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# Project Summary

# TRS-80 In-Stack Opacity Computer Programs: User and Programmer Manual

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**The manual describes a microcomputer program written to estimate in-stack opacity from ducted sources. Input data required to run the program are the particle size distribution, particle refractive index, mass emission concentration, wavelength of light, particle density, and stack diameter. The particle size distribution may be entered either as a histogram of particle diameter and fraction-greater-than-stated diameter or as log normal particle size distribution. The program calculates and displays the in-stack opacity. The program is written in the BASIC computer language and is specifically designed for the TRS-80 Model I, III, and IV computers. A moderate effort will be required to convert the programs to the IBM-PC and similar computers.**

***This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).***

## Introduction

Most particulate regulations set a limit on both the mass of the particulate matter being emitted and the opacity of the plume due to particulate emissions. Although in the past plume opacity was measured by a trained observer, the trend is to measure the opacity in the stack with a transmissometer. Considerable empirical effort has been spent relating the mass and opacity standards to each other to ensure that they are compatible. These efforts have not always been successful because they neglected the effects of particle size distribution and other important factors.

A model was developed to predict in-stack opacity from a knowledge of the important particulate properties and the stack diameter. The model is based on verified physics and is rigorous for spherical particles. The output from the model is in-stack opacity as measured by a transmissometer. The model has been implemented in the Radio Shack TRS-80 Models I, III, and IV computers. Complete details of the models and the computer program are included in the full manual.

## Opacity Theory

The transmission of light through a volume containing an aerosol is described by the Beer-Lambert law:

$$\text{Opacity} = 1 - \text{transmittance} = 1 - I/I_o = 1 - \exp(-B_e L)$$

where

$I$ = transmitted light,
$I_o$ = incident light,
$B_e$ = the light extinction coefficient, and
$L$ = the illumination pathlength (the stack diameter in this case).

The aerosol mass concentration is related to the optical transmittance through a modified form of the Beer-Lambert law:

$$I/I_o = \exp[-(MLS_v/\rho)]$$

where

$M$ = the particle mass concentration (actual conditions),

$S_v$ = the ratio of the light extinction coefficient to the specific particulate volume, and

$\rho$ = the average particle density.

$S_v$ is a function of the particle size distribution, particle index of refraction, wavelength of light, and particle mass.

Parameter K, the reciprocal of $S_v$, can be defined and used to relate the transmittance and the mass by:

$$M = 1n(I/I_o)\ K\ \rho/L$$

Parameter K can be calculated from the Mie theory of light extinction.

## Error Analysis of the Computed Results

Two main areas which introduce error into the opacity prediction are:

1. Inherent errors in the programs caused by roundoff errors, numerical truncation, numerical approximations, and program limitations.
2. Sensitivity of the opacity prediction to errors in the input data.

The full manual represents a detailed error analysis of these two sources of error.

The major source of error in the opacity prediction is in the measurement of the input data—particularly the particle size distribution and the particulate mass concentration. The inherent error is generally less than 4 percent, much less than the error in the measured input data. The error in the opacity prediction is about the same as the errors in the measured input data. For example, if the particulate mass is in error by 10 percent, the error in the calculated in-stack opacity will also be 10 percent. If the opacity is much greater than 20 percent, the error in calculated opacity is no longer linear with the error in mass concentration.

If proper care is taken in making the measurements, the error in the input data can be held to less than 30 percent. Thus the error in the predicted opacity should also be less than 30 percent in most cases of interest for air pollution control.

## Computer Program

Two computer programs were written to predict opacity. The difference between the two programs is the type of particle size distribution used as data input: one requires a log normal particle size distribution; the other, a histogram particle size distribution.

The log normal size distribution program was developed to allow prediction of opacity when the only data available are the log normal parameters of mass mean diameter and the geometric standard deviation. The log normal model is also useful for estimating the effects of various factors on in-stack opacity.

The histogram model was developed to allow use of data from cascade impactor measurements. The histogram model can also be used in conjunction with particulate control device models developed by EPA for electrostatic precipitators, fabric filters, and venturi scrubbers.

Data for both the histogram and the log normal models are entered using a menu format. The menu for the log normal model is shown in Figure 1. The histogram has two menus: one for entering general data; the other for entering size distribution data. These two menus are shown in Figures 2 and 3, respectively.

## System Requirements

The programs are written in Microsoft BASIC as implemented on the Radio Shack TRS-80 Model I, III, and IV family. The programs require at least 48K RAM, 1 disk drive, and disk BASIC. A printer is useful but not required. The programs can also be compiled by the Microsoft BASIC compiler for the TRS-80 Model I.

If the data input module is rewritten, the programs can run on a CP/M-based microcomputer with 64K RAM, 1 disk drive, and microsoft BASIC 5.x or the IBM-PC and other MS-DOS computers with 128K RAM and Microsoft BASIC.

Complete documentation, including program listing and user instructions, is contained in the full manual.

## Conclusion and Results

Programs for predicting the in-stack opacity due to particulate emissions have been developed and documented. The programs provide a rapid means of estimating the opacity from particulate emissions if the particle size distribution, mass emissions, and stack diameter are known. The models can be used with either log normal or histogram particle size distribution data.

*OPACITY DATA ENTRY PAGE 1*

| | | |
|---|---|---|
| → | *REAL PART OF INDEX OF REFRACTION* | *1.50* |
| | *IMAGINARY PART OF INDEX OF REFRACTION* | *0.000 I* |
| | *WAVELENGTH OF LIGHT* | *0.55 MICRONS* |
| | *MASS CONCENTRATION* | *0.010 G/M³* |
| | *PARTICLE DENSITY* | *2.4 G/CC* |
| | *STACK DIAMETER* | *6.9 METERS* |
| | *MASS MEAN DIAMETER* | *1.000 MICRONS* |
| | *GEOMETRIC STD DEVIATION* | *2.000* |

*↑↓ ARE ACTIVE*
*USE * TO INITIATE CALCULATIONS. USE H FOR HELP.*

***Figure 1.*** *Log normal size distribution program data input menu.*

*OPACITY DATA ENTER PAGE 1*

| | | |
|---|---|---|
| → | *REAL PART OF INDEX OF REFRACTION* | *1.50* |
| | *IMAGINARY PART OF INDEX OF REFRACTION* | *0.000 I* |
| | *WAVELENGTH OF LIGHT* | *0.55 MICRONS* |
| | *MASS CONCENTRATION* | *0.010 G/M³* |
| | *PARTICLE DENSITY* | *2.4 G/CC* |
| | *STACK DIAMETER* | *5.00 METERS* |

*↑↓ ARE ACTIVE. USE > TO GO TO NEXT PAGE.*
*USE * TO INITIATE CALCULATIONS.*
*USE H FOR HELP.*

***Figure 2.*** *Histogram size distribution program input menu for entering general data.*

| I. | DIAMETER MICRONS | CUMULATIVE MASS (<) |
|---|---|---|
| 1 | →.2 | .0101184 |
| 2 | .4 | .0930961 |
| 3 | .5 | .158655 |
| 4 | .7 | .303426 |
| 5 | 1 | .5 |
| 6 | 1.5 | .720713 |
| 7 | 2 | .841345 |
| 8 | 2.5 | .906904 |
| 9 | 4 | .97725 |

↑↓→← ARE ACTIVE. USE * TO START CALCULATIONS.
USE > TO GO TO NEXT PAGE, < TO GO TO PREVIOUS PAGE.

***Figure 3.*** *Histogram size distribution program input menu for entering size distribution data.*

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*The complete report, entitled "TRS-80 In-Stack Opacity Computer Program: User and Programmer Manual," (Order No. PB 86-130 218/AS; Cost: $11.95, subject to change) will be available only from:*

*National Technical Information Service*
*5285 Port Royal Road*
*Springfield, VA 22161*
*Telephone: 703-487-4650*

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