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Research Laboratory
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Research and Development

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Project Summary

An Interactive Computer Model for Calculating V-I Curves in ESPs Version 1.0

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The manual describes two microcomputer programs written to estimate the performance of electrostatic precipitators (ESPs): the first, to estimate the electrical conditions for round discharge electrodes in the ESP; and the second, a modification of the EPA/SRI ESP model, to estimate the particle collection efficiency of the ESP operating with the electrical conditions predicted by the first program. Both programs, written in the BASIC computer language, are designed for the IBM-PC and compatible computers and the Tandy 2000 computer. The programs require Advanced BASIC and a color graphics adapter.

The V-I program allows prediction of electrical conditions for both positive and negative corona and for arbitrary discharge electrode diameters and wire-to-wire spacing. This means that most commercial discharge electrode geometries can be simulated by proper selection of wire diameters and spacing.

Both the V-I and performance models are completely documented in the report, including a discussion of the theory on which the models are based. Most of the report is devoted to instructions, with examples, for using both models. Guidance for adapting the programs to other computers is also presented.

The models are quite useful and allow rapid assessment of expected ESP performance under a wide variety of conditions.

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

Electrostatic precipitators (ESPs) are used to collect particulate pollutants from a wide range of sources. Considerable effort has been spent developing computer models for predicting the performance of ESPs. The most successful of these models is the EPA/SRI ESP model. The predictions of the EPA/SRI ESP model have been verified for several sources—especially for coal-fired power plants. Before the EPA/SRI ESP model can be used, the electrical operating conditions in the ESP must be estimated by the user because the model cannot calculate electrical conditions.

Because electrical conditions in the ESP are so important, the V-I predictor model described in this report was written. In the initial development of the model, it became apparent that rapid mathematical computation would be necessary. Thus, it was decided to use analytic approximations as much as possible and to avoid use of numerical solutions of partical differential equations. This led to the development of several new approximations for the electrical conditions in an ESP. These approximations have been checked against experimental data and the detailed numerical solutions. In all cases, the answers provided by the approximations were in excellent agreement.

Model Version 1.0 enables the prediction of the electrical conditions for round-wire discharge electrodes. The wires in a given section can have varying diameters and be at various spacings. The effects of an immobile, constant space charge can be included, and this component of space charge can decrease by a certain fraction for each wire, thereby simulating the effects of real particulate space charge. This

version has been verified experimentally for clean wires operating in positive or negative glow corona. Extensions of the model (including negative tuft corona, positive streamer corona, dirty wires, and particulate space charge) can be made but currently are supported only by theory. The model can be used to simulate the electrical operating characteristics of various commercial discharge electrode geometries by careful selection of wire diameters and wire-to-wire spacing.

A version of the EPA/SRI model is coupled to the V-I predictor model so that particle collection efficiency can be estimated. The entire set of models have been implemented in the BASIC computer language for the IBM-PC and compatibles and the Tandy 2000 microcomputer.

Prediction of V-I Curves

The first step in predicting the electrical conditions (current density and electric field) of an ESP is to predict the V-I curve for the ESP. The model uses the analytical solutions for the electric field around a round wire as the starting point. The model considers the perturbations of the field around one wire due to the nearby wires at the same potential and then determines the corona onset voltage for each wire electrode.

The next step is evaluating the current density on the plate directly opposite the wire. Both experimental evidence and theoretical considerations have shown that this current density can be described by the same relations that predict the current density in wire-cylinder corona devices.

The third step is determining the current density on the plate at points between the wires. Several useful approximate relations for the angular dependence of current density and electric field have been discovered and verified by numerical computations. Experimental evidence also indicates that the currents emanating from adjacent wires become truncated at their common boundary. These conditions make it possible to evaluate the voltage dependence of the current from each wire. This amounts to the prediction of the V-I curve for each wire.

The last step is evaluating the V-I curve characteristics of the whole electrical section. This depends on interpolating the V-I curves of each wire at a common voltage and then averaging the current over the whole plate area. Thus, the composite V-I curve extends only from the lowest corona starting voltage to the maximum wire voltage on the individual V-I curves.

A modified version of the EPA/SRI ESP performance model was written to interface with the V-I predictor model. This modified EPA/SRI model uses the electrical conditions calculated by the V-I prediction model as input data for calculating the performance of an ESP. The performance model uses the same input data format as does the V-I model.

The Models

The entire operation of the program is governed by menus. A menu is displayed on the screen of the computer with the user selecting actions to be taken. The cursor positioning keys (arrow keys) move the flashing cursor to the desired location on the screen. The action that follows depends on the type of menu involved.

There are three types of menus: operating menus, single-parameter data entry menus (or forms), and multi-parameter data entry menus (or forms). In an operating menu (once the cursor is positioned), the only possible actions are to press the <ENTER> key to activate the operation, the <ESC> key to abort the operation, or the cursor keys to move to anothe location.

In a single-parameter data entry menu either numbers or letters may be entere at the cursor location. The entry term nates by pressing the <ENTER> key. Th value entered then replaces the currer value (displayed to the left of the screer when the replacement operation is ind cated specifically.

In a multiple-parameter data entry men the operation proves somewhat mo complex. Here, several parameters of th same type are grouped together. The ai of this menu is to allow for quick revie and modification of all these values. A though only one set may be displayed c the screen at a time, cursor operatior allow other sets to be displayed easil New values may be entered in the sam way as in a single-parameter data men When values are changed, however, the take effect immediately.

Examples of the menus for the V-I pr dictor model are shown in Figures 1, 2, ar 3. Examples of the menus for the ESP pe formance model are shown in Figures and 5.

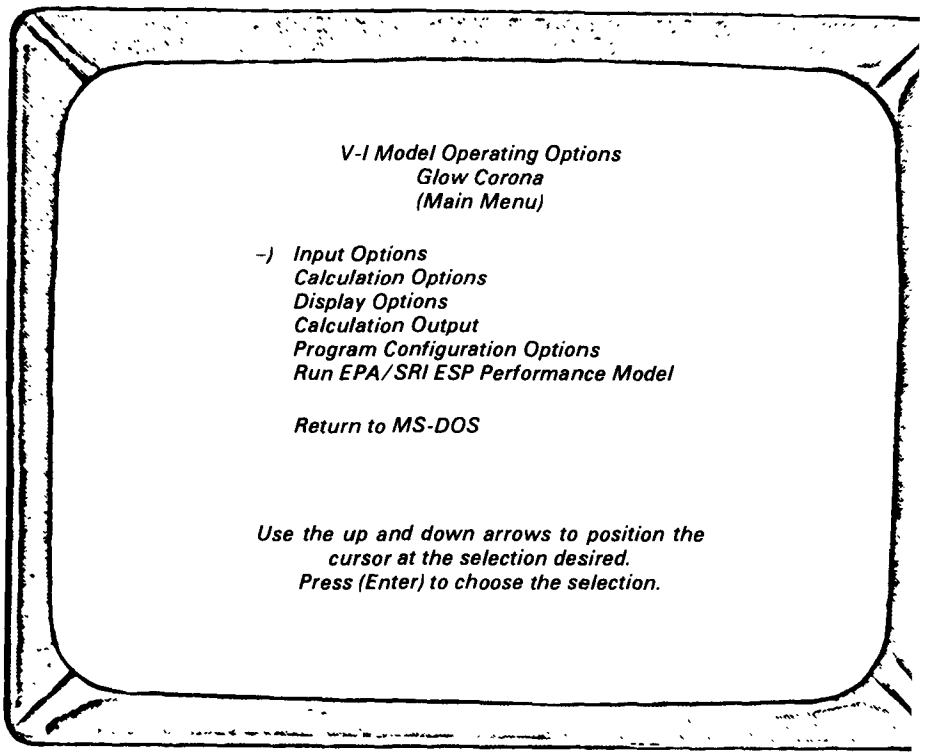

Figure 1. *Opening menu of the model program.*

The current file name is: default.esp
New name ?

<Enter> uses the current name.
<Space>+<Enter> will abort the operation.

Figure 2. *Example of single parameter menu.*

Program outputs from the V-I model range from the simple output of the operating voltage and current density for use by the performance model to detailed graphical output for the current density and electric fields in the electrical section. The outputs include graphical output of the voltage current curves and numerical printout of the curves. Examples of the output are shown in Figures 6, 7, and 8.

Outputs of the EPA/SRI performance model include summary performance as well as detailed performance as a function of particle diameter. Examples of the output from the performance model are shown in Figures 9 and 10.

System Requirements

The programs, developed on a Tandy 2000 microcomputer, make full use of all its graphic capabilities. Because of the large number of IBM-PCs in use, the program was written to include the capability to run on those machines without modification. However, some sacrifices in graphics are noticed when the models are run in the IBM mode.

Tables 1 and 2 list the minimum hardware and software requirements for running the program and suggest options that will enhance the use of the programs.

The models could be rewritten to run on other computers. However, the modifications required to adapt the data entry portions of the program to computers that do not use Microsoft BASIC would be extensive.

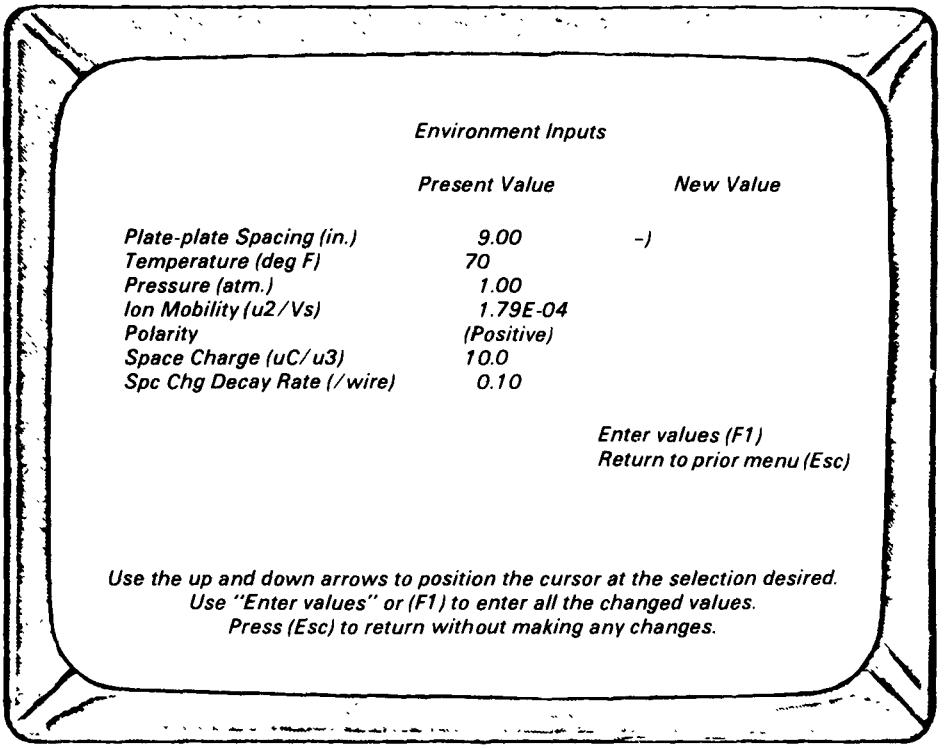

Figure 3. *Data input menu for environmental inputs.*

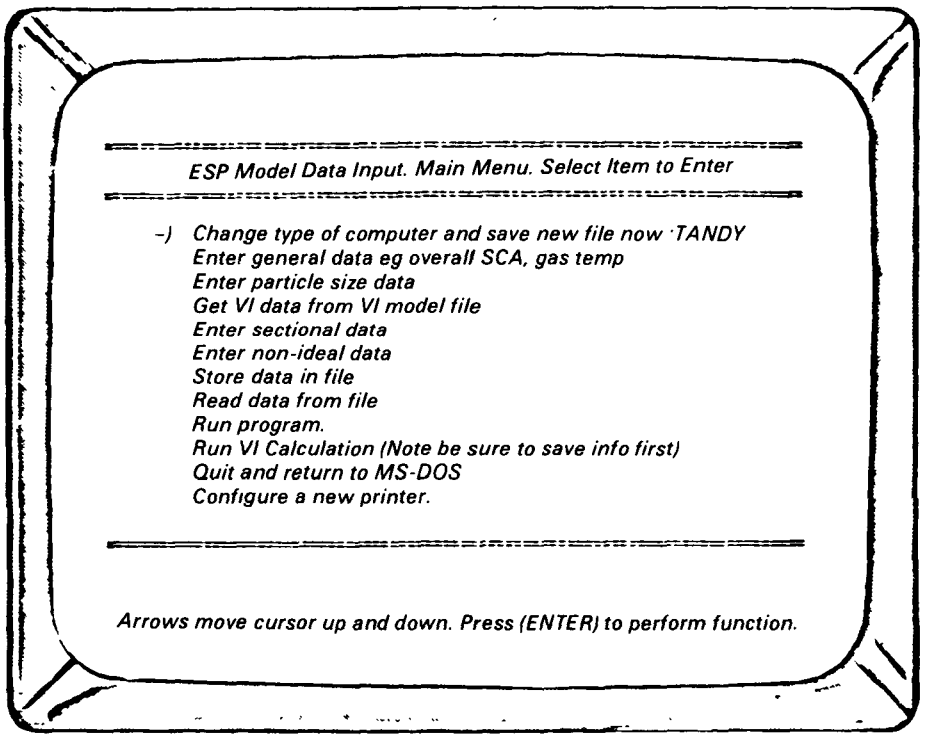

Figure 4. *Main menu.*

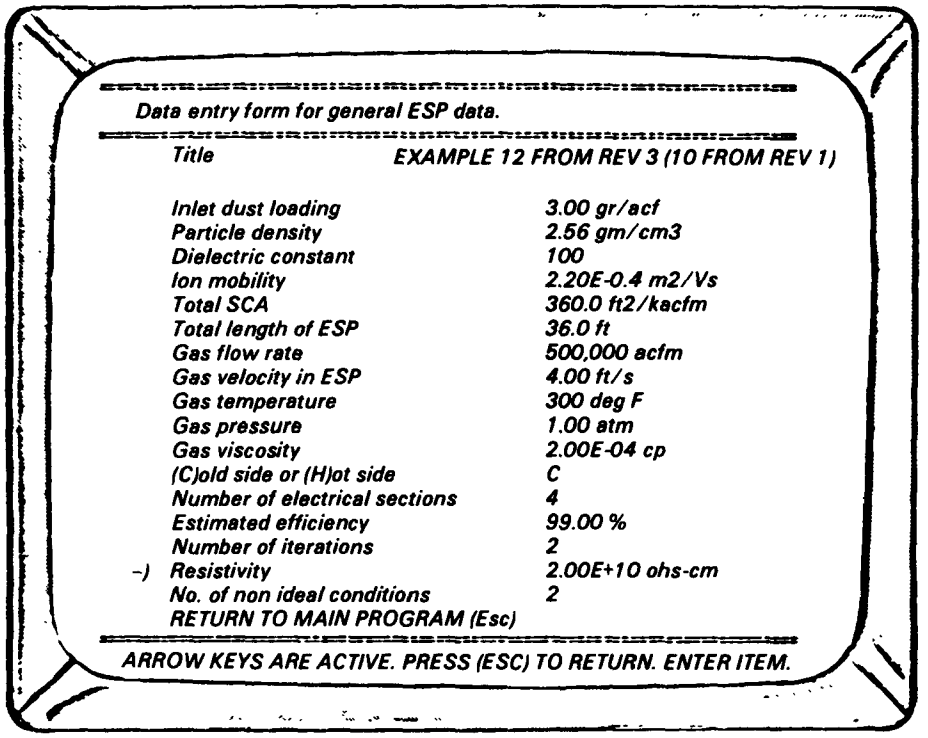

Figure 5. Data entry form for general ESP data.

EPA/SRI Model Section Output Data

Section	Voltage (V)	CD (nA/cm2)	E Plate (kV/cm)	File
1	58200	106.7	3.07	default.esp

What is the section number?

A section number of 0 will abort any update.

Figure 6. Example output from V-I program.

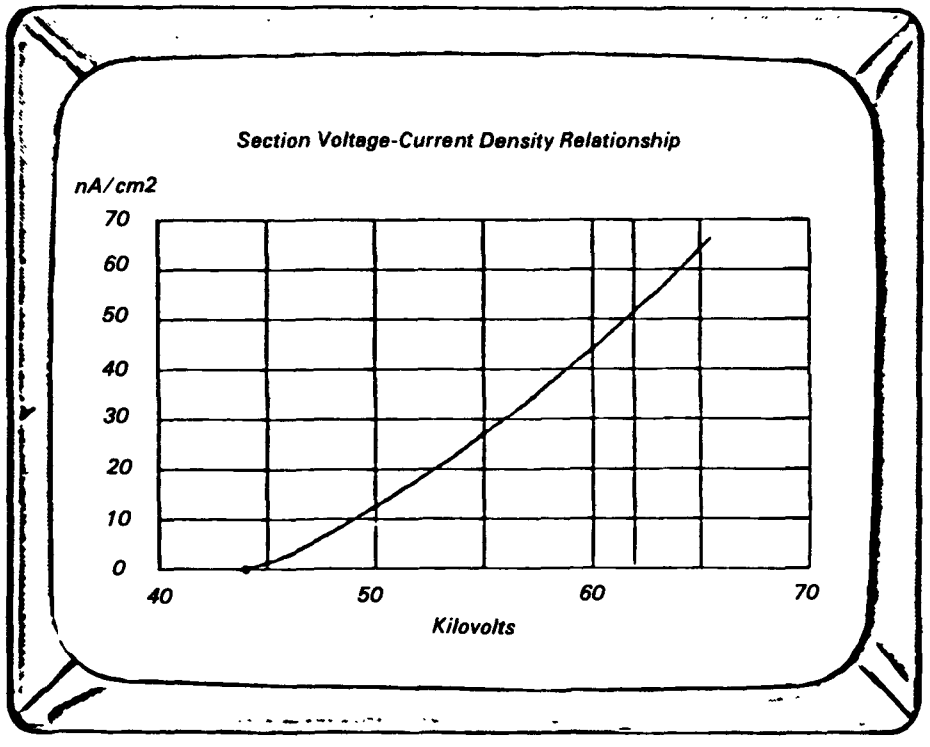

Figure 7. Graphic display of total section current density curve.

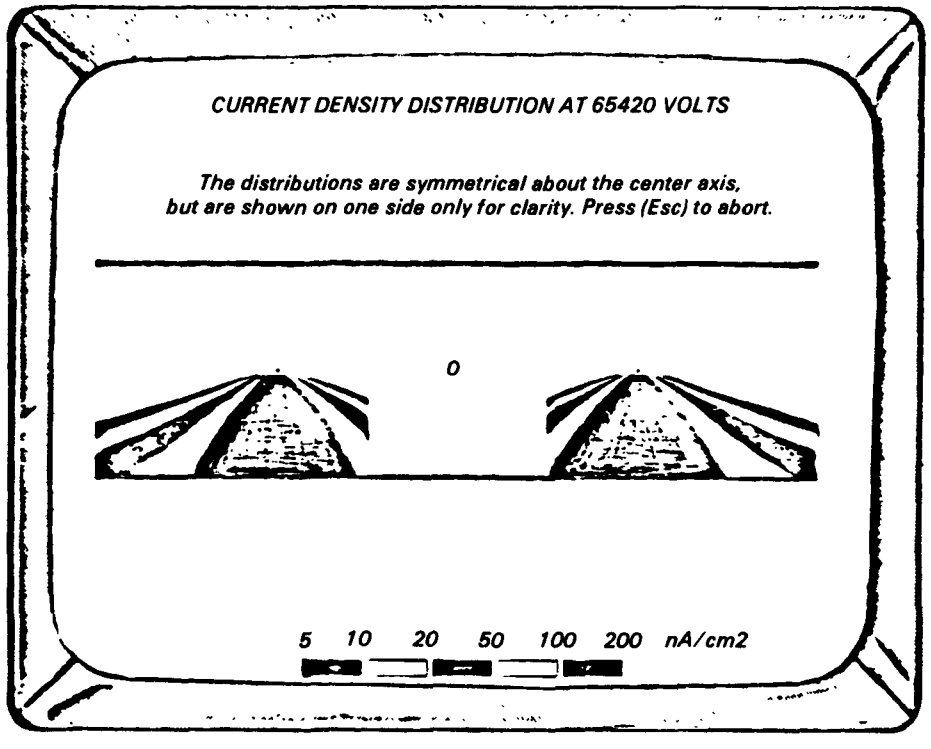

Figure 8. Graphic display of current density distribution when Displays *is B&W.*

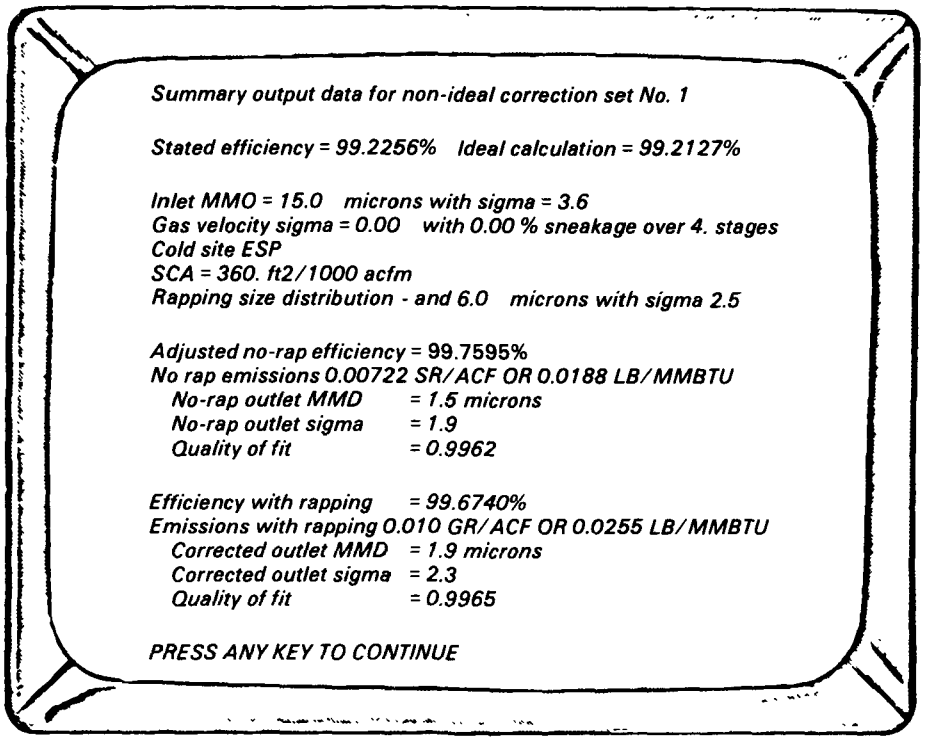

Figure 9. *Results of the model calculations for the first non-ideal data set.*

Particle size results for non-ideal set 1

	IDEAL		NO-RAP with SNEAKAGE		with RAPPING	
Diam	effic	pt	effic	pt	effic	pt
0.3000	0.937449	0.062551	0.997994	0.002006	0.99179	0.00821
0.5500	0.927252	0.072748	0.994156	0.005844	0.98682	0.01318
0.8500	0.942833	0.057167	0.993540	0.006460	0.98346	0.01654
1.2500	0.963790	0.036210	0.994794	0.005206	0.98343	0.01657
1.7500	0.980908	0.019092	0.996516	0.003484	0.98898	0.01102
2.5000	0.993077	0.006923	0.998152	0.001848	0.99480	0.00520
3.5000	0.998234	0.001766	0.999125	0.000875	0.99604	0.00396
4.5000	0.999550	0.000450	0.999550	0.000450	0.99560	0.00440
6.0000	0.999944	0.000056	0.999944	0.000056	0.99564	0.00436
8.5000	0.999998	0.000002	0.000008	0.000002	0.99761	0.00239
12.5000	0.999999	0.000001	0.999999	0.000001	0.99911	0.00089
20.0000	0.999999	0.000001	0.999999	0.000001	0.99980	0.00020
27.5000	0.999999	0.000001	0.999999	0.000001	0.99993	0.00007
65.0000	0.999999	0.000001	0.999999	0.000001	0.99999	0.00001

Figure 10. *Example output from performance model.*

Table 1. *Tandy 2000 Hardware Requirements*

System	Minimum	Beneficial
RAM	*256*	>256
Disks	1 floppy, double sided	2 floppies or 1 floppy/1 hard
Graphics	High resolution	
Color	Optional	Standard or Tandy CGP-220 for graphics[a]
Software	GW-BASIC	
DOS	2.11 or higher	

[a]If high resolution color is not available, the Tandy 2000 can be run as an IBM configured computer.

Table 2. *IBM/PC/PC-XT/PC-AT Requirements*

System	Minimum	Beneficial
RAM	*128K*	>256K
Disks	1 floppy, double sided	2 floppies or 1 floppy/1 hard
Graphics	Optional	High resolution, B&W
Color	Optional	Color monitor
Printer	Optional	Standard
Software	BASICA (Advanced BASIC)	
DOS	2.0 or higher	

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The complete report consists of two parts, entitled "An Interactive Computer Model for Calculating V-I Curves in ESPs, Version 1.0,"
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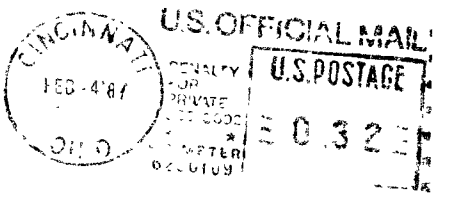

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