system. For SMART, filter responses were taken from measurements made by the Physical Science Laboratory (PSL) under contract to ARL as a part of the Transmissometer Evaluation (TRANSVAL) effort. The PSL designations for the mid- and far-IR filters are SMART4IR and SMART9IR, respectively.

SMART in the mid IR uses a PbSe detector. The PbSe response function detector archived in BITS was used. For SMART in the far IR, measured responses by PSL taken during the TRANSVAL effort were used. This detector is designated IR ASSOC HCT-100 S/N L-9104 by PSL. The REVIRT mid- and far-IR detector responses were also taken from measurements by PSL (designations IR ASSOC. DET S/N L-8859-2 InSb SIDE and IR ASSOC. DET S/N L-8859-2 HgCdTe SIDE, respectively).

Figures 6 through 9 show the response curves for each component of each system. In each plot, the source (target) signal curve was normalized to the maximum value in the specified band.

Figures 10 and 11 compare the results from BITS to measurements from CECATS trial 131. The plots show mid- versus far-IR optical depth for the REVIRT and SMART systems. The individual points are measured values from the CECATS trial 131. In both plots, the solid line represents the band-integrated transmittances produced in the output of BITS. The plots show that the BITS predictions fit the measured data very well at small optical depths. At larger optical depths, BITS still compares favorably with the measured values, although deviations from the measured values of the SMART system are evident at large optical depths.

The REVIRT data set shown in figure 10 contains data points significantly above the main body of data. The cause of the anomalous data points is unclear, and BITS does not describe them. BITS does not account for nonlinear optical or electronic system effects. It is not known whether nonlinearity in the system is the cause of the anomalous data.

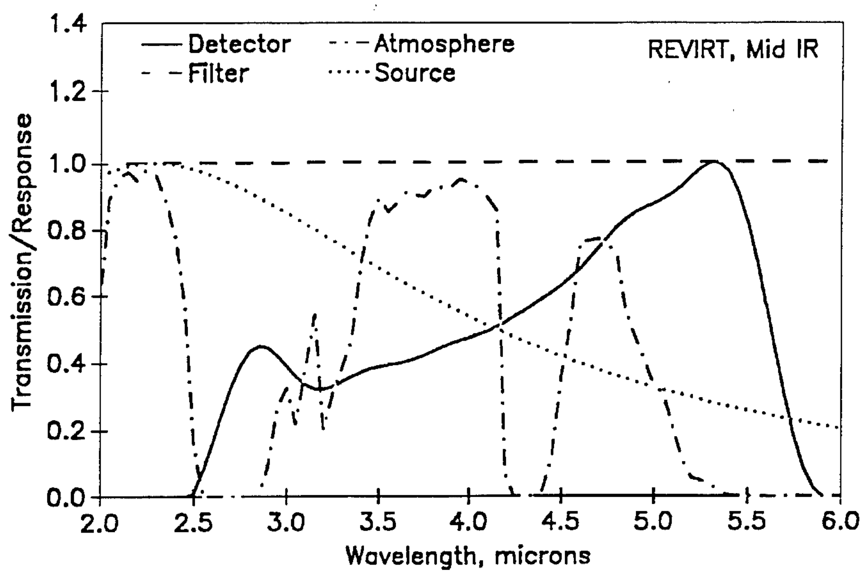

Figure 6. System response curves for REVIRT components in the mid-IR region used for BITS/CECATS trial 131 data comparison. The target signal curve was normalized.

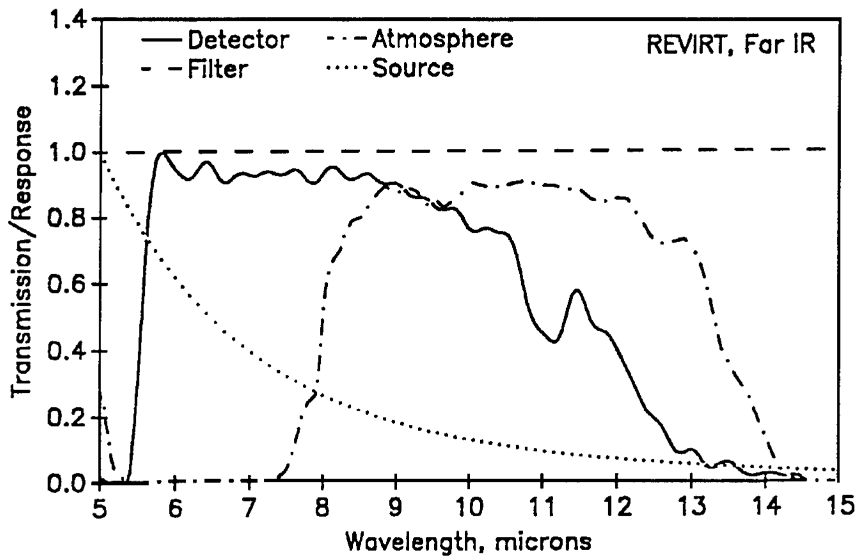

Figure 7. System response curves for REVIRT components in the far-IR region used for BITS/CECATS trial 131 data comparison. The target signal curve was normalized.

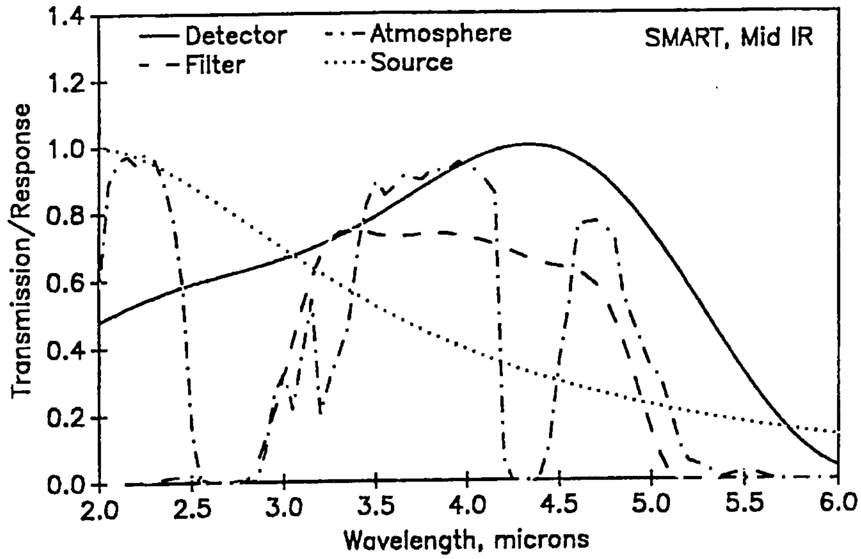

Figure 8. System response curves for SMART components in the mid-IR region used for BITS/CECATS trial 131 data comparison. The target signal curve was normalized.

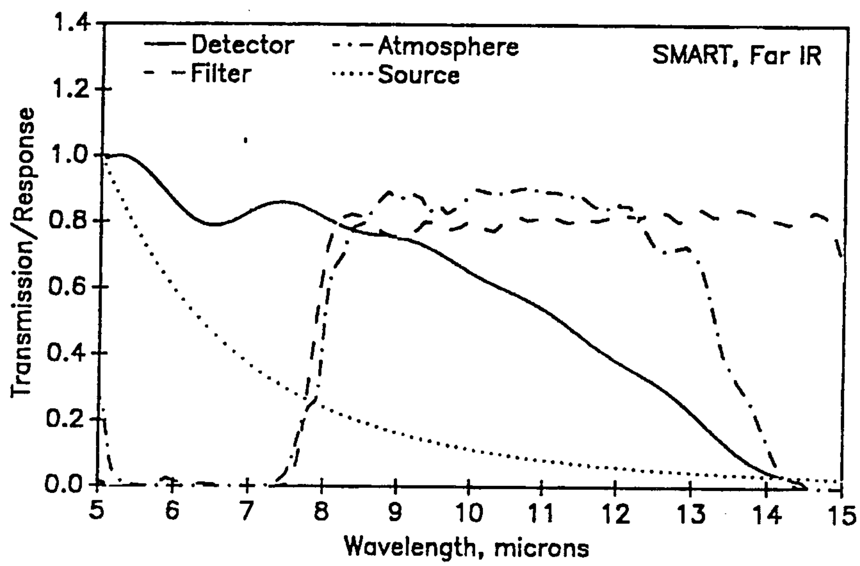

Figure 9. System response curves for SMART components in the far-IR region used for BITS/CECATS trial 131 data comparison. The target signal curve was normalized.

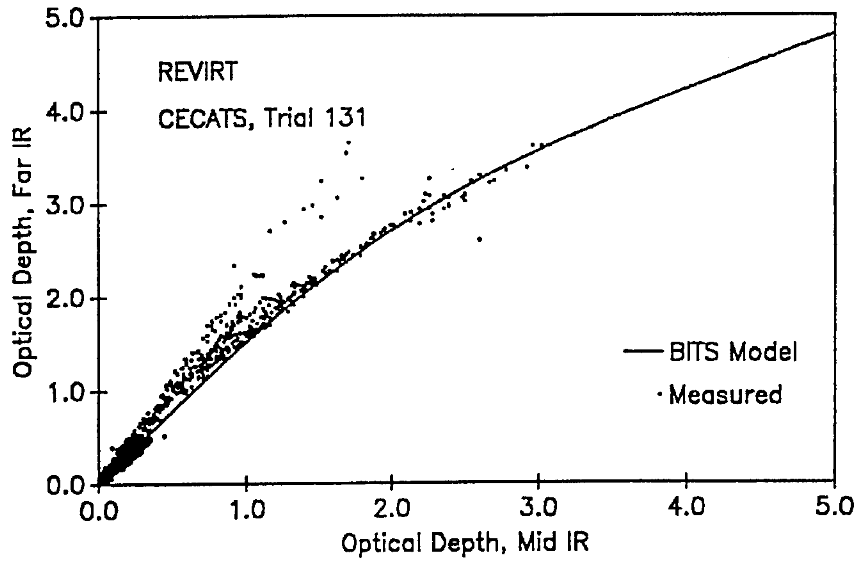

Figure 10. **Comparison of BITS output for REVIRT system with data taken at CECATS trial 131. System component data shown in figures 6 and 7 were used as BITS input.**

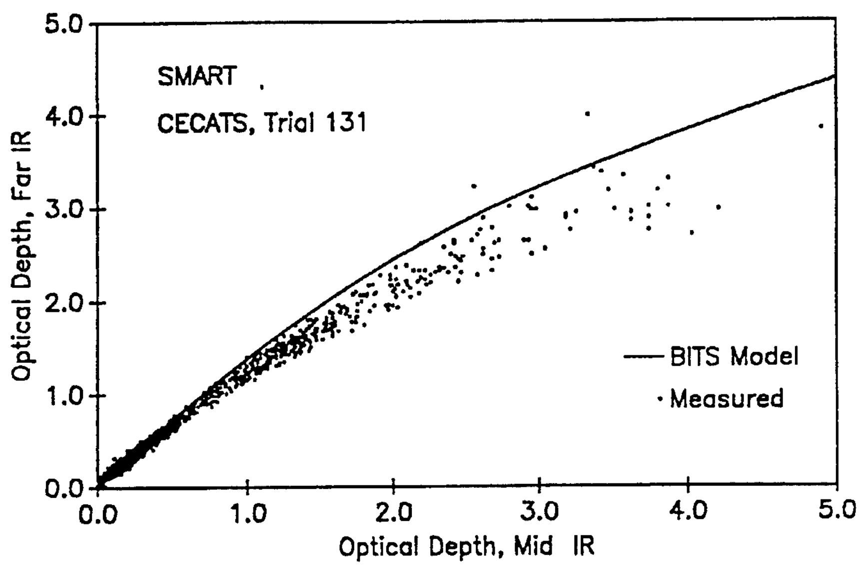

Figure 11. **Comparison of BITS output for SMART system with data taken at CECATS trial 131. System component data shown in figures 8 and 9 were used as BITS input.**

4. Operations Guide

This section lists the data sets archived as part of the BITS module. Sections 4.2 and 4.3 describe BITS input and output, respectively.

4.1 Data Sets Available

The BITS module includes archived spectral response data for a limited number of system components, smokes, and obscurants that are of potential interest to the user. Table 3 shows the archived spectral response data available in the current version of BITS. Curves for the data are given in the appendix. These archived data files are undefined outside the wavelength interval specified in the table. Therefore, when using any of these data sets, the user should be sure that the endpoints of the wavelength interval specified in the BAND card coincide with or are inside the wavelength extremes of the data set (see section 3.3.1).

4.2 Input

To run, BITS needs an input file containing the necessary parameters. EOSAEL87 requires that this input file be in the form of a set of card images. Each card image is a record that begins with a four-character (uppercase only) card identifier in the first four columns. The identifier is followed by the parameters, a series of numerical values, needed by BITS. The card identifier serves as a tag that allows the code to interpret the values that follow. In several cases, the order of cards within the input file is unimportant. These special cases have been identified on their input card description.

The pages following table 3 describe the input cards individually. At the top of each page, the card identifier is shown in uppercase. *The user must use the card identifiers as shown in uppercase only*. Following the card identifier is a list of the card parameters with a detailed description of each.

Some cards are always required; others are required only when certain options are chosen. The user should take note of these requirements. Only one card, the GO card, is completely optional.

Table 3. Summary of BITS archived spectral responses

System (Card)	Type	Wavelength Interval (μm)	Reference
Smokes: (ALFA)	WP, RH = 17%	0.4-13.5	[2]
	WP, RH = 50%	0.6-13.5	[2]
	WP, RH = 90%	2.0-13.5	[2]
	HC, RH = 85%	2.0-13.5	[2]
	Diesel fuel oil	0.6-13.5	[2]
	Fog oil	0.6-13.5	[2]
Targets: (TRGT)	Blackbody	(Function of temp)	
	Quartz lamp	0.2-1.8	[3]
Detectors: (DETC)	Photopic	0.38-0.77	[4]
	Silicon CCD	0.38-0.77	[4]
	HgCdTe (-196 °C)	8.0-13.5	[5]
	InSb (-196 °C)	1.0-6.0	[6]
	Germanium (25 °C)	0.8-1.8	[7]
	PbSe (-78 °C)	1.0-6.0	[8]
Internal Optics: (SYSM)	Silver surface	0.2-10.0	[4]
	Aluminum surface	0.2-10.0	[4]
	Gold surface	0.2-10.0	[4]

Card Identifier: NAME (required)

Card Parameters: INAME(70)

The NAME card must be the first card of the input file. If BITS is recycled (see GO card), a NAME card must begin each set of input cards.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
NAME          INAME(70)
```

INAME(70): User-chosen label of up to 70 characters. If no label is desired, leave blank. Always include the NAME card, however, even if it is left blank.

Card Identifier: BAND (required)

Card Parameters: WV1, WV2, DELWV

The BAND card defines the waveband to be used in the calculations. All calculations are made in microns and the three parameters that follow must be specified in microns.

The format for reading this card is (A4,6X,7(F10.3)).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
BAND      WV1       WV2       DELWV
```

WV1: Short-wavelength limit of waveband, μm

WV2: Long-wavelength limit of waveband, μm

DELWV: Spectral resolution, μm

The quantity (WV1 - WV2)/DELWV + 1 must not be greater than 401.

CAUTION: For BITS results to be an accurate representation of the physical response of the system, the specified waveband must completely encompass all nonzero system, atmosphere, and obscurant spectral responses. For example, if the user defines a waveband interval from 3 to 5 μm and the system has a nonzero response at 2.8 μm (as in the case of a filter leak with a detector that has sensitivity outside the band), the BITS results will not take these responses into account.

However, all system spectral response data must be fully defined up to and including the limits of the waveband specified in the BAND card. BITS does not perform extrapolation, and if the data are not all defined within the specified waveband, the program issues an error message and aborts. See section 3.3.1 for further discussion.

Card Identifier: ALFA (required)

Card Parameters: IOPTN, IUNIT

The ALFA card defines the mass extinction coefficients as a function of wavelength. The wavelength region covered by this card must completely cover the waveband defined in the BAND card, or the program aborts.

The format for reading this card is (A4,6X,7(F10.3)).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
ALFA      IOPTN     IUNIT
```

IOPTN: This parameter selects one of the following options:

0.0 = User input. The user inserts mass extinction coefficient data. When this option is selected, the user must follow this card with a series of EXTR cards that contain wavelength and mass extinction coefficient pairs. See discussion of the EXTR card.

1.0 = WP smoke, relative humidity 17 percent. The spectral region covers 0.4 to 13.5 μm.

2.0 = WP smoke, relative humidity 50 percent. The spectral region covers 0.6 to 13.5 μm.

3.0 = WP smoke, relative humidity 90 percent. The spectral region covers 2.0 to 13.5 μm.

4.0 = Hexachloroethane (HC) smoke, relative humidity 85 percent. The spectral region covers 2.0 to 13.5 μm. No data are between 5.0 and 7.0 μm; however, the code interpolates around this region.

5.0 = Diesel fuel oil smoke. The spectral region covers 0.6 to 13.5 μm. There are no data at 2.5 and 3.5 μm and between 5.0 and 6.0 μm; however, the code interpolates around these regions.

6.0 = Fog oil. The spectral region covers 0.6 to 13.5 μm. There are no data at 2.5 μm and between 5.0 and 6.0 μm; however, the code interpolates around these regions.

IUNIT: This parameter selects units assumed to be in the user's data when user input (IOPTN = 0.0) is selected. This parameter is otherwise ignored.

0.0 = Wavelengths are assumed to be in microns.

1.0 = Wavelengths are assumed to be in inverse centimeters.

Card Identifier: EXTR (required when IOPTN = 0.0 in the ALFA card)

Card Parameters: ALPHA(1,N), ALPHA(2,N)

A series of EXTR cards is used to input the user's mass extinction coefficient data versus wavelength. Data points are entered as pairs consisting of a wavelength and a mass extinction coefficient. The EXTQ card (discussed next) must immediately follow the last EXTR card.

The format for reading these cards is (A4,6X,7(F10.3)).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
EXTR      ALPHA(1,N)ALPHA(2,N)  ...
```

ALPHA(1,N): Wavelength. Units assumed by the program depend on the value for the parameter IUNIT in the ALFA card: microns or inverse centimeters. A wavelength of 0.0 is ignored, as is the corresponding ALPHA value.

ALPHA(2,N): Mass extinction coefficient, $m^2 g^{-1}$

Example: The following shows an example data set of wavelength versus mass extinction coefficient:

Wavelength (μm)	Mass Extinction Coefficient
1.2	7.43
2.0	6.54
1.5	6.98
1.34	5.54
3.0	6.43
3.62	7.02
4.1	6.1
6.0	5.64
5.43	6.49

The preceding data can be entered into the input file as follows:

```
        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
EXTR          1.2       7.43      2.0       6.54      1.5       6.98
EXTR          3.62      7.02      4.1       6.1       1.34      5.54
EXTR          6.0       5.64      3.0       6.43
EXTR          5.43      6.49
```

The data points need not be ordered by wavelength. Up to three pairs may be placed on a single EXTR card, but fewer pairs are allowed. A pair cannot be broken up between two EXTR cards.

Card Identifier: EXTQ (required when IOPTN = 0.0 in ALFA card)

Card Parameters: none

The EXTQ card is used to signal the end of user input of data and has no data values. This card must immediately follow the last EXTR card, even if only one EXTR card is used.

The following example illustrates the use of this card to enter data:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
NAME
              [Other cards]
ALFA           0.0       0.0
EXTR           1.2       7.43      2.0       6.54      1.5       6.98
EXTR           3.62      7.02      4.1       6.1       1.34      5.54
EXTR           6.0       5.64      3.0       6.43
EXTR           5.43      6.49
EXTQ
              [Other cards]

DONE
```

Card Identifier: ATMO (required)

Card Parameters: IOPTN, IUNIT, NHEAD, WVCOL, TRNCOL

The ATMO card defines the atmospheric transmittances as a function of wavelength. The wavelength region covered by this card must completely cover the waveband defined in the BAND card, or the program aborts.

The format for reading this card is (A4,6X,7(F10.3)).

```
          1         2         3         4         5         6         7         8
01234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
ATMO      IOPTN     IUNIT     NHEAD     WVCOL     TRNCOL
```

IOPTN: This parameter selects one of the following options:

0.0 = User input. Insert atmospheric transmittance data. When this option is selected, follow this card with a series of ATMR cards, containing wavelength and atmospheric transmittance pairs. See ATMR card.

1.0 = Spectrally flat transmittance (= 1.0) across the band.

2.0 = LOWTRN module output file is to be the input. To use this option, the user must be sure that LOWTRN has been run and has produced an output file containing transmittances versus wavelength.

When this option is selected, the filename of the LOWTRN output file must be given in an ATMR card (see ATMR card discussion).

3.0 = Transmittance data input comes from a user-supplied data file. This data file can be any file containing transmittances (0.0 through 1.0) and wavelengths (microns or inverse centimeters). This data file must be column oriented, with columns separated only by spaces. The relevant data must be within the first 80 characters of each line. Header lines are allowed at the top of the data file, but there can be no analogous lines at the bottom. Data columns need not be formatted because BITS reads the data as character strings.

When this option is selected, the filename of the user's data file must be given in an ATMR card (see ATMR card discussion).

IUNIT: This parameter selects the units assumed to be in the user's input data when user input (IOPTN = 0.0) is selected, or when a file is selected as input (IOPTN = 3.0). This parameter is otherwise ignored.

0.0 = Wavelengths are assumed to be in microns.

1.0 = Wavelengths are assumed to be in inverse centimeters.

NHEAD: Number of header lines to skip over in user's input data file. This parameter is used only when IOPTN = 3.0.

WVCOL: Column number of column containing wavelengths. The units assumed for these wavelengths are those specified by the IUNITS parameter above. The first column of a data file is column 1. This parameter is used only when IOPTN = 3.0.

TRNCOL: Column number of column containing the atmospheric transmittances. The first column of a data file is column 1. This parameter is used only when IOPTN = 3.0.

Card Identifier: ATMR (required when IOPTN = 0.0, 2.0, or 3.0 in ATMO card)

Card Parameters: ATMOS(1,N), ATMOS(2,N) when IOPTN = 0.0

or

LFLE when IOPTN = 2.0 or 3.0

When IOPTN = 0.0 on the ATMO card

A series of ATMR cards is used to input pairs consisting of atmospheric transmittance and wavelength. The ATMQ card (discussed next) must immediately follow the last ATMR card when this option is selected.

The format for reading these cards is (A4,6X,7(F10.3)).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
ATMR      ATMOS(1,N)ATMOS(2,N) ...
```

ATMOS(1,N): Wavelength. Units assumed by the program depend on the value for the parameter IUNIT in the ATMO card: microns or inverse centimeters. A wavelength of 0.0 and its corresponding atmospheric transmittance are ignored.

ATMOS(2,N): Atmospheric transmittance in range 0.0 to 1.0.

Example: The following shows an example data set of wavelength versus atmospheric transmittance:

Wavelength (μm)	Atmospheric Transmittance
0.4	0.78
0.7	0.21
0.32	0.01
0.543	0.98
0.42	0.871
0.59	0.912
0.55	1.0

The preceding data can be entered into the input file as follows:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
ATMR              0.4       0.78      0.7       0.21      0.32      0.01
ATMR              0.543     0.98      0.42      0.871     0.59      0.912
ATMR              0.55      1.0
```

The data need not be ordered by wavelength. Up to three pairs may be placed on a single ATMR card, but fewer pairs are allowed. A pair cannot be broken up between two ATMR cards.

When IOPTN = 2.0 or 3.0 on the ATMO card

A single ATMR card is used to enter the filename of either the LOWTRN output file (when IOPTN = 2.0) or the user's data file (when IOPTN = 3.0). *When an ATMR card is used for a filename, an ATMQ card should not follow.*

LFLE: Filename of up to 70 characters beginning in column 11. Include the full path name if the file is not in the current directory. BITS aborts if the file does not exist.

Example 1: In this example, a file is chosen as input. This file has no header lines. The wavelengths (in microns) are in column 10; the transmittances are in column 1.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
ATMO              3.0       0.0       0.0       10.0      1.0
ATMR      MYFILE.DAT
```

Example 2: Here, the output of a LOWTRN run is chosen to supply the atmospheric transmittances.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
ATMO              2.0       0.0
ATMR      /home/users/data/lowtrn.out
```

Note that the filenames must comply with the requirements of the computer operating system being used.

Card Identifier: ATMQ (required when IOPTN = 0.0 in ATMO card)

Card Parameters: none

The ATMQ card signals the end of user data input and has no data values. This card must immediately follow the last ATMR card, even if only one ATMR card was used for data input. Only use this card when IOPTN = 0.0 in the ATMO card.

The following example illustrates how this card is used to enter data:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
NAME
              [Other cards]
ATMO          0.0       0.0
ATMR          0.4       0.78      0.7       0.21
ATMR          0.32      0.01      0.543     0.98
ATMR          0.42      0.871
ATMR          0.59      0.912     0.55      1.0
ATMQ
              [Other cards]
DONE
```

Card Identifier: TRGT (required)

Card Parameters: IOPTN, IUNIT, BTMP

The TRGT card defines the spectral signature of the target as a function of wavelength. The wavelength region covered by this card must completely cover the waveband defined in the BAND card, otherwise the program aborts.

The format for reading this card is (A4,6X,7(F10.3)).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
TRGT      IOPTN     IUNIT     BTMP
```

IOPTN: This parameter selects one of the following options:

0.0 = User input. Insert target spectral signature data. When this option is selected, follow this card with a series of TGTR cards that contain wavelength and target signature pairs. (See discussion of the TGTR card.)

1.0 = Spectrally flat signature (= 1.0) across the band.

2.0 = Blackbody spectral signature. When this option is selected, give a value for the blackbody temperature in the BTMP parameter (see below).

3.0 = Quartz lamp that radiates from 0.2 to 1.8 μm.

IUNIT: This parameter selects the units assumed to be in the user's data when user input is selected (IOPTN = 0.0). This parameter is otherwise ignored.

0.0 = Wavelengths are assumed to be in microns.

1.0 = Wavelengths are assumed to be in inverse centimeters.

BTMP: Blackbody temperature in degrees Celsius. The target spectral signature is computed using the Planck function at this temperature. This parameter must be specified when IOPTN = 2.0. It is otherwise ignored.

Card Identifier: TGTR (required when IOPTN = 0.0 in TRGT card)

Card Parameters: TARGT(1,N), TARGT(2,N)

A series of TGTR cards is used to input the user's target spectral signature data versus wavelength. Data points are entered as pairs consisting of wavelength and relative target signal. The TGTQ card (discussed next) must immediately follow the last TGTR card.

The format for reading these cards is (A4,6X,7(F10.3)).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
TGTR      TARGT(1,N)TARGT(2,N)...
```

TARGT(1,N): Wavelength. Units assumed by the program depend on the value for the parameter IUNIT in the TRGT card: microns or inverse centimeters. A wavelength of 0.0 and its corresponding target signal are ignored.

TARGT(2,N): Relative target signal. Values are normalized by the code.

Example: The following shows an example data set of wavelength versus relative target signal:

Wavelength (cm^{-1})	Target Signal
400.0	806.85
700.0	679.3
502.0	756.3
600.0	939.4
455.0	984.0

The preceding data can be entered into the input file as follows:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
TGTR         400.0     806.85    700.0     679.3
TGTR         502.0     756.3     600.0     939.4
TGTR         455.0     984.0
```

The data need not be ordered by wavelength. Up to three pairs may be placed on a single TGTR card, but fewer pairs are allowed. A pair cannot be broken up between two TGTR cards.

Card Identifier: TGTQ (required when IOPTN = 0.0 in TRGT card)

Card Parameters: none

The TGTQ card is used to signal the end of user data input and has no data values. This card must immediately follow the last TGTR card, even if only one TGTR card is used for data input. Only use this card when IOPTN = 0.0 is on the TRGT card.

The following example illustrates how this card is used to enter data:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
NAME
               [Other cards]
TRGT             0.0       1.0
TGTR           400.0     806.85    700.0     679.3
TGTR           502.0     756.3     600.0     939.4
TGTR           455.0     984.0
TGTQ
              [Other cards]
DONE
```

Card Identifier: DETC (required)

Card Parameters: IOPTN, IUNIT

The DETC card defines the spectral response of the detector as a function of wavelength. The wavelength region covered by this card must completely cover the waveband defined in the BAND card, otherwise the program aborts. This requirement is true even for detectors with spectral data archived in the program; therefore, the user should check response ranges (below) against the chosen waveband.

The format for reading this card is (A4,6X,7(F10.3)).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
DETC      IOPTN     IUNIT
```

IOPTN: This parameter selects one of the following options:

0.0 = User input. Insert detector spectral response data. When this option is selected, follow this card with a series of DETR cards containing wavelength and detector response pairs. See discussion of the DETR card.

1.0 = Spectrally flat response (= 1.0) across the band.

2.0 = Photopic response in range 0.38 to 0.77 μm.

3.0 = Generic silicon CCD response in range 0.38 to 0.77 μm.

4.0 = HgCdTe (MCT) detector response (cooled to -196 °C) in range 8.0 to 13.5 μm.

5.0 = InSb detector response (cooled to -196 °C) in range 1.0 to 6.0 μm.

6.0 = Germanium detector response (at 25 °C) in range 0.8 to 1.8 μm.

7.0 = PbSe detector response (cooled to -78 °C) in range 1.0 to 6.0 μm.

IUNIT: This parameter selects the units assumed to be in the user's data when user input is selected (IOPTN = 0.0). This parameter is otherwise ignored.

0.0 = Wavelengths are assumed to be in microns.

1.0 = Wavelengths are assumed to be in inverse centimeters.

Card Identifier: DETR (required when IOPTN = 0.0 in DETC card)

Card Parameters: DETCR(1,N), DETCR(2,N)

A series of DETR cards is used to input the user's detector spectral response data versus wavelength. Data are put in as pairs consisting of wavelength and detector spectral response. The DETQ card (discussed next) must immediately follow the last DETR card.

The format for reading these cards is (A4,6X,7(F10.3)).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
DETR      DETCR(1,N)DETCR(2,N) ...
```

DETCR(1,N): Wavelength. Units assumed depend on the value for the parameter IUNIT on the DETC card: microns or inverse centimeters. A wavelength of 0.0 and its corresponding detector response are ignored.

DETCR(2,N): Detector spectral response in range 0.0 to 1.0

Example: The following shows a sample data set of wavelength versus detector spectral response:

Wavelength (μm)	Detector Response
8.0	0.59
9.0	0.74
10.0	0.93
11.0	0.99
12.0	0.87
13.0	0.34
14.0	0.08

The above data can be entered into the input file as follows:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
DETR             8.0      0.59       9.0      0.74      10.0      0.93
DETR            12.0      0.87      13.0      0.34      11.0      0.99
DETR            14.0      0.08
```

The data need not be ordered by wavelength. Up to three pairs may be placed on a single DETR card, but fewer pairs are allowed. A pair cannot be broken up between two DETR cards.

Card Identifier: DETQ (required when IOPTN = 0.0 in DETC card)

Card Parameters: none

The DETQ card is used to signal the end of user data input and has no data values. This card must immediately follow the last DETC card, even if only one DETR card was used for data input. Only use this card when IOPTN = 0.0 in the DETC card.

The following example illustrates how the DETQ card is used to enter data:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
NAME
             [Other cards]
DETC           0.0       0.0
DETR           8.0       0.59      9.0       0.74      10.0      0.93
DETR          12.0       0.87     13.0       0.34      11.0      0.99
DETR          14.0       0.08
DETQ
             [Other cards]
DONE
```

Card Identifier: FILT (required)

Card Parameters: IOPTN, IUNIT

The FILT card defines the spectral response of the filter as a function of wavelength. The wavelength region covered by this card must completely cover the waveband defined in the BAND card, otherwise the program aborts.

The format for reading this card is (A4,6X,7(F10.3)).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
FILT      IOPTN     IUNIT
```

IOPTN: This parameter selects one of the following options:

0.0 = User input. Insert filter spectral response data. When this option is selected, the user must follow this card with a series of FILR cards containing wavelength and filter response pairs. See discussion of the FILR card.

1.0 = Spectrally flat response (= 1.0) across the band.

IUNIT: This parameter selects the units assumed to be in the user's data when the user selects user input (IOPTN = 0.0). This parameter is otherwise ignored.

0.0 = Wavelengths are assumed to be in microns.

1.0 = Wavelengths are assumed to be in inverse centimeters.

Card Identifier: FILR (required when IOPTN = 0.0 in FILT card)

Card Parameters: FILTR(1,N), FILTR(2,N)

A series of FILR cards is used to input the user's filter spectral response versus wavelength data. Data points are entered as pairs consisting of wavelength and filter spectral response. The FILQ card (discussed next) must immediately follow the last FILR card.

The format for reading these cards is (A4,6X,7(F10.3)).

```
            1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
FILR      FILTR(1,N)FILTR(2,N) ...
```

FILTR(1,N): Wavelength. Units assumed by the program depend on the value for the parameter IUNIT in the FILT card: microns or inverse centimeters. A wavelength of 0.0 and its corresponding filter response pairs are ignored.

FILTR(2,N): Filter spectral response in range 0.0 to 1.0

Example: The following shows an example data set of wavelength versus filter spectral response:

Wavelength (μm)	Filter Response
0.1	0.34
0.7	0.65
0.9	1.0
0.3	0.45

The preceding data can be entered into the input file as follows:

```
            1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
FILR             0.1      0.34       0.7      0.65       0.9       1.0
FILR                       0.3      0.45
```

The data need not be ordered by wavelength. Up to three pairs may be placed on a single FILR card, but fewer pairs are allowed. A pair cannot be broken up between two FILR cards.

Card Identifier: FILQ (required when IOPTN = 0.0 in FILT card)

Card Parameters: none

The FILQ card is used to signal the end of user data input and has no data values. This card must immediately follow the last FILR card, even if only one FILR card was used for data input. Only use this card when IOPTN = 0.0 in the FILT card.

The following example illustrates how this card is used to enter data:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
NAME
               [Other cards]
FILT           0.0       0.0
FILR           0.1       0.34      0.7       0.65      0.9       1.0
FILR           0.3       0.45
FILQ
               [Other cards]
DONE
```

Card Identifier: SYSM (required)

Card Parameters: IOPTN, IUNIT

The SYSM card defines the spectral response of other system optics as a function of wavelength. The wavelength region covered by this card must completely cover the waveband defined in the BAND card, otherwise the program aborts. This is true even for surfaces with spectral data archived in the program; therefore, check response ranges against the chosen waveband.

The format for reading this card is (A4,6X,7(F10.3)).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
SYSM      IOPTN     IUNIT
```

IOPTN: This parameter selects one of the following options:

0.0 = User input. Insert system optics response data. When this option is selected, follow this card with a series of SYSR cards, containing wavelength and system response pairs. See discussion of the SYSR card.

1.0 = Spectrally flat response (= 1.0) across the band.

2.0 = Silver reflecting surface with response in range 0.2 to 10.0 μm.

3.0 = Aluminum reflecting surface with response in range 0.2 to 10.0 μm.

4.0 = Gold reflecting surface with response in range 0.2 to 10.0 μm.

IUNIT: This parameter selects the units assumed to be in the user's data when the user input (IOPTN = 0.0) is selected. This parameter is otherwise ignored.

0.0 = Wavelengths are assumed to be in microns.

1.0 = Wavelengths are assumed to be in inverse centimeters.

Card Identifier: SYSR (required when IOPTN = 0.0 in SYSM card)

Card Parameters: OSYSM(1,N), OSYSM(2,N)

A series of SYSR cards is used to input the user's system optics response data versus wavelength. Data points are entered as pairs consisting of wavelength and system optics response. Up to three such pairs may be on one SYSR card. The total number of pairs allowed is 401. The SYSQ card (discussed next) must immediately follow the last SYSR card.

The format for reading these cards is (A4,6X,7(F10.3)).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
SYSR      OSYSM(1,N)OSYSM(2,N) ...
```

OSYSM(1,N): Wavelength. Units assumed by the program depend on the value for the parameter IUNIT in the SYSM card: microns or inverse centimeters. A wavelength of 0.0 and its corresponding system response are ignored.

OSYSM(2,N): System optics spectral response in range 0.0 to 1.0

Example: The following example shows a data set of wavelength versus system optics spectral response:

Wavelength (μm)	System Optics Response
0.1	0.34
0.7	0.65
0.9	1.0
0.3	0.45

The preceding data can be entered into the input file as follows:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
SYSR             0.1      0.34       0.7      0.65       0.9       1.0
SYSR                       0.3      0.45
```

The data need not be ordered by wavelength. Up to three pairs may be placed on a single SYSR card, but fewer pairs are allowed. A pair cannot be broken up between two SYSR cards.

Card Identifier: SYSQ (required when IOPTN = 0.0 in SYSM card)

Card Parameters: none

The SYSQ card is used to signal the end of user data input and has no data values. This card must immediately follow the last SYSR card, even if only one SYSR card was used for data input. Only use this card when IOPTN = 0.0 in the SYSM card.

The following example illustrates how this card is used to enter data:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
NAME
               [Other cards]
SYSM           0.0       0.0
SYSR           0.1       0.34      0.7       0.65      0.9       1.0
SYSR           0.3       0.45
SYSQ
               [Other cards]
DONE
```

Card Identifier: CONL (required)

Card Parameters: IOPTN, IUNIT, NHEAD, IDXCOL, CLCOL

The CONL card specifies the CL data. Up to 401 CL values may be input to the code.

The format for reading this card is (A4,6X,7(F10.3)).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
CONL      IOPTN     IUNIT     NHEAD     IDXCOL    CLCOL
```

IOPTN: This parameter selects one of the following options:

0.0 = User input. Insert CL data. Follow this card with a series of CLNR cards containing CL index and CL pairs. See discussion of CLNR card.

1.0 = Input from a COMBIC module output file. To use this option, be sure that COMBIC was run and produced an output file containing CLs. With this option, the filename of the COMBIC output file must be given on a CLNR card (see CLNR card discussion). In the BITS output, the CL index listed with each CL value is the time (in seconds) from the COMBIC output file.

2.0 = Input from a user-supplied data file. This data file can be any file containing CLs (in g m^{-2}) versus an arbitrary index. This data file must be column oriented, with columns separated by spaces only. The relevant data must be within the first 80 characters of each line. Header lines are allowed at the top of the data file, but there can be no analogous lines at the bottom. Data columns need not be formatted, because BITS reads the data as character strings.

When this option is selected, the filename of the user's data file must be given on a CLNR card.

NHEAD: Number of header lines to skip over in user's data file. *This parameter is used only when IOPTN = 2.0.*

IDXCOL: Column number of the column containing the CL indices. This number is arbitrary and can be for any column to correctly tag the CL values. The first column of a data file is column 1. *This parameter is used only when* IOPTN *= 2.0.*

CLCOL: Column number of the column containing the CLs. The first column of a data file is column 1. *This parameter is used only when* IOPTN *= 2.0.*

Card Identifier: CLNR (required)

Card Parameters: CONCL(1,N), CONCL(2,N) when IOPTN = 0.0 on CONL card

or

CFLE when IOPTN = 1.0 or 2.0 on CONL card

A series of CLNR cards is used to input the user's CL data versus an arbitrary index, or a single CLNR card is used to input the filename of a file containing CL versus an arbitrary index.

When IOPTN = 0.0 on the CONL card:

A series of CLNR cards is used to input pairs consisting of CL versus an index. Up to three such pairs may be on one CLNR card. The total number of pairs allowed is 401. The CLNQ card (discussed next) must immediately follow the last CLNR card.

The format for reading these cards is (A4,6X,7(F10.3)).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
CLNR      CONCL(1,N)CONCL(2,N)  ...
```

CONCL(1,N): CL index. The CL index is arbitrary. It serves only to tag each CL value, and is not used in any calculations. It can be a time, a spatial coordinate, or simply a running index.

CONCL(2,N): CL, g m^{-2}

Example: The following shows an example data set of time versus concentration length:

CL (g m^{-2})	Time
0.168	5.0
0.844	10.0
1.234	15.0
1.343	20.0
1.676	25.0
1.999	30.0
3.456	35.0
2.654	40.0
1.855	45.0
1.044	50.0
0.711	55.0
0.032	60.0

The preceding data could be entered into the input file as:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
CLNR            5.0        0.168      10.0        0.844
CLNR           15.0        1.234      20.0        1.343
CLNR           25.0        1.676      30.0        1.999
CLNR           35.0        3.456      40.0        2.654
CLNR           45.0        1.855      50.0        1.044
CLNR           55.0        0.711      60.0        0.032
```

The data need not be ordered by CL index. Up to three pairs may be placed on a single CLNR card, but fewer pairs are allowed. A pair cannot be broken up between two CLNR cards.

When IOPTN = 1.0 or 2.0 on the CONL card:

A single CLNR card is used to enter the filename of either the COMBIC output file (when IOPTN = 1.0) or the user's data file (when IOPTN = 2.0). When a CLNR card is used for a filename, a CLNQ card should not follow.

CFLE: Filename of up to 70 characters beginning in column 11. Include the full path if the file is not in the current directory. BITS aborts if the file does not exist.

Example 1: The user chooses to use a COMBIC output file for the CL input.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
CONL           1.0       0.0
CLNR      COMBIC.DAT
```

Example 2: The user specifies a data file. This file has three header lines. The CL indices are in column 1 and the CLs are in column 7.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
CONL           2.0       3.0       1.0       7.0
CLNR     /home/users/data/myowndat.out
```

Note that filenames must comply with the requirements of the computer operating system being used.

Card Identifier: CLNQ (required when IOPTN = 0.0 in CONL card)

Card Parameters: none

The CLNQ card is used to signal the end of user data input and has no data values. This card must immediately follow the last CLNR card, even if only one CLNR card was used for data input. Only use this card when IOPTN = 0.0 in the CONL card.

The following example illustrates how this card is used to enter data:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
NAME
              [Other cards]
CONL            0.0       0.0
CLNR            5.0       0.168     10.0      0.844
CLNR           15.0       1.234     20.0      1.343
CLNR           25.0       1.676     30.0      1.999
CLNR           35.0       3.456     40.0      2.654
CLNR           45.0       1.855     50.0      1.044
CLNR           55.0       0.711     60.0      0.032
CLNQ
              [Other cards]
DONE
```

Card Identifier: DONE (required)

Card Parameters: none

The DONE card signifies the end of the job and returns control to EOEXEC or what is being used as the BITS driver. This card must always be the last card in an input set. A DONE card should only appear once per input deck.

Card Identifier: GO (optional)

Card Parameters: none

The GO card is used to recycle the BITS module. When used, it replaces the DONE card. Immediately after the GO card, the code expects to see a complete, new set of input cards, beginning with the NAME card.

The user may recycle the module as many times as desired. Always place a GO card at the end of an input set of cards when another set is to follow. The last cycle or set should terminate with the DONE.

4.3 Output

The output files produced by BITS have four sections:

1. First, at the top of each output file, the input card images are echoed. The data cards, if any, are not echoed in the output.

2. The second section displays a summary of the various options selected for each of the system components.

3. The third section lists the interpolated response arrays for each of the system components as functions of wavelength. These arrays are computed by interpolating the input responses (either archived within the module or input by the user) to a consistent wavelength resolution, which is specified in the BAND card.

4. The last section of the output file contains computed results of the BITS module. For each CL, a wavelength-independent Beer's law transmittance, an ideal transmittance (using wavelength-independent system, atmosphere, and source, but a band-integrated extinction coefficient), and a broad-band transmittance are computed. The transmittances are listed in an output table with the CLs and the CL indices.

If the BITS module has been recycled a number of times using GO cards, the output from each cycle is appended to the first output file.

See the output files from the examples in section 5 for illustrations of this arrangement.

5. Sample Runs

This section gives the sample inputs and outputs, exactly as they would come from the BITS module, for three sample runs. The runs are of increasing complexity and illustrate several typical uses of BITS. The last example includes three BITS runs with different types of input and illustrates how several BITS runs may be executed together through the recycling feature.

5.1 Example 1

In the first example, the waveband is defined from 0.4 to 0.75 μm on the BAND card. The band increment (third parameter on the BAND card) is set to 0.01 μm. The number of resolution elements within the band is (0.75 - 0.4)/0.01 + 1 = 36. The maximum number of allowed increments is 401. The filter and atmosphere are given a flat transmittance across the waveband by specifying the first parameter on the ATMO and FILT cards, IOPTN, to be 1.0. For the detector, the IOPTN parameter is set to 3.0. This option selects the generic silicon CCD detector. It is important to note that the CCD detector is defined for wavelengths 0.38 to 0.77 μm; hence, its definition completely covers the defined waveband. For the target, a blackbody source (IOPTN = 2.0) was selected. Selecting this target option requires the user to specify a blackbody temperature on the same card (parameter BTMP). A temperature of 6000.0 °C was specified. On the SYSM card, a silver reflecting surface was chosen by setting IOPTN = 2.0 on that card.

For the CLs, it was opted to specify them in the input file. First, the IOPTN of the CONL card was set to 0.0. This choice requires that the CONL card is followed by at least one CLNR card. In example 1, there are 15 CLNR cards, each with one pair of index/CL values. The index is completely arbitrary and has meaning only to the user. In this example, the CL indices represent time in seconds. It should also be noted that up to three pairs of CL indexes could have been placed on any or all the CLNR cards. Immediately following the last CLNR card is a CLNQ card signifying to BITS the end of CL data. Leaving out the CLNQ card results in an error message and program termination.

The last card of the input deck is the DONE card. This card tells BITS that the module is not to recycle but is to end (see example 3 for recycling of BITS). A DONE card must be the very last card of every input card deck.

The output from this example run is typical of all BITS runs. The card input is echoed, and data cards are not echoed. The various options selected are listed for each of the components of the system.

The "interpolated arrays" section of the output lists the response versus wavelength values for each of the components. These responses are the result of the program interpolating each response function chosen to a common wavelength resolution. This common wavelength resolution is that of the waveband defined in the BAND card. Because the wavelength increment was set to 0.01 μm in this example, each response function of the various components was interpolated to a 0.01-μm resolution. The results of these interpolations are shown in this section of the output.

The last section of the output lists the results of the computations carried out by BITS. The data listed in this section are listed versus CL index. The quantities printed out in this table are explained in section 4.2.

5.1.1 Example 1 Input

```
NAME   EXAMPLE 1
BAND   0.4     0.75     0.01
ALFA   1.0     0.00
ATMO   1.0     0.0
DETC   3.0     0.0
TRGT   2.0     0.0      6000.0
FILT   1.0     0.0
SYSM   2.0     0.0
CONL   0.0
CLNR   1.0     0.25
CLNR   2.0     0.50
CLNR   3.0     0.75
CLNR   4.0     1.0
CLNR   5.0     1.5
CLNR   6.0     2.0
CLNR   7.0     2.5
```

```
CLNR   8.0    3.0
CLNR   9.0    4.0
CLNR  10.0    5.0
CLNR  11.0    7.0
CLNR  12.0    9.0
CLNR  13.0   10.0
CLNR  14.0   15.0
CLNR  15.0   20.0
CLNQ
DONE
```

5.1.2 Example 1 Output

```
**********************************
*                                *
*             B I T S            *
*    BROAD BAND INTEGRATED       *
*        TRANSMITTANCES          *
*   NOT FOR OPERATIONAL USE      *
*                                *
* EOSAEL87  REV 1.00  12/19/90   *
*                                *
**********************************
```

```
1
******************************************************************************
*****************************   BITS MODULE   ********************************
******************************************************************************
```

*****MODULE BITS CARD INPUT*****

NAME	EXAMPLE 1						
BAND	0.400	0.750	0.010	0.000	0.000	0.000	0.000
ALFA	1.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMO	1.000	0.000	0.000	0.000	0.000	0.000	0.000
DETC	3.000	0.000	0.000	0.000	0.000	0.000	0.000
TRGT	2.000	0.000	6000.000	0.000	0.000	0.000	0.000
FILT	.000	0.000	0.000	0.000	0.000	0.000	0.000
SYSM	2.000	0.000	0.000	0.000	0.000	0.000	0.000
CONL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DONE	0.000	0.000	0.000	0.000	0.000	0.000	0.000

*****INPUT*****

DETECTOR:
OPTION: GENERIC CCD

ATMOSPHERE:
OPTION: FLAT TRANSMISSION

FILTER:
OPTION: FLAT RESPONSE

CONCENTRATION LENGTHS:
OPTION: USER INPUT

SYSTEM:	OBSCURANT:
OPTION: SILVER SURFACE	OPTION: WP, RH = 17%
TARGET:	BAND:
OPTION: BLACK BODY	LIMITS: 0.400 TO 0.750 MICRONS
BB TEMP: 6000.00 DEGREES CELSIUS	RESOLUTION: 0.010 MICRONS

1 *****INTERPOLATED ARRAYS*****

WAVELENGTH (MICRONS)	OBSCURANT (M**2/G)	DETECTOR RESPONSE	FILTER RESPONSE	SYSTEM RESPONSE	TARGET SIGNATURE	ATMOSPHERE TRANSMIT
0.400	3.800	0.250	1.000	0.850	0.949	1.000
0.410	3.778	0.310	1.000	0.860	0.965	1.000
0.420	3.756	0.370	1.000	0.870	0.978	1.000
0.430	3.734	0.430	1.000	0.880	0.987	1.000
0.440	3.712	0.480	1.000	0.890	0.994	1.000
0.450	3.690	0.540	1.000	0.900	0.998	1.000
0.460	3.668	0.560	1.000	0.902	1.000	1.000
0.470	3.646	0.600	1.000	0.904	0.999	1.000
0.480	3.624	0.640	1.000	0.906	0.997	1.000
0.490	3.602	0.670	1.000	0.908	0.992	1.000
0.500	3.580	0.700	1.000	0.910	0.985	1.000
0.510	3.555	0.730	1.000	0.912	0.978	1.000
0.520	3.530	0.760	1.000	0.914	0.968	1.000
0.530	3.505	0.780	1.000	0.916	0.958	1.000
0.540	3.480	0.820	1.000	0.918	0.946	1.000
0.550	3.455	0.840	1.000	0.920	0.933	1.000
0.560	3.430	0.860	1.000	0.922	0.920	1.000
0.570	3.405	0.880	1.000	0.924	0.906	1.000
0.580	3.380	0.900	1.000	0.926	0.891	1.000
0.590	3.355	0.920	1.000	0.928	0.876	1.000
0.600	3.330	0.950	1.000	0.930	0.861	1.000
0.610	3.240	0.960	1.000	0.932	0.845	1.000
0.620	3.150	0.970	1.000	0.934	0.829	1.000
0.630	3.060	0.980	1.000	0.936	0.813	1.000
0.640	2.996	0.990	1.000	0.938	0.796	1.000
0.650	2.931	0.990	1.000	0.940	0.780	1.000
0.660	2.867	0.990	1.000	0.942	0.764	1.000
0.670	2.803	1.000	1.000	0.944	0.747	1.000
0.680	2.739	1.000	1.000	0.946	0.731	1.000
0.690	2.674	0.990	1.000	0.948	0.715	1.000
0.700	2.610	0.990	1.000	0.950	0.699	1.000
0.710	2.547	0.990	1.000	0.952	0.683	1.000
0.720	2.484	0.980	1.000	0.954	0.668	1.000
0.730	2.421	0.970	1.000	0.956	0.652	1.000
0.740	2.358	0.960	1.000	0.958	0.637	1.000
0.750	2.295	0.940	1.000	0.960	0.622	1.000

1 *****RELATIVE TRANSMITTANCES*****

CL INDEX	CL(G/M**2)	BEER'S LAW	IDEAL TRAN	BAND INTGR
1.0000	2.500E-01	4.457E-01	4.485E-01	4.528E-01
2.0000	5.000E-01	1.986E-01	2.039E-01	2.075E-01
3.0000	7.500E-01	8.852E-02	9.396E-02	9.624E-02
4.0000	1.000E+00	3.945E-02	4.392E-02	4.521E-02
5.0000	1.500E+00	7.836E-03	1.001E-02	1.036E-02
6.0000	2.000E+00	1.557E-03	2.405E-03	2.488E-03
7.0000	2.500E+00	3.092E-04	6.056E-04	6.235E-04
8.0000	3.000E+00	6.141E-05	1.584E-04	1.620E-04
9.0000	4.000E+00	2.423E-06	1.181E-05	1.188E-05
10.0000	5.000E+00	9.559E-08	9.490E-07	9.404E-07
11.0000	7.000E+00	1.488E-10	6.927E-09	6.710E-09
12.0000	9.000E+00	2.316E-13	5.532E-11	5.279E-11
13.0000	1.000E+01	9.137E-15	5.049E-12	4.790E-12
14.0000	1.500E+01	8.734E-22	3.636E-17	3.385E-17
15.0000	2.000E+01	8.349E-29	2.979E-22	2.744E-22

END MODULE BITS

5.2 Example 2

A more typical use of BITS is illustrated by example 2. In this example, for a waveband of 5.0 to 15.0 μm with a resolution of 1.0 μm, all response functions have been specified in the card deck. No archived component data sets were chosen. By setting the IOPTN parameter of the ALFA, ATMO, DETC, and FILT cards to 0.0, the user told BITS to expect response functions on data cards for each of these components. The data cards for a particular component immediately follow the corresponding option card. An appropriate quit card (EXTQ, ATMQ, DETQ, FILQ) immediately follows the data cards for each component. It should also be noted that the defined waveband was completely covered in wavelength by each of the user-defined components. An error and program termination results if, for example, the wavelength coverage in the ATMR cards only goes to 14.5 μm (see section 3.3).

In this second example, the user specified that the CL values be read in from a separate file. This file is called testie.data. Note that the filename is contained on a single CLNR card (beginning in column 11) and that no CLNQ card follows. The specifications for reading this file are contained on the CONL card. The first parameter IOPTN has been set to 2.0. This option tells BITS that an external file is to be the source of the CL data. The second parameter NHEAD tells BITS the number of header lines to skip over in the file. On this same card, the third parameter IDXCOL was set to 3.0 and the fourth parameter CLCOL was set to 1.0. Thus, BITS interprets the third column in testie.data as CL indices and the first column as CL values.

The output of this example run is completely analogous to that of example 1.

5.2.1 Example 2 Input

NAME EXAMPLE 2

BAND	5.0	15.0	1.00			
ALFA	0.0	0.00				
EXTR	5.000	0.182	5.20	0.182	5.40	0.186
EXTR	6.00	0.228	6.2	0.215	6.4	0.197
EXTR	7.0	0.166	7.2	0.204	7.4	0.246
EXTR	8.0	0.533	8.2	0.483	8.4	0.441
EXTR	9.0	0.441	9.2	0.474	9.4	0.503
EXTR	10.0	0.418	10.2	0.399	10.4	0.383
EXTR	11.0	0.268	11.2	0.222	11.4	0.171
EXTR	12.0	0.129	12.2	0.128	12.4	0.129
EXTR	13.0	0.136	13.2	0.134	13.4	0.133
EXTR	14.0	0.138	14.2	0.138	15.0	0.138
EXTR	5.60	0.196	5.80	0.212	6.6	0.184
EXTR	6.8	0.172	7.6	0.329	7.8	0.441
EXTR	8.6	0.424	8.8	0.430	9.6	0.491
EXTR	9.8	0.455	10.6	0.354	10.8	0.307
EXTR	11.6	0.141	11.8	0.136	12.6	0.130
EXTR	12.8	0.133	13.6	0.133	13.8	0.136
EXTQ						
ATMO	0.0	0.0				
ATMR	5.000	0.277	5.20	0.035	5.40	0.001
ATMR	7.40	0.010	7.44	0.019	7.52	0.047
ATMR	8.0	0.495	8.2	0.667	8.4	0.788
ATMR	9.0	0.867	9.2	0.894	9.4	0.831
ATMR	10.0	0.889	10.2	0.897	10.4	0.899
ATMR	11.0	0.893	11.2	0.890	11.4	0.881
ATMR	12.0	0.860	12.2	0.838	12.4	0.763
ATMR	13.0	0.709	13.2	0.598	13.4	0.402
ATMR	14.0	0.130	14.2	0.035	14.4	0.003
ATMR	5.6	0.0	7.32	0.002	7.6	0.095
ATMR	7.8	0.240	8.6	0.828	8.8	0.881
ATMR	9.6	0.844	9.8	0.849	10.6	0.900
ATMR	10.8	0.909	11.6	0.863	11.8	0.839
ATMR	12.6	0.711	12.8	0.723	13.6	0.317
ATMR	13.8	0.243	14.6	0.0	15.0	0.0
ATMQ						
DETC	0.0	0.0				
DETR	5.000	0.986	5.20	1.000	5.40	0.990
DETR	6.00	0.857	6.2	0.815	6.4	0.793

DETR	7.0	0.832	7.2	0.852	7.4	0.861
DETR	8.0	0.813	8.2	0.791	8.4	0.775
DETR	9.0	0.754	9.2	0.744	9.4	0.726
DETR	10.0	0.649	10.2	0.625	10.4	0.605
DETR	11.0	0.539	11.2	0.509	11.4	0.476
DETR	12.0	0.383	12.2	0.357	12.4	0.330
DETR	13.0	0.227	13.2	0.183	13.4	0.141
DETR	14.0	0.005	14.2	0.003	14.4	0.002
DETR	5.6	0.957	5.8	0.909	6.6	0.792
DETR	6.8	0.808	7.6	0.855	7.8	0.837
DETR	8.6	0.765	8.8	0.760	9.6	0.702
DETR	9.8	0.675	10.6	0.585	10.8	0.564
DETR	11.6	0.443	11.8	0.411	12.6	0.301
DETR	12.8	0.267				
DETR	13.6	0.102	13.8	0.071	14.6	0.00
DETR	15.0	0.00				
DETQ						
TRGT	2.0	0.0	1200.0			
FILT	0.0	0.0				
FILR	5.000	0.002	5.04	0.001	5.08	0.000
FILR	5.8	0.011	5.84	0.019	5.88	0.024
FILR	6.00	0.021	6.04	0.014	6.08	0.006
FILR	6.4	0.008	6.44	0.011	6.48	0.011
FILR	6.60	0.004	6.64	0.000	7.52	0.000
FILR	7.64	0.064	7.68	0.109	7.72	0.167
FILR	7.84	0.393	7.88	0.473	7.92	0.549
FILR	8.0	0.676	8.2	0.782	8.4	0.827
FILR	9.0	0.754	9.2	0.769	9.4	0.810
FILR	10.0	0.810	10.2	0.776	10.4	0.793
FILR	11.0	0.819	11.2	0.807	11.4	0.804
FILR	12.0	0.826	12.2	0.814	12.4	0.831
FILR	13.0	0.834	13.2	0.829	13.4	0.812
FILR	14.0	0.810	14.2	0.802	14.4	0.805
FILR	15.0	0.656	14.96	0.701	14.92	0.737
FILR	5.6	0.0	5.76	0.002	5.92	0.026
FILR	5.96	0.025	6.12	0.0	6.36	0.004
FILR	6.52	0.010	6.56	0.007	7.56	0.011
FILR	7.60	0.032	7.76	0.236	7.8	0.312
FILR	7.96	0.618	8.6	0.805	8.8	0.766
FILR	9.6	0.787	9.8	0.779	10.6	0.823
FILR	10.8	0.806	11.6	0.811	11.8	0.808
FILR	12.6	0.839	12.8	0.804	13.6	0.843
FILR	13.8	0.826	14.6	0.836	14.8	0.806
FILR	14.88	0.765	14.84	0.788		

```
FILQ
SYSM      1.0      0.0
CONL      2.0      2.0      3.0      1.0
CLNR      testie.data
DONE
```

5.2.2 Example 2 Output

```
*********************************
*                               *
*            B I T S            *
*    BROAD BAND INTEGRATED      *
*       TRANSMITTANCES          *
*   NOT FOR OPERATIONAL USE     *
*                               *
*  EOSAEL87  REV 1.00  03/29/91 *
*                               *
*********************************
```

```
1
***************************************************************************
*****************************     BITS MODULE     *****************************
***************************************************************************
```

*****MODULE BITS CARD INPUT*****

NAME	EXAMPLE 2						
BAND	5.000	15.000	1.000	0.000	0.000	0.000	0.000
ALFA	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMO	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DETC	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TRGT	2.000	0.000	1200.000	0.000	0.000	0.000	0.000
FILT	1.000	0.000	0.000	0.000	0.000	0.000	0.000
SYSM	1.000	0.000	0.000	0.000	0.000	0.000	0.000
CONL	2.000	2.000	3.000	1.000	0.000	0.000	0.000
DONE	0.000	0.000	0.000	0.000	0.000	0.000	0.000

*****INPUT*****

DETECTOR:
OPTION: USER INPUT

ATMOSPHERE:
OPTION: USER INPUT

FILTER:
OPTION: USER INPUT

CONCENTRATION LENGTHS:
OPTION: USER DATA FILE
FILENAME: test.data

SYSTEM:
OPTION: FLAT RESPONSE

OBSCURANT:
OPTION: USER INPUT

TARGET:
OPTION: BLACK BODY
BB TEMP: 1200.00 DEGREES CELSIUS

BAND:
LIMITS: 5.000 TO 15.000 MICRONS
RESOLUTION: 1.000 MICRONS

1 *****INTERPOLATED ARRAYS*****

WAVELENGTH (MICRONS)	OBSCURANT (M**2/G)	DETECTOR RESPONSE	FILTER RESPONSE	SYSTEM RESPONSE	TARGET SIGNATURE	ATMOSPHERE TRANSMIT
5.000	0.182	0.986	0.002	1.000	1.000	0.277
6.000	0.228	0.857	0.021	1.000	0.594	0.000
7.000	0.166	0.832	0.000	1.000	0.371	0.002
8.000	0.533	0.813	0.676	1.000	0.242	0.495
9.000	0.441	0.754	0.754	1.000	0.163	0.867
10.000	0.418	0.649	0.810	1.000	0.114	0.889
11.000	0.268	0.539	0.819	1.000	0.082	0.893
12.000	0.129	0.383	0.826	1.000	0.060	0.860
13.000	0.136	0.227	0.834	1.000	0.045	0.709
14.000	0.138	0.005	0.810	1.000	0.035	0.130
15.000	0.138	0.000	0.656	1.000	0.027	0.000

1 *****RELATIVE TRANSMITTANCES*****

CL INDEX	CL(G/M**2)	BEER'S LAW	IDEAL TRAN	BAND INTGR
1.0000	2.500E-01	4.457E-01	4.485E-01	4.528E-01
1.0000	2.188E+00	5.641E-01	5.894E-01	4.226E-01
4.0000	1.202E+01	4.304E-02	1.002E-01	2.695E-02
7.0000	9.024E+00	9.427E-02	1.624E-01	5.155E-02
10.0000	1.045E+01	6.486E-02	1.286E-01	3.722E-02
13.0000	9.759E+00	7.778E-02	1.439E-01	4.342E-02
16.0000	6.879E+00	1.653E-01	2.344E-01	9.004E-02
19.0000	5.041E+00	2.673E-01	3.280E-01	1.564E-01
22.0000	5.562E+00	2.333E-01	2.974E-01	1.328E-01
25.0000	4.906E+00	2.770E-01	3.366E-01	1.633E-01

END MODULE BITS

5.3 Example 3

The third example comprises three runs. These three runs were done as a single job; the three runs were invoked with a single input card deck.

The first run or cycle consists of the cards up to and including the first GO card. In this cycle, note that the user has chosen a spectrally flat smoke. This specification was accomplished by giving the response of the smoke at only two wavelengths, the wavelengths that define the limits of the waveband. Because BITS interpolates the extinction coefficients to the same wavelength resolution as the waveband, the value of the extinction coefficient at all wavelengths is set to 1.0. This outcome is easily verified in the output file, where the values in the interpolated arrays are listed.

The last card of the first cycle is not a DONE card but the GO card. A GO card tells BITS that the code is to be re-run with a new set of input cards. This new set of input cards must be a complete set and, as such, must begin with the NAME card.

The second cycle is identical to the first except, an archived smoke data file for WP at a relative humidity of 17 percent replaces the spectrally flat defined smoke. The second set of input cards terminates with another GO card that tells BITS to expect a third set of cards representing the third cycle.

In the third cycle, the user chose the archived fog oil data file as the smoke. However, unlike cycles 1 and 2, the CL values are specified to come from a COMBIC output file. This specification is accomplished by selecting IOPTN = 1.0 on the CONL card. The IOPTN value tells BITS that the CL values are to come from an output file produced by the COMBIC module. The name of this file is given on a single CLNR card with no CLNQ card following.

The very last card of example 3 card deck is the DONE card. The DONE card must be the last card of every BITS input card deck file.

The output from the example 3 input file is similar to that of the previous two examples. The main difference is that three cycles of BITS results are contained in the single output file. The legends "MODULE CYCLE 2" and "MODULE CYCLE 3" precede the output from the second and third cycles. A similar message does not precede the first cycle.

5.3.1 *Example 3 Input*

```
NAME   EXAMPLE 3, CYCLE 1, spectrally flat smoke
BAND      0.4        0.75       0.01
ALFA      0.0        0.00
EXTR      0.40       1.000      0.75       1.000
EXTQ
ATMO      1.0        0.0
DETC      3.0        0.0
TRGT      2.0        0.0     6000.0
FILT      1.0        0.0
SYSM      2.0        0.0
CONL      0.0
CLNR      1.0        0.25
CLNR      1.0        0.0
DETC      3.0        0.0
TRGT      2.0        0.0     6000.0
FILT      1.0        0.0
SYSM      2.0        0.0
CONL      0.0
CLNR      2.0        0.50
CLNR      1.0        0.0
DETC      3.0        0.0
TRGT      2.0        0.0     6000.0
FILT      1.0        0.0
SYSM      2.0        0.0
CONL      0.0
CLNR      3.0        0.75
CLNR      1.0        0.0
DETC      3.0        0.0
TRGT      2.0        0.0     6000.0
FILT      1.0        0.0
SYSM      2.0        0.0
CONL      0.0
CLNR      4.0        1.0
CLNR      3.0        0.0
TRGT      2.0        0.0     6000.0
FILT      1.0        0.0
```

SYSM	2.0	0.0	
CONL	0.0		
CLNR	5.0	1.5	
CLNR	3.0	0.0	
TRGT	2.0	0.0	6000.0
FILT	1.0	0.0	
SYSM	2.0	0.0	
CONL	0.0		
CLNR	6.0	2.0	
CLNR	2.0	0.0	
CONL	0.0		
CLNR	5.0	1.5	
CLNR	3.0	0.0	
TRGT	2.0	0.0	6000.0
FILT	1.0	0.0	
SYSM	7.0	2.5	
CLNR	6.0	2.0	
CLNR	2.0	0.0	
CONL	0.0		
CLNR	5.0	1.5	
CLNR	3.0	0.0	
TRGT	2.0	0.0	6000.0
FILT	1.0	0.0	
SYSM	8.0	3.0	
CLNR	1.0	0.0	
SYSM	7.0	2.5	
CLNR	6.0	2.0	
CLNR	2.0	0.0	
CONL	0.0		
CLNR	5.0	1.5	
CLNR	3.0	0.0	
TRGT	2.0	0.0	6000.0
FILT	1.0	0.0	
SYSM	9.0	4.0	
CLNR	6.0	2.0	
CLNR	2.0	0.0	
CONL	0.0		
CLNR	5.0	1.5	
CLNR	3.0	0.0	
TRGT	2.0	0.0	6000.0
FILT	1.0	0.0	
SYSM	10.0	5.0	
CLNR	6.0	2.0	
CLNR	2.0	0.0	

```
CONL      0.0
CLNR      5.0       1.5
CLNR      11.0      7.0
CLNR      6.0       2.0
CLNR      2.0       0.0
CONL      0.0
CLNR      5.0       1.5
CLNR      12.0      9.0
CLNR      6.0       2.0
CLNR      2.0       0.0
CONL      0.0
CLNR      5.0       1.5
CLNR      13.0      10.0
CLNR      14.0      15.0
CLNR      15.0      20.0
CLNQ
GO
NAME      EXAMPLE 3, CYCLE 2, WP RH=17%
BAND      0.4       0.75      0.01
ALFA      1.0       0.00
ATMO      1.0       0.0
DETC      3.0       0.0
TRGT      2.0       0.0       6000.0
FILT      1.0       0.0
SYSM      2.0       0.0
CONL      0.0
CLNR      1.0       0.25
CLNR      2.0       0.50
CLNR      3.0       0.75
CLNR      4.0       1.0
CLNR      5.0       1.5
CLNR      6.0       2.0
CLNR      7.0       2.5
CLNR      8.0       3.0
CLNR      9.0       4.0
CLNR      10.0      5.0
CLNR      11.0      7.0
CLNR      12.0      9.0
CLNR      13.0      10.0
CLNR      14.0      15.0
CLNR      15.0      20.0
CLNQ
GO
NAME      EXAMPLE 3, CYCLE 3, FOG OIL
```

BAND	1.0	5.00	0.20
ALFA	6.0	0.00	
ATMO	1.0	0.0	
DETC	7.0	0.0	
TRGT	2.0	0.0	6000.0
FILT	.0	0.0	
SYSM	1.0	0.0	
CONL	1.0		
CLNR	combic3.out		
DONE			

5.3.2 *Example 3 Output*

```
**********************************
*                                *
*            B I T S             *
*   BROAD BAND INTEGRATED        *
*        TRANSMITTANCES          *
*  NOT FOR OPERATIONAL USE       *
*                                *
*  EOSAEL87  REV 1.00  05/16/91  *
*                                *
**********************************
```

```
1
******************************************************************************
******************************   BITS MODULE   *******************************
******************************************************************************
```

*****MODULE BITS CARD INPUT*****

NAME EXAMPLE 3, CYCLE 1, spectrally flat smoke

BAND	0.400	0.750	0.010	0.000	0.000	0.000	0.000
ALFA	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMO	1.000	0.000	0.000	0.000	0.000	0.000	0.000
DETC	3.000	0.000	0.000	0.000	0.000	0.000	0.000
TRGT	2.000	0.000	6000.000	0.000	0.000	0.000	0.000
FILT	1.000	0.000	0.000	0.000	0.000	0.000	0.000
SYSM	2.000	0.000	0.000	0.000	0.000	0.000	0.000
CONL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GO	0.000	0.000	0.000	0.000	0.000	0.000	0.000

*****INPUT*****

DETECTOR:
OPTION: GENERIC CCD

ATMOSPHERE:
OPTION: FLAT TRANSMISSION

FILTER:
OPTION: FLAT RESPONSE

CONCENTRATION LENGTHS:
OPTION: USER INPUT

SYSTEM:	OBSCURANT:
OPTION: SILVER SURFACE	OPTION: USER INPUT
TARGET:	BAND:
OPTION: BLACK BODY	LIMITS: 0.400 TO 0.750 MICRONS
BB TEMP: 6000.00 DEGREES CELSIUS	RESOLUTION: 0.010 MICRONS

1 *****INTERPOLATED ARRAYS*****

WAVELENGTH (MICRONS)	OBSCURANT (M**2/G)	DETECTOR RESPONSE	FILTER RESPONSE	SYSTEM RESPONSE	TARGET SIGNATURE	ATMOSPHERE TRANSMIT
0.400	1.000	0.250	1.000	0.850	0.949	1.000
0.410	1.000	0.310	1.000	0.860	0.965	1.000
0.420	1.000	0.370	1.000	0.870	0.978	1.000
0.430	1.000	0.430	1.000	0.880	0.987	1.000
0.440	1.000	0.480	1.000	0.890	0.994	1.000
0.450	1.000	0.540	1.000	0.900	0.998	1.000
0.460	1.000	0.560	1.000	0.902	1.000	1.000
0.470	1.000	0.600	1.000	0.904	0.999	1.000
0.480	1.000	0.640	1.000	0.906	0.997	1.000
0.490	1.000	0.670	1.000	0.908	0.992	1.000
0.500	1.000	0.700	1.000	0.910	0.985	1.000
0.510	1.000	0.730	1.000	0.912	0.978	1.000
0.520	1.000	0.760	1.000	0.914	0.968	1.000
0.530	1.000	0.780	1.000	0.916	0.958	1.000
0.540	1.000	0.820	1.000	0.918	0.946	1.000
0.550	1.000	0.840	1.000	0.920	0.933	1.000
0.560	1.000	0.860	1.000	0.922	0.920	1.000
0.570	1.000	0.880	1.000	0.924	0.906	1.000
0.580	1.000	0.900	1.000	0.926	0.891	1.000
0.590	1.000	0.920	1.000	0.928	0.876	1.000
0.600	1.000	0.950	1.000	0.930	0.861	1.000
0.610	1.000	0.960	1.000	0.932	0.845	1.000
0.620	1.000	0.970	1.000	0.934	0.829	1.000
0.630	1.000	0.980	1.000	0.936	0.813	1.000
0.640	1.000	0.990	1.000	0.938	0.796	1.000
0.650	1.000	0.990	1.000	0.940	0.780	1.000
0.660	1.000	0.990	1.000	0.942	0.764	1.000
0.670	1.000	1.000	1.000	0.944	0.747	1.000
0.680	1.000	1.000	1.000	0.946	0.731	1.000
0.690	1.000	0.990	1.000	0.948	0.715	1.000
0.700	1.000	0.990	1.000	0.950	0.699	1.000
0.710	1.000	0.990	1.000	0.952	0.683	1.000
0.720	1.000	0.980	1.000	0.954	0.668	1.000
0.730	1.000	0.970	1.000	0.956	0.652	1.000
0.740	1.000	0.960	1.000	0.958	0.637	1.000
0.750	1.000	0.940	1.000	0.960	0.622	1.000

1 *****RELATIVE TRANSMITTANCES*****

CL INDEX	CL(G/M**2)	BEER'S LAW	IDEAL TRAN	BAND INTGR
1.0000	2.500E-01	7.788E-01	7.788E-01	7.788E-01
2.0000	5.000E-01	6.065E-01	6.065E-01	6.065E-01
3.0000	7.500E-01	4.724E-01	4.724E-01	4.724E-01
4.0000	1.000E+00	3.679E-01	3.679E-01	3.679E-01
5.0000	1.500E+00	2.231E-01	2.231E-01	2.231E-01
6.0000	2.000E+00	1.353E-01	1.353E-01	1.353E-01
7.0000	2.500E+00	8.208E-02	8.208E-02	8.209E-02
8.0000	3.000E+00	4.979E-02	4.979E-02	4.979E-02
9.0000	4.000E+00	1.832E-02	1.832E-02	1.832E-02
10.0000	5.000E+00	6.738E-03	6.738E-03	6.738E-03
11.0000	7.000E+00	9.119E-04	9.119E-04	9.119E-04
12.0000	9.000E+00	1.234E-04	1.234E-04	1.234E-04
13.0000	1.000E+01	4.540E-05	4.540E-05	4.540E-05
14.0000	1.500E+01	3.059E-07	3.059E-07	3.059E-07
15.0000	2.000E+01	2.061E-09	2.061E-09	2.061E-09

MODULE CYCLE 2

1
****
****************************** BITS MODULE ******************************
****

*****MODULE BITS CARD INPUT*****

NAME	EXAMPLE 3, CYCLE 2, WP RH=17%						
BAND	0.400	0.750	0.010	0.000	0.000	0.000	0.000
ALFA	1.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMO	1.000	0.000	0.000	0.000	0.000	0.000	0.000
DETC	3.000	0.000	0.000	0.000	0.000	0.000	0.000
TRGT	2.000	0.000	6000.000	0.000	0.000	0.000	0.000
FILT	1.000	0.000	0.000	0.000	0.000	0.000	0.000
SYSM	2.000	0.000	0.000	0.000	0.000	0.000	0.000
CONL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GO	0.000	0.000	0.000	0.000	0.000	0.000	0.000

*****INPUT*****

DETECTOR: OPTION: GENERIC CCD	ATMOSPHERE: OPTION: FLAT TRANSMISSION
FILTER: OPTION: FLAT RESPONSE	CONCENTRATION LENGTHS: OPTION: USER INPUT
SYSTEM: OPTION: SILVER SURFACE	OBSCURANT: OPTION: WP, RH = 17%
TARGET: OPTION: BLACK BODY BB TEMP: 6000.00 DEGREES CELSIUS	BAND: LIMITS: 0.400 TO 0.750 MICRONS RESOLUTION: 0.010 MICRONS

1 *****INTERPOLATED ARRAYS*****

WAVELENGTH (MICRONS)	OBSCURANT (M**2/G)	DETECTOR RESPONSE	FILTER RESPONSE	SYSTEM RESPONSE	TARGET SIGNATURE	ATMOSPHERE TRANSMIT
0.400	3.800	0.250	1.000	0.850	0.949	1.000
0.410	3.778	0.310	1.000	0.860	0.965	1.000
0.420	3.756	0.370	1.000	0.870	0.978	1.000
0.430	3.734	0.430	1.000	0.880	0.987	1.000
0.440	3.712	0.480	1.000	0.890	0.994	1.000
0.450	3.690	0.540	1.000	0.900	0.998	1.000
0.460	3.668	0.560	1.000	0.902	1.000	1.000
0.470	3.646	0.600	1.000	0.904	0.999	1.000
0.480	3.624	0.640	1.000	0.906	0.997	1.000
0.490	3.602	0.670	1.000	0.908	0.992	1.000
0.500	3.580	0.700	1.000	0.910	0.985	1.000
0.510	3.555	0.730	1.000	0.912	0.978	1.000
0.520	3.530	0.760	1.000	0.914	0.968	1.000
0.530	3.505	0.780	1.000	0.916	0.958	1.000
0.540	3.480	0.820	1.000	0.918	0.946	1.000
0.550	3.455	0.840	1.000	0.920	0.933	1.000
0.560	3.430	0.860	1.000	0.922	0.920	1.000
0.570	3.405	0.880	1.000	0.924	0.906	1.000
0.580	3.380	0.900	1.000	0.926	0.891	1.000
0.590	3.355	0.920	1.000	0.928	0.876	1.000
0.600	3.330	0.950	1.000	0.930	0.861	1.000
0.610	3.240	0.960	1.000	0.932	0.845	1.000
0.620	3.150	0.970	1.000	0.934	0.829	1.000
0.630	3.060	0.980	1.000	0.936	0.813	1.000
0.640	2.996	0.990	1.000	0.938	0.796	1.000
0.650	2.931	0.990	1.000	0.940	0.780	1.000
0.660	2.867	0.990	1.000	0.942	0.764	1.000
0.670	2.803	1.000	1.000	0.944	0.747	1.000
0.680	2.739	1.000	1.000	0.946	0.731	1.000
0.690	2.674	0.990	1.000	0.948	0.715	1.000
0.700	2.610	0.990	1.000	0.950	0.699	1.000
0.710	2.547	0.990	1.000	0.952	0.683	1.000
0.720	2.484	0.980	1.000	0.954	0.668	1.000
0.730	2.421	0.970	1.000	0.956	0.652	1.000
0.740	2.358	0.960	1.000	0.958	0.637	1.000
0.750	2.295	0.940	1.000	0.960	0.622	1.000

1 *****RELATIVE TRANSMITTANCES*****

CL INDEX	CL(G/M**2)	BEER'S LAW	IDEAL TRAN	BAND INTGR
1.0000	2.500E-01	4.457E-01	4.485E-01	4.528E-01
2.0000	5.000E-01	1.986E-01	2.039E-01	2.075E-01
3.0000	7.500E-01	8.852E-02	9.396E-02	9.624E-02
4.0000	1.000E+00	3.945E-02	4.392E-02	4.521E-02
5.0000	1.500E+00	7.836E-03	1.001E-02	1.036E-02
6.0000	2.000E+00	1.557E-03	2.405E-03	2.488E-03
7.0000	2.500E+00	3.092E-04	6.056E-04	6.235E-04
8.0000	3.000E+00	6.141E-05	1.584E-04	1.620E-04
9.0000	4.000E+00	2.423E-06	1.181E-05	1.188E-05
10.0000	5.000E+00	9.559E-08	9.490E-07	9.404E-07
11.0000	7.000E+00	1.488E-10	6.927E-09	6.710E-09
12.0000	9.000E+00	2.316E-13	5.532E-11	5.279E-11
13.0000	1.000E+01	9.137E-15	5.049E-12	4.790E-12
14.0000	1.500E+01	8.734E-22	3.636E-17	3.385E-17
15.0000	2.000E+01	8.349E-29	2.979E-22	2.744E-22

MODULE CYCLE 3

1
****
******************************** BITS MODULE ********************************
****

*****MODULE BITS CARD INPUT*****

NAME EXAMPLE 3, CYCLE 3, FOG OIL

BAND	1.000	5.000	0.200	0.000	0.000	0.000	0.000
ALFA	6.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMO	1.000	0.000	0.000	0.000	0.000	0.000	0.000
DETC	7.000	0.000	0.000	0.000	0.000	0.000	0.000
TRGT	2.000	0.000	6000.000	0.000	0.000	0.000	0.000
FILT	1.000	0.000	0.000	0.000	0.000	0.000	0.000
SYSM	1.000	0.000	0.000	0.000	0.000	0.000	0.000
CONL	1.000	0.000	0.000	0.000	0.000	0.000	0.000
DONE	0.000	0.000	0.000	0.000	0.000	0.000	0.000

*****INPUT*****

DETECTOR:
OPTION: PbSe (-78 DEG C)

ATMOSPHERE:
OPTION: FLAT TRANSMISSION

FILTER:
OPTION: FLAT RESPONSE

CONCENTRATION LENGTHS:
OPTION: COMBIC MODULE
FILENAME: combic3.out

SYSTEM:
OPTION: FLAT RESPONSE

OBSCURANT:
OPTION: FOG OIL

TARGET:
OPTION: BLACK BODY
BB TEMP: 6000.00 DEGREES CELSIUS

BAND:
LIMITS: 1.000 TO 5.000 MICRONS
RESOLUTION: 0.200 MICRONS

1 *****INTERPOLATED ARRAYS*****

WAVELENGTH (MICRONS)	OBSCURANT (M**2/G)	DETECTOR RESPONSE	FILTER RESPONSE	SYSTEM RESPONSE	TARGET SIGNATURE	ATMOSPHERE TRANSMIT
1.000	3.980	0.250	1.000	1.000	1.000	1.000
1.200	2.915	0.270	1.000	1.000	0.621	1.000
1.400	2.078	0.290	1.000	1.000	0.400	1.000
1.600	1.522	0.326	1.000	1.000	0.266	1.000
1.800	1.246	0.378	1.000	1.000	0.183	1.000
2.000	0.970	0.430	1.000	1.000	0.130	1.000
2.200	0.870	0.470	1.000	1.000	0.094	1.000
2.400	0.770	0.510	1.000	1.000	0.070	1.000
2.600	0.670	0.564	1.000	1.000	0.053	1.000
2.800	0.570	0.632	1.000	1.000	0.041	1.000
3.000	0.470	0.700	1.000	1.000	0.032	1.000
3.200	0.682	0.740	1.000	1.000	0.025	1.000
3.400	0.894	0.780	1.000	1.000	0.020	1.000
3.600	0.846	0.830	1.000	1.000	0.017	1.000
3.800	0.538	0.890	1.000	1.000	0.014	1.000
4.000	0.230	0.950	1.000	1.000	0.011	1.000
4.200	0.202	0.970	1.000	1.000	0.009	1.000
4.400	0.174	0.990	1.000	1.000	0.008	1.000
4.600	0.150	0.964	1.000	1.000	0.007	1.000
4.800	0.130	0.892	1.000	1.000	0.006	1.000
5.000	0.110	0.820	1.000	1.000	0.005	1.000

1 *****RELATIVE TRANSMITTANCES*****

CL INDEX	CL(G/M**2)	BEER'S LAW	IDEAL TRAN	BAND INTGR
5.0000	1.680E-01	8.599E-01	8.678E-01	7.420E-01
10.0000	1.680E-01	8.599E-01	8.678E-01	7.420E-01
15.0000	1.610E-01	8.653E-01	8.727E-01	7.507E-01
20.0000	1.560E-01	8.692E-01	8.761E-01	7.571E-01
25.0000	1.560E-01	8.692E-01	8.761E-01	7.571E-01
30.0000	1.450E-01	8.778E-01	8.839E-01	7.712E-01
35.0000	1.450E-01	8.778E-01	8.839E-01	7.712E-01
40.0000	1.340E-01	8.866E-01	8.918E-01	7.858E-01
45.0000	1.340E-01	8.866E-01	8.918E-01	7.858E-01
50.0000	1.340E-01	8.866E-01	8.918E-01	7.858E-01
55.0000	1.240E-01	8.946E-01	8.991E-01	7.994E-01
60.0000	1.240E-01	8.946E-01	8.991E-01	7.994E-01
65.0000	1.150E-01	9.018E-01	9.058E-01	8.120E-01
70.0000	1.150E-01	9.018E-01	9.058E-01	8.120E-01
75.0000	1.060E-01	9.091E-01	9.126E-01	8.248E-01
80.0000	1.060E-01	9.091E-01	9.126E-01	8.248E-01
85.0000	1.060E-01	9.091E-01	9.126E-01	8.248E-01
90.0000	9.800E-02	9.157E-01	9.187E-01	8.364E-01
95.0000	9.800E-02	9.157E-01	9.187E-01	8.364E-01
100.0000	9.100E-02	9.215E-01	9.241E-01	8.468E-01
105.0000	9.100E-02	9.215E-01	9.241E-01	8.468E-01
110.0000	9.100E-02	9.215E-01	9.241E-01	8.468E-01
115.0000	8.400E-02	9.273E-01	9.295E-01	8.573E-01
120.0000	8.400E-02	9.273E-01	9.295E-01	8.573E-01
125.0000	7.800E-02	9.323E-01	9.342E-01	8.665E-01
130.0000	7.800E-02	9.323E-01	9.342E-01	8.665E-01
135.0000	7.200E-02	9.374E-01	9.390E-01	8.759E-01
140.0000	7.200E-02	9.374E-01	9.390E-01	8.759E-01
145.0000	7.200E-02	9.374E-01	9.390E-01	8.759E-01
150.0000	6.700E-02	9.416E-01	9.430E-01	8.838E-01
155.0000	6.700E-02	9.416E-01	9.430E-01	8.838E-01
160.0000	6.200E-02	9.458E-01	9.471E-01	8.918E-01
165.0000	6.200E-02	9.458E-01	9.471E-01	8.918E-01
170.0000	6.200E-02	9.458E-01	9.471E-01	8.918E-01
175.0000	5.800E-02	9.492E-01	9.503E-01	8.982E-01
180.0000	5.800E-02	9.492E-01	9.503E-01	8.982E-01
185.0000	5.400E-02	9.526E-01	9.536E-01	9.048E-01
190.0000	5.400E-02	9.526E-01	9.536E-01	9.048E-01
195.0000	5.000E-02	9.561E-01	9.569E-01	9.114E-01
200.0000	5.000E-02	9.561E-01	9.569E-01	9.114E-01

205.0000	5.000E-02	9.561E-01	9.569E-01	9.114E-01
210.0000	4.600E-02	9.595E-01	9.602E-01	9.181E-01
215.0000	4.600E-02	9.595E-01	9.602E-01	9.181E-01
220.0000	4.300E-02	9.621E-01	9.627E-01	9.231E-01
225.0000	4.300E-02	9.621E-01	9.627E-01	9.231E-01
230.0000	4.000E-02	9.647E-01	9.652E-01	9.282E-01
235.0000	3.900E-02	9.656E-01	9.661E-01	9.299E-01
240.0000	3.900E-02	9.656E-01	9.661E-01	9.299E-01
245.0000	3.600E-02	9.682E-01	9.686E-01	9.351E-01
250.0000	3.600E-02	9.682E-01	9.686E-01	9.351E-01
255.0000	3.400E-02	9.699E-01	9.703E-01	9.385E-01
260.0000	3.400E-02	9.699E-01	9.703E-01	9.385E-01
265.0000	3.400E-02	9.699E-01	9.703E-01	9.385E-01
270.0000	3.100E-02	9.725E-01	9.729E-01	9.437E-01
275.0000	3.100E-02	9.725E-01	9.729E-01	9.437E-01
280.0000	2.900E-02	9.743E-01	9.746E-01	9.472E-01
285.0000	2.900E-02	9.743E-01	9.746E-01	9.472E-01
290.0000	2.600E-02	9.769E-01	9.771E-01	9.525E-01
295.0000	2.600E-02	9.769E-01	9.771E-01	9.525E-01
300.0000	2.600E-02	9.769E-01	9.771E-01	9.525E-01

END MODULE BITS

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Acronyms and Abbreviations

ARL	Army Research Laboratory
BITS	Broadband Integrated Transmittances
CECATS	Characterization, Evaluation, and Comparison of Army Transmissometer Systems
CCD	charged-coupled device
CL	concentration length
CSL	Chemical Systems Laboratory
HC	hexachloroethane
IR	infrared
PSL	Physical Science Laboratory
REVIRT	research visible and infrared transmissometer
SMART	simultaneous multispectral absolute radiometer transmissometer
STC	Science and Technology Corporation
TRANSVAL	Transmissometer Evaluation
WP	white phosphorous

Appendix

Figures A-1 through A-16 show system and obscurant response curves for the archived data included in the BITS module and listed in table 3. In all plots, dots represent the archived data points, and lines are linear interpolations between the points.

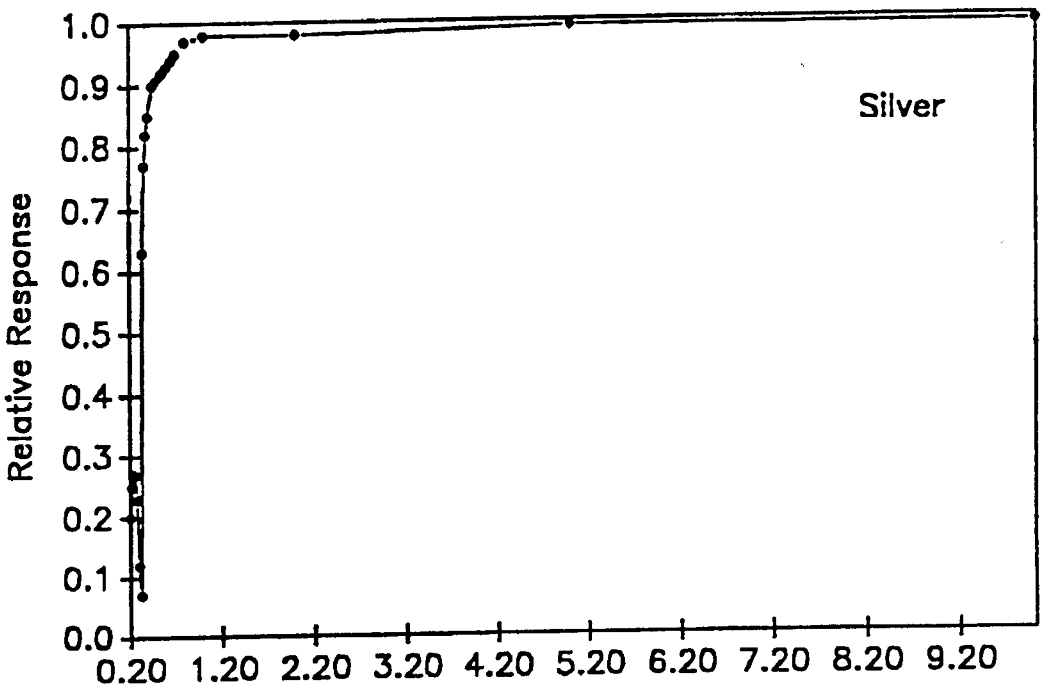

Figure A-1. Archived response curve for silver-coated optical surface.

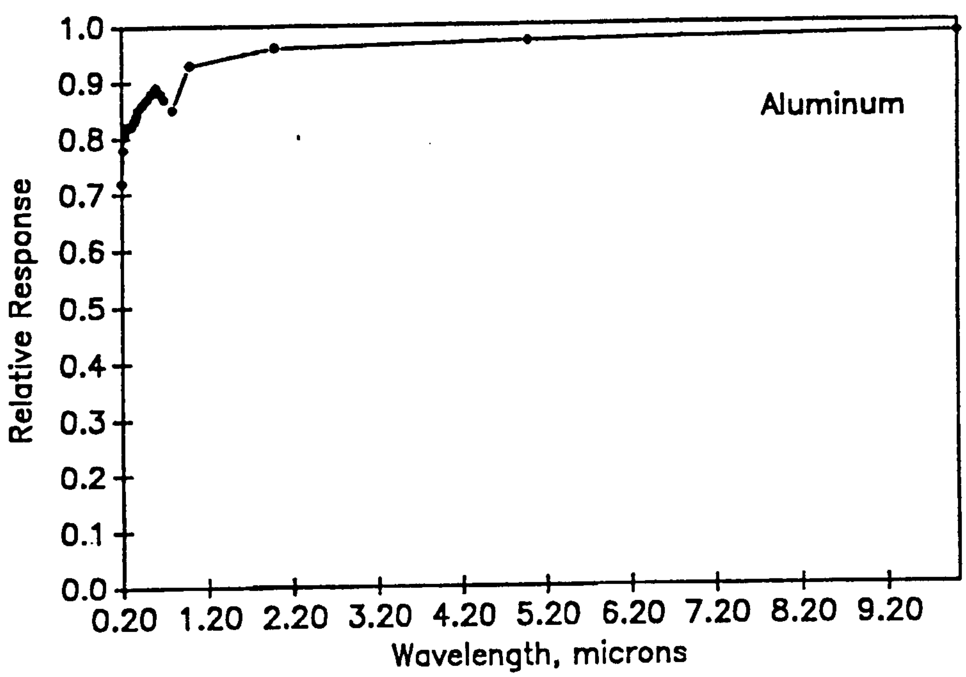

Figure A-2. Archived response curve for aluminum-coated optical surface.

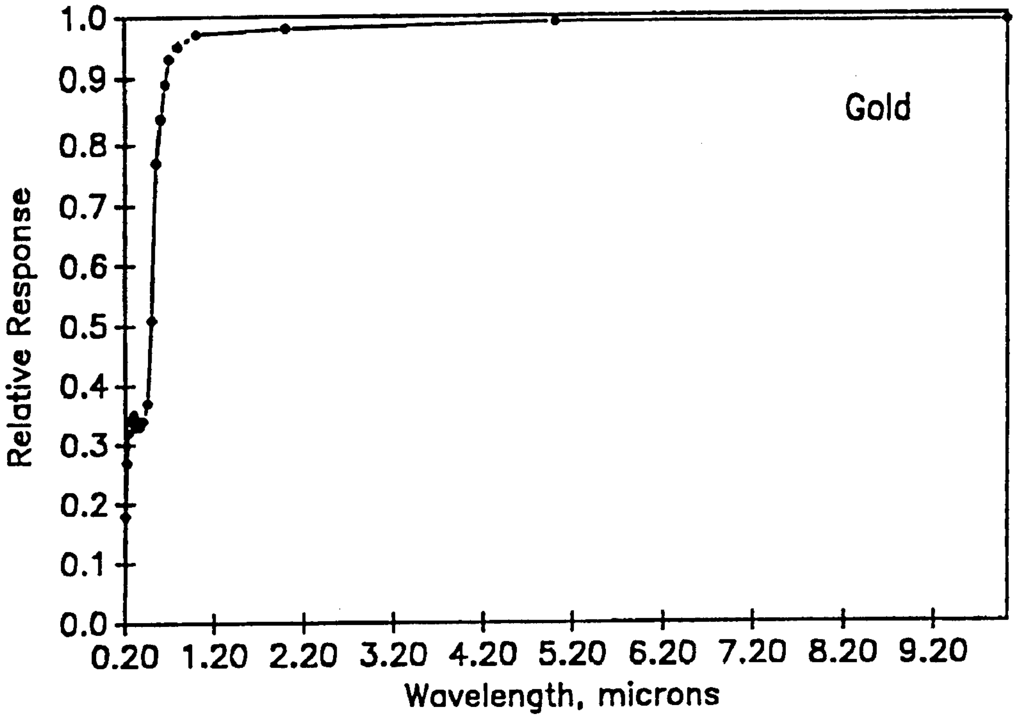

Figure A-3. Archived response curve for gold-coated optical surface.

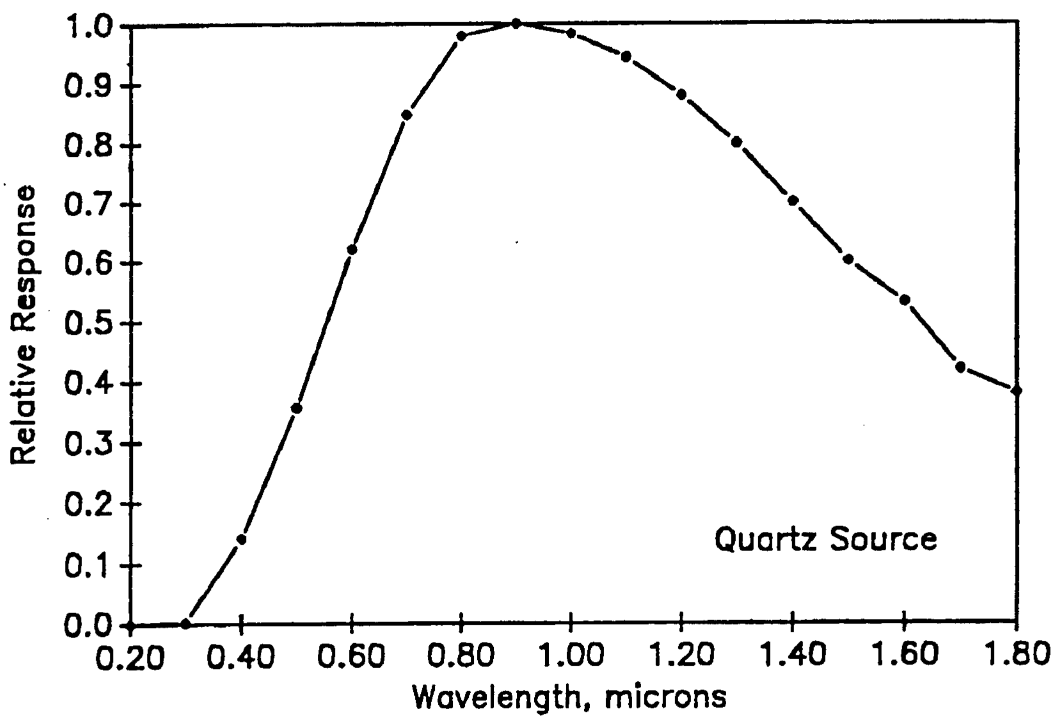

Figure A-4. Archived spectral response for quartz transmissometer source.

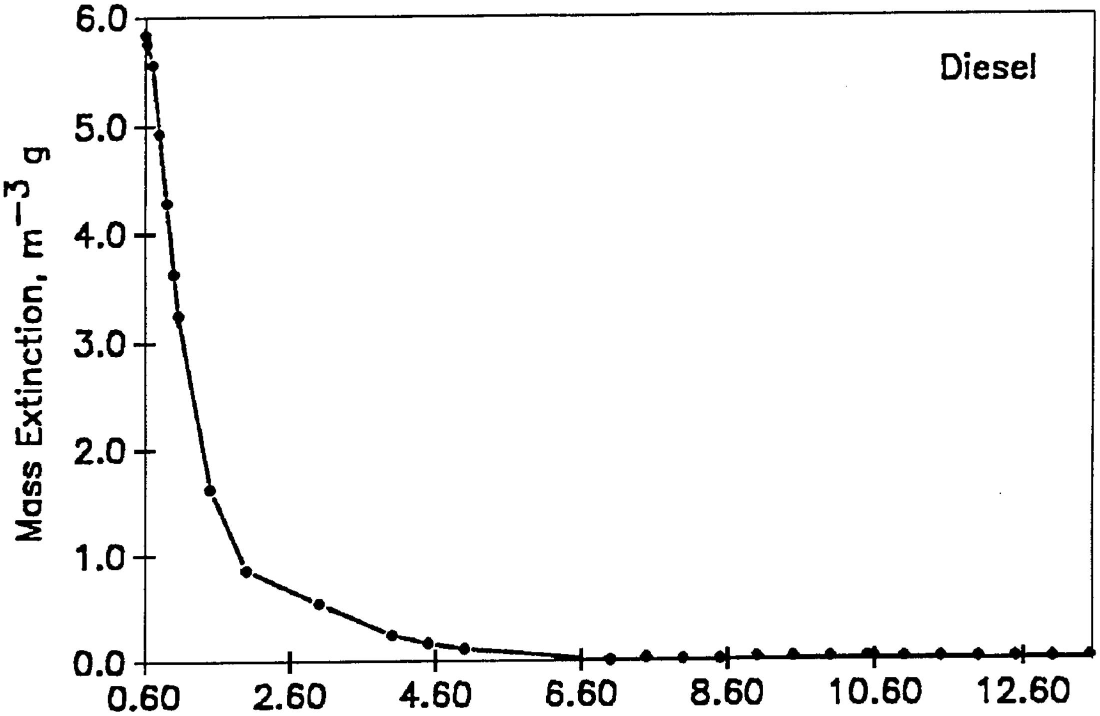

Figure A-5. Archived mass extinction coefficient spectrum for diesel obscurant.

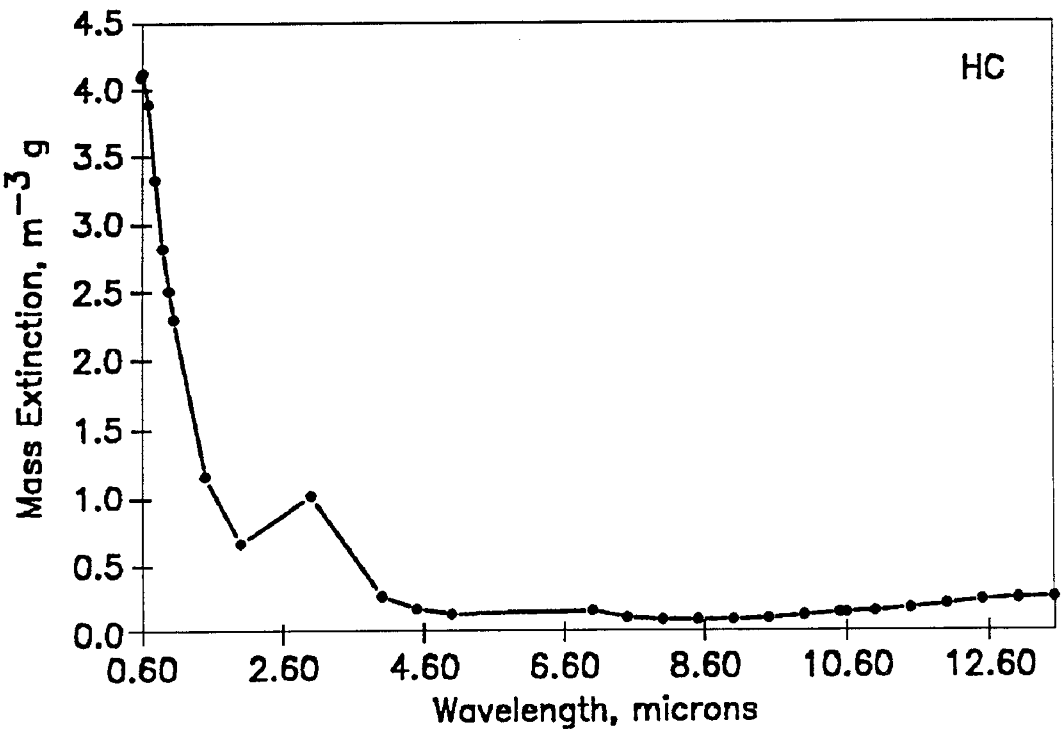

Figure A-6. Archived mass extinction coefficient spectrum for HC obscurant.

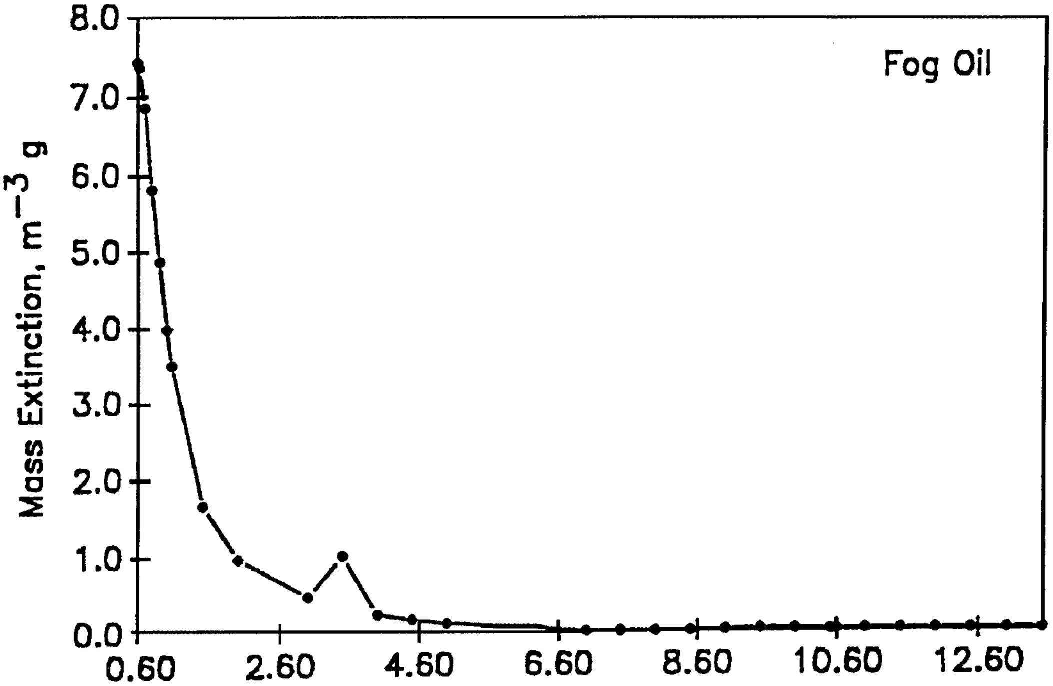

Figure A-7. Archived mass extinction coefficient spectrum for fog oil obscurant.

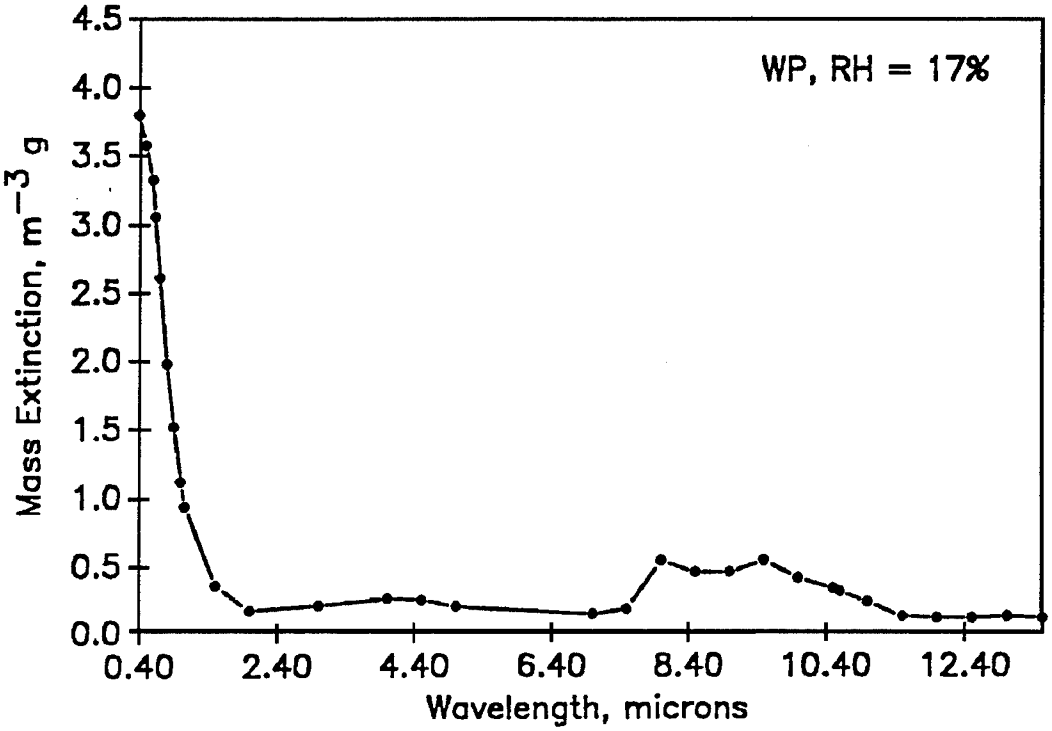

Figure A-8. Archived mass extinction coefficient spectrum for WP, RH = 17 percent.

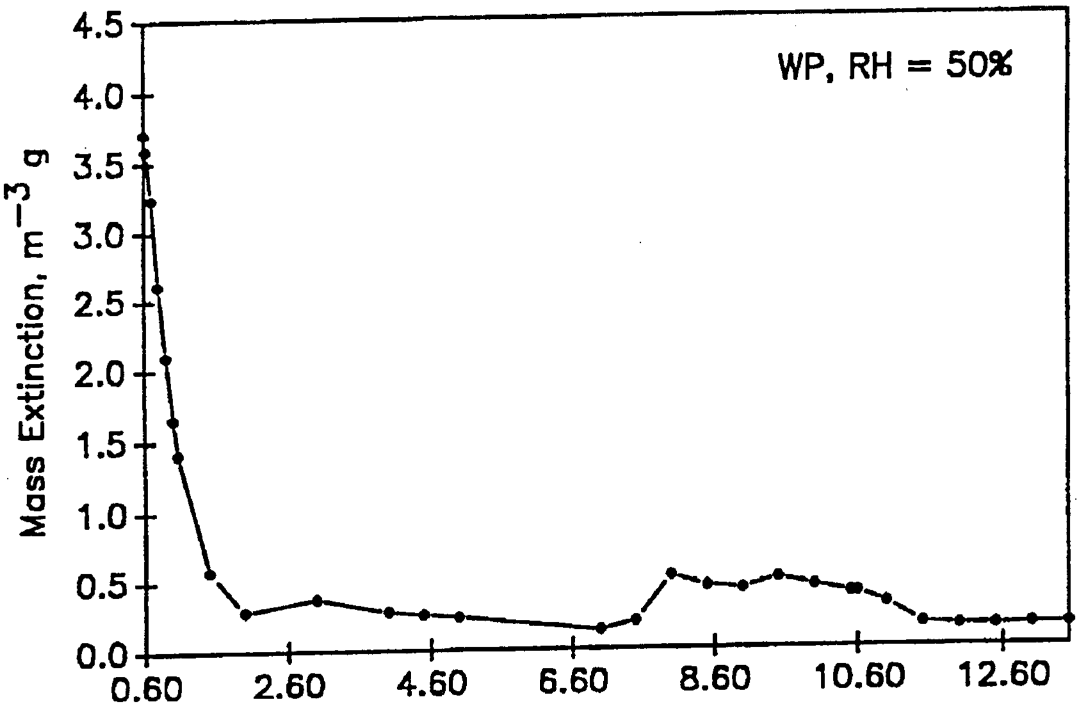

Figure A-9. Archived mass extinction coefficient spectrum for WP, RH = 50 percent.

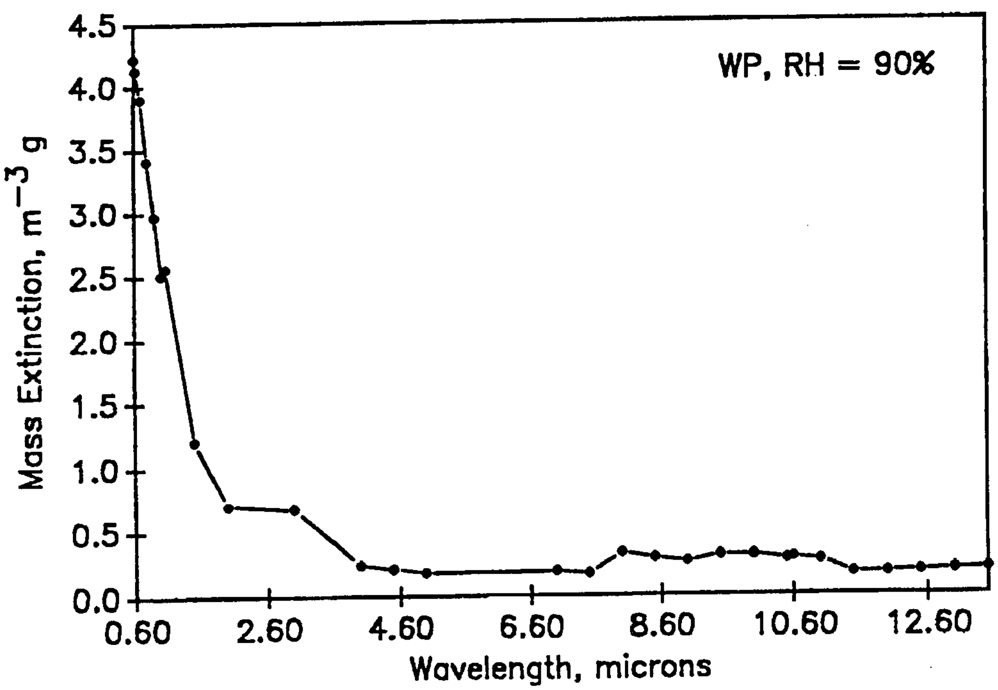

Figure A-10. Archived mass extinction coefficient spectrum for WP, RH = 90 percent.

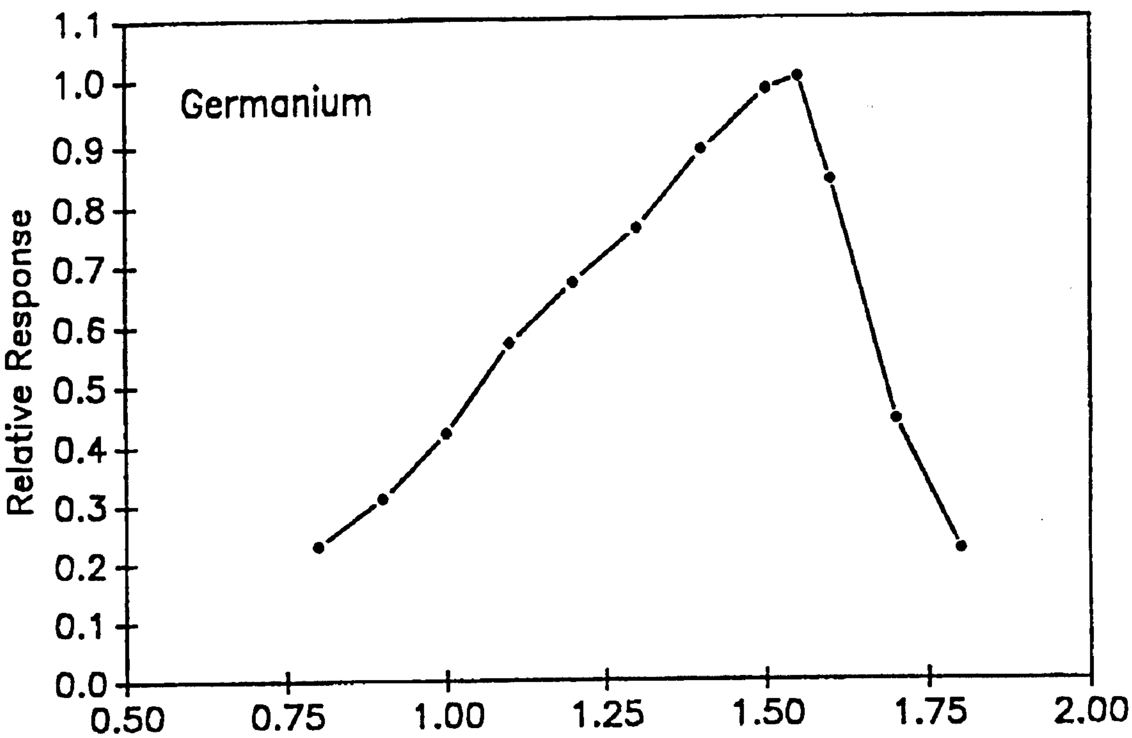

Figure A-11. Archived spectral response data for germanium detector.

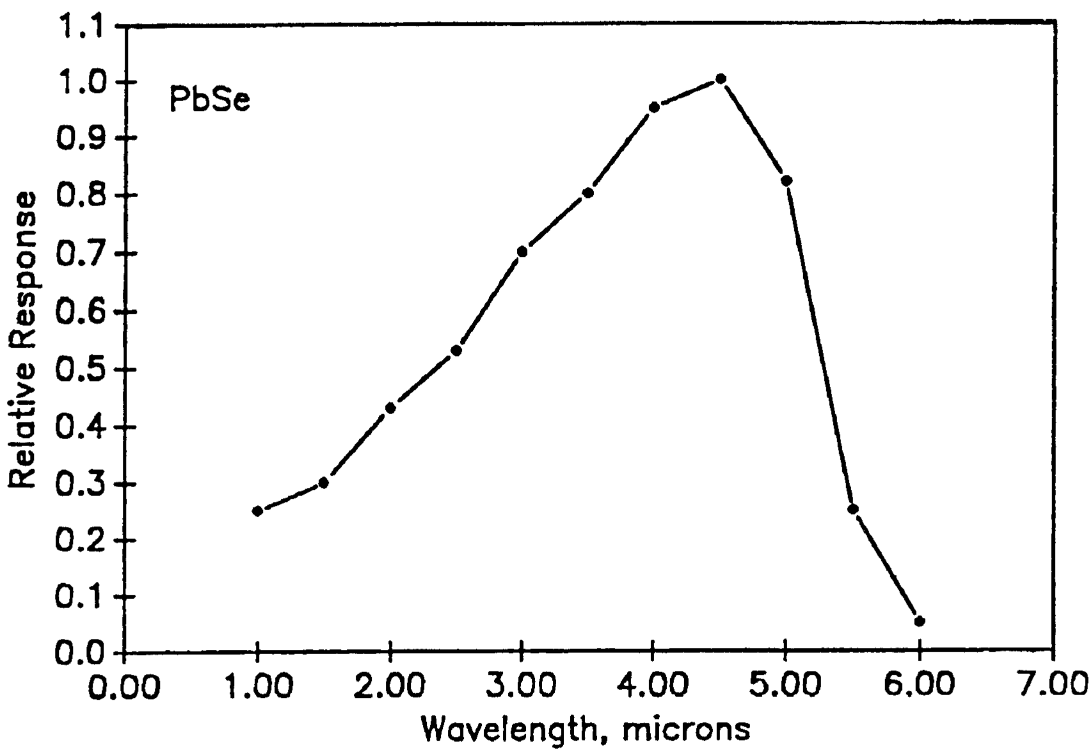

Figure A-12. Archived spectral response data for PbSe detector.

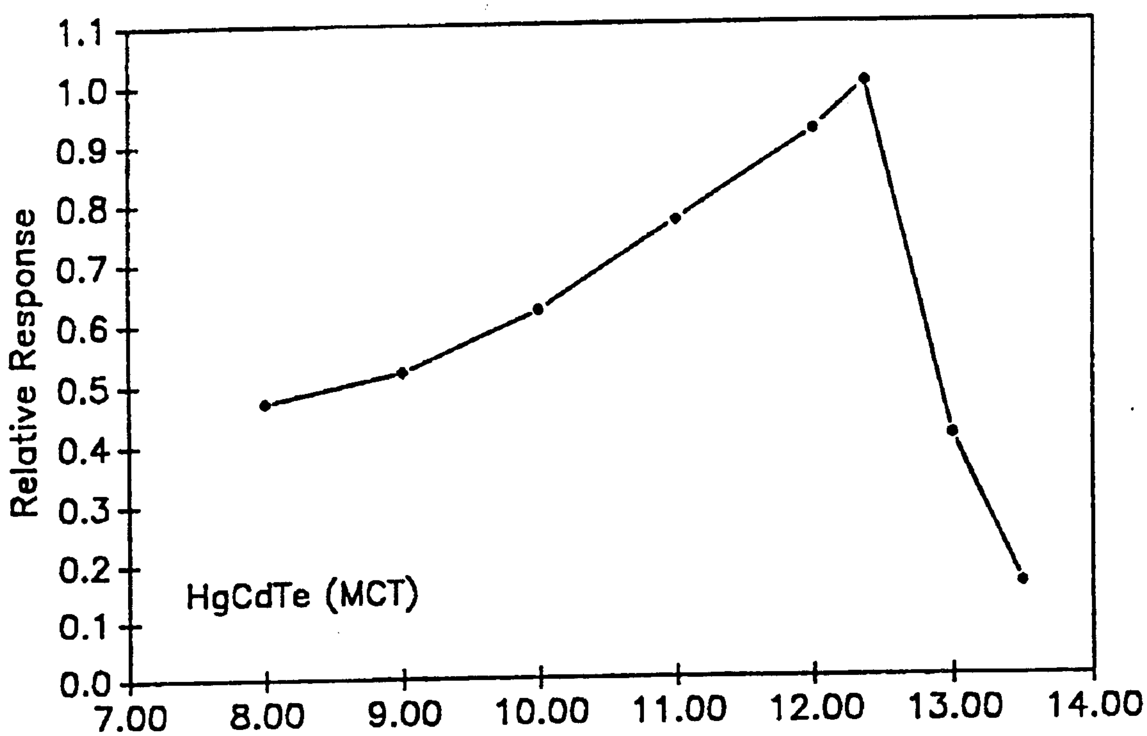

Figure A-13. Archived spectral response data for HgCdTe detector.

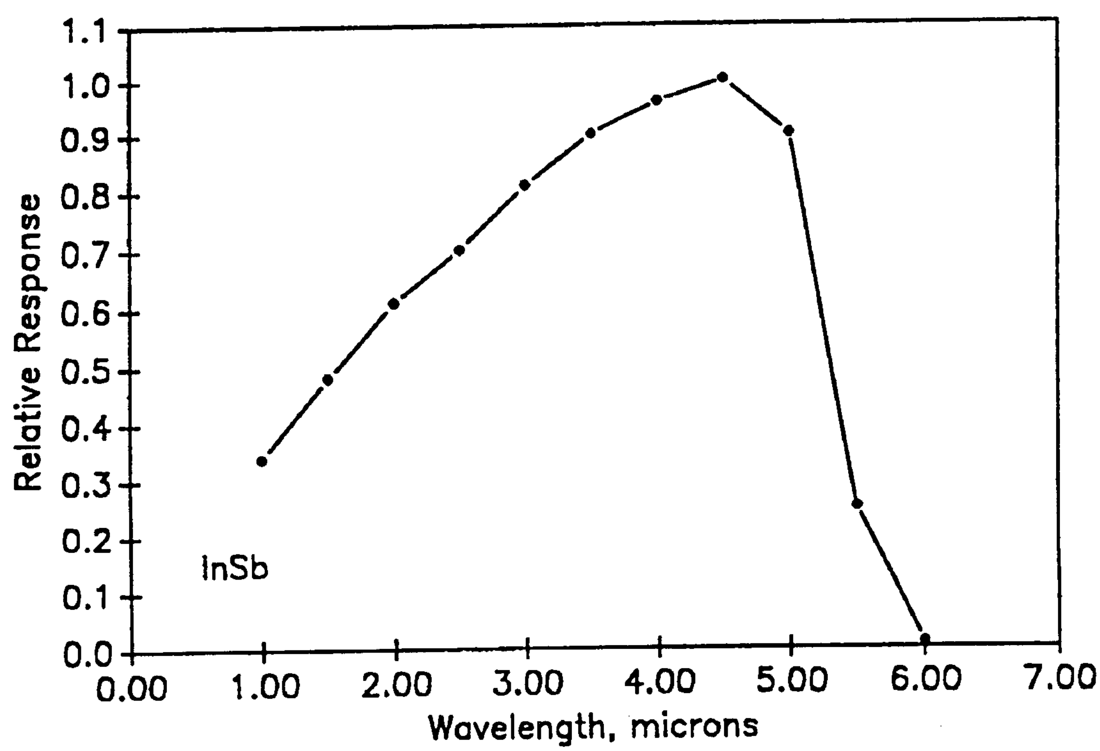

Figure A-14. Archived spectral response data for InSb detector.

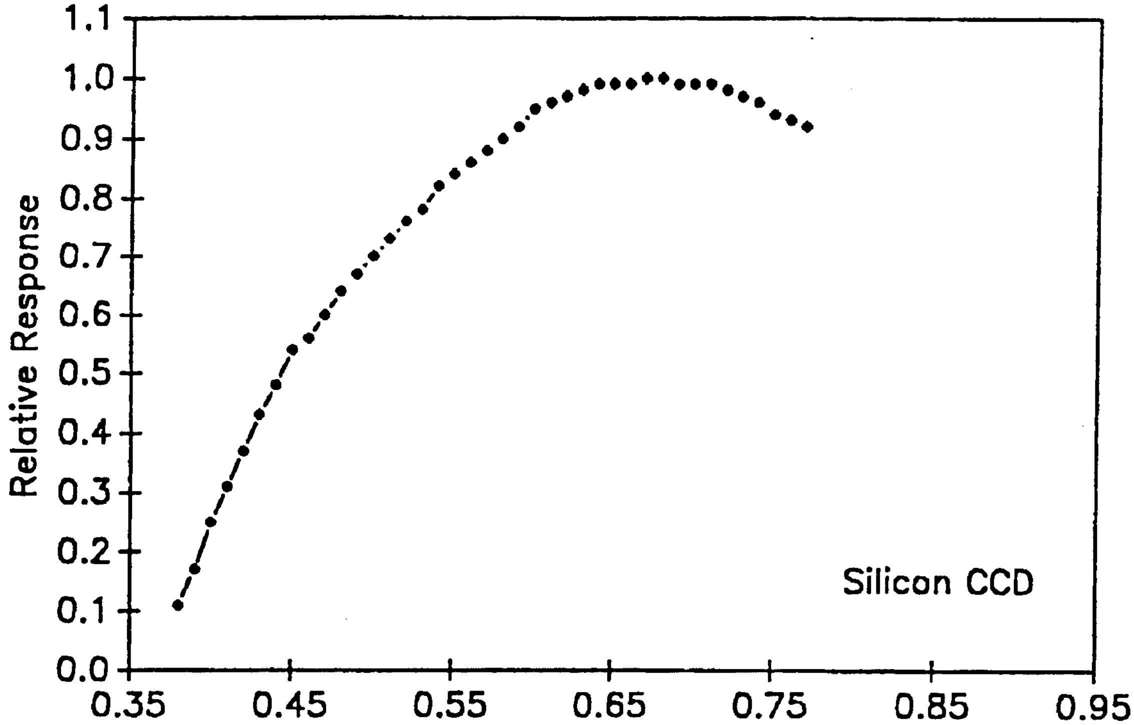

Figure A-15. Archived spectral response data for silicon CCD detector.

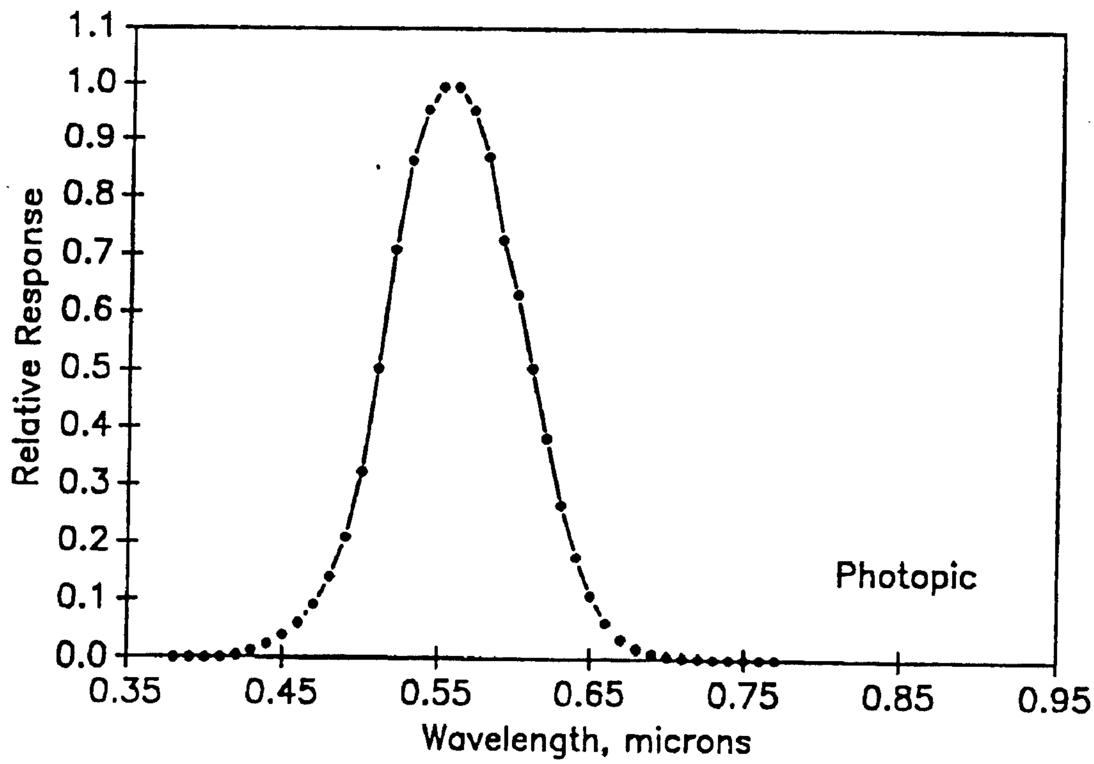

Figure A-16. Archived spectral response data for photopic detector.

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